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Cover photos (top to bottom): Agro-ecosystem used for thousands of years in the vicinities of the Mycenae palace (located about 90 km south-west of Athens, in the north-eastern Peloponnese, Greece). In the second millennium BC Mycenae was one of the major centres of Greek civilization (photo P. Ibisch).

Modern anthropogenic urban ecosystem dominated by concrete, glass and steel materials (London City Hall, Great Britain) (photo P. Ibisch).

Undernourished child in deforested and desertified inter-Andean dry valley ecosystem (between La Viña and Toro Toro, northern Potosí, Bolivia) (photo P. Ibisch).

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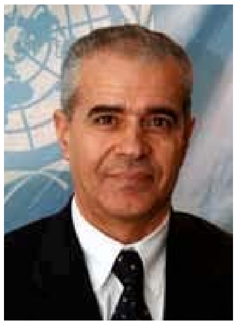

At its second meeting, held in Jakarta, November 1995, the Conference of the Parties of the Convention on Biological Diversity adopted the ecosystem approach as the primary framework for action under the Convention. The Ecosystem Approach recognizes that humans, with their cultural diversity, are an integral component of ecosystems. This has been known for a long time, but it has yet to be internalized by the whole society to assure present and future human survival.

Our modern civilization experiences—due to increased urbanisation and compartmentalised knowledge—an increasing alienation from nature obscuring common understanding of our real dependence on biodiversity and ecosystems. The complex global economy interwoven with a worldwide financial architecture has obscured the fact that all these human systems remain nested as sub-systems in the broader Earth eco-system. Humans and everything we create by using natural renewable or non renewable resources is subordinated to the general laws of nature that rule the functioning of this unique Earth system. Even though we are just a sub-system, human resource use driven by an ever accelerating growth and globalization of societies' activities has the power to catalyze irreversible degradation of the global ecosystem compromising human well-being and maybe even the existence of our civilization. As the Global Biodiversity Outlook 3 (GBO3) points out we are rapidly approaching critical tipping-points of life-supporting systems, if we don't break business as usual attitudes and habits.

Rediscovering the insights of these risks, the current technical series explores the manifold interrelations and interdependencies between biodiversity and human development. Applying system theory and through a transdisciplinary analysis of bio-cultural evolution, concrete up-to-date case studies and global statistical correlations this technical series goes deeply into the root-causes and drivers of environmental degradation and biodiversity loss. It shows that understanding the role and value of biodiversity and ecosystems for human well-being is more than ever a crucial pre-requisite and vital question for new and urgent needed development paradigms. In line with other initiatives like TEEB, IPBES or the Green Economy, among others, the technical series explores appropriate means and ways to translate proven knowledge and open questions into policy-relevant messages.

To find real solutions to both preserving biodiversity and securing sustainable development for the future in times of global socio-economic and environmental change, the authors of the technical series present and call for an in-depth understanding and comprehensive application of the CBD ecosystem approach. This requires to shift away from merely treating the symptoms of the biodiversity crisis. Following a precautionary approach, both knowledge and uncertainties should strategically be factored into decision-making to preserve the interests of current and future generations. New management systems for production, consumption for the global economy needs to be developed through a much more proactive management and by mimicking natural systems.

We are pleased to introduce this volume of the Technical Series of the Convention on Biological Diversity as a very useful contribution and enrichment of the debate on new paradigms for sustainable development in harmony with nature that actually move the agenda of committed scientists, policymakers and practitioners worldwide.

Dr. Ahmed Djoghlaf
Executive Secretary
Convention on Biological Diversity

B. Background papers

B.2.2 THE INTEGRATED ANTHROPOSYSTEM: GLOBALIZING HUMAN EVOLUTION AND DEVELOPMENT WITHIN THE GLOBAL ECOSYSTEM

Pierre L. Ibisch & Peter Hobson

ABSTRACT

This paper, in a transdiciplinary approach, draws together concepts and evidence from biological, anthropological, paleoecological, historical, political and economic research and presents a comprehensive theory to explain past, present and future evolution of the anthroposystem in terms of natural sciences and system theory.

Pleistocenic African *Homo sapiens* evolved as a biological subsystem in a systemic play of changing habitat conditions and existing traits. Many important physical and psychological traits date back to this time of early human evolution. Above-needs consumption emerged as a distinctive social trait, as well as the ability to recognise unsustainability, and to incentivize individuals to practice ecological rationality. We see evidence that nature-culture antagonism and increasing alienation from ecosystems started very early in human evolution. The ability demonstrated by *Homo sapiens*, to alter ecosystems in such a way as to 'cheat' the natural laws of carrying capacity and resource depletion, adapting intelligently to arising consequences, might help explain why locally unsustainable patterns of behaviour continued unchecked through the course of human evolution. It is even probable that unsustainable ecosystem 'management' and subsequent resource shortage in many cases triggered technological innovations. There are manifold examples of feedback loops of drivers and consequences of cultural evolution. Especially, agricultural development spawned a social revolution including changes in organization, cosmovision and religion. Improvements in social organisation and the development of economic constructs were relatively rapid and demanded political and regulatory frameworks if they were not to collapse. Population growth expanded dramatically around these social hubs putting pressure on local resources and setting off conflicts and warfare with neighbouring centres over territory and much needed natural capital. The emergence of urban centres greatly increased demands for material and energy, altered the spatial configuration of the landscape, and also contributed to the unsustainability by subtle socio-psychological and political effects. Finally, information technology brought more and more ever better educated people together allowing exchange and fusion of ideas, leading to innovations and accelerating cultural evolution.

Cultural and technological evolution led to the creation of ever more interconnected subsystems of the anthroposystem and to the formation of systems of higher order on the local, regional and finally the global level. The globalization of the anthropo-subsystem, in the sense of expanding networks, both at the institutional and the individual level, has greatly increased concerns of achieving and maintaining sustainability. Human travel and trade marked the beginning of the atopization of ecosystem use. Communities no longer depended exclusively on local ecosystem goods and services. Globalization, together with urbanization, has contributed to the apparent de-coupling between culture and nature. A combination of freedom of choice and loosely defined membership to various social structures has fostered a perception of individual liberation from systems of higher order. This fuels notions of a sustainability that is dependent on the functioning of economical and financial systems and independent from ecosystems.

Modern trade is completely exosomatic, and a mainly fossil-fuel-dependent driver of economic growth. By the late 19th century, world trade started to decouple from world production, growing much more rapidly and leading to increasing openness of more and more local and regional systems. This contributes to hiding environmental costs and masking inter-dependency between economic and natural systems. The externalization of environmental costs in so-called developed countries implies that the negative

consequences of the (over)use of ecosystem services is exported to other territories. Environmental problems including contamination, ecosystem degradation, fragmentation and conversion manifest in landscapes beyond the boundaries of origin but may not impact on local systems until some time later, once critical levels of tolerance have been exceeded. In this context it is important to highlight that humans depend on ecosystem services that are not just produced locally. In the short run, the most important challenge is to address problems of climate change in order to avoid catastrophic events that are likely to effective the survival of human civilization. The conservation of *global* regulating ecosystem services, especially those related to hydroclimatic processes, is at least of equal importance as the maintenance of the *local* provisioning and supporting services.

Present-day landscapes and their biodiversity cannot be understood without knowledge about history and prehistory (Balée & Erickson 2006a). If we want to apprehend the current problems of biodiversity loss and how it is interrelated with human development it is necessary to analyze the trends and the mechanisms that drive the current situation and continue to be relevant. A lot of evidence indicates that the history of human development and subsequent anthropogenic biodiversity loss is not a sequence of coincidental events, which simply happened. Without invoking teleological or theological interpretations it is possible to see the paradox that biological and cultural evolution are a theoretically open-ended, and, in retroperspect, a tendentially directional process that can be explained on the basis of natural science and systems theory (see Hobson & Ibisch, B.2.1. in this document). The same paradox, based on characteristics of non-equilibrium open systems, implies that it is impossible to predict and explain single events, while it is feasible to explain and predict trends and patterns.

Evidence for the existence of systemic drivers and constraints that are derived from long-term biological and cultural evolution is compelling, and suggests that information and understanding based on the current situation or recent history only is limited. Although in the history of nature conservation much has been written about the development of conservation through history, specifically, the ethical and cultural element of conservation, surprisingly, in current discourses about applied biodiversity conservation and policy, anthropo-evolutionary and historical perspectives are commonly absent.

Conservation is more often discussed and dealt with in the context of the current relationship between the diverse cultural heritage, in particular that of indigenous peoples, and biodiversity (compare the CBD's article 8j; see also e.g., Alcorn 1993, Orlove & Brush 1996, Hames 2007, see also Herrmann *et al.*, B.1.3. in this document). In contrast, fundamental principles of social evolution and environmental history, and the types of issues and problems that have emerged from a long evolutionary and historical partnership between society and nature are mostly neglected. In particular, there is urgency for research and the development of comprehensive theories that focus on factors and aspects of human culture responsible for creating the system-immanent mechanisms of unsustainability.

This paper draws together various concepts and evidence from biological, anthropological, paleoecological, historical, political and economic research and presents a comprehensive theory to explain human evolution in terms of natural sciences and system theory. Cultural evolution, history of mankind and even the ecologically unsustainable performance of people are seen as the continuation and part of biological evolution of a species that was and still is an integral part of a holarchical subsystem, the Earth's ecosystem. Things that are often treated as purely cultural in humans "*have deep roots in our animal past and thus are quite likely to rest on direct genetic foundations*" (Hamilton 1975). Additionally, with Prigogine *et al.* (1977), we are convinced of the need that "*the basis for any natural law describing the evolution of social systems must be the physical laws governing open systems, i.e., systems embedded in their environment with which they exchange matter and energy.*" This might be a trivial statement for many modern anthropologists and many natural scientists, but it is far from being part of general knowledge and education.

Homo sapiens evolved as a biological subsystem of a concrete local ecosystem: a small population of Pleistocenic African primates that started a new evolutionary lineage. Common to all other forms of animal life, the evolution of humans was a result of a systemic process of interaction with other species as well as with the abiotic components of its 'home' ecosystem. What is particularly distinguishing about human evolution from that of other animal species is the emergence of intelligent, self-reflective individuals, whose complex social behaviour and cognitive skills extend far beyond the boundaries of instinctive behaviour. Complex social behaviour exists in many taxonomic groups including insects, birds and mammals but it is the sophistication and subtlety in human behaviour that allows for forward planning, anticipation of outcomes, constructivism, and application of reason to actions that sets this species apart from all others, and by some considerable margin. The ability to exercise social cooperation has given rise to the ever accelerating formation and complexification of subsystems driven by interacting people, communities and the wider society. The result is the emergence of a complex anthroposystem that is not driven just by biological interactions and corresponding rules and restrictions, but also by the emergence of cognitive constructs that serve as complex metaphors for the physical heterogeneity. Furthermore, the evolution of intelligence has allowed for increasingly complex abstract interpretations of reality that lead to social interactions with an inherent logic (which however can be explained as traits that have arisen during biological evolution). Furthermore, the development of intellectual skills to 'read' and anticipate the thoughts and actions of others (theory of mind and Cognitive Hierarchy Theory) has greatly advanced human social systems. Even human empathy, prospection, intentionality and strategic ecosystem management come into the play. However, the systemic nature of evolution—both biological and cultural suggest that it is not a sequence of accidental events and chaotic diversification; but rather, it is the tendential creation of order—at the cost of energy turn-over and the increase of entropy in other systems—and, thus, a certain driveness along "evolution's arrow" (Stewart 2000).

Balée & Erickson (2006b) try to construct a conflict between natural and system sciences on the one hand, and historical ecology on the other. They repudiate the idea that human systems adapt to the environment and claim that "*the concepts of the ecosystem, systems ecology, and cultural ecology ultimately tend to deny human agency in positively shaping the environment over time*". This interpretation applies rather simplistic and mechanistic principles of systemics to anthropology. An alternative thesis is offered in this paper that argues the case that special circumstances including the complex interaction of a diverse range of social systems at several scales as well as interactions with holarchically nested metasystems as part of the global ecosystem have given rise to a "supertramp" species capable of modifying the environment it lives in according to its needs.

History is littered with examples of large scale changes to local and regional landscapes as a result of human behaviour including wars, trade and socio-economic development. For instance, centuries ago, in the far east, large reservoirs were constructed at Angkor wat; the Beijing-Hangzhou Grand Canal was built in China; and an estimated 70,000,000,000 kg/m^3 of stone, earth and brick were extracted from the surrounding landscape to create the 6,000 km long Great Wall of China. Equally, in Eastern Europe, long-standing battles between the Russians and the Tartars were responsible for the creation of the Zasechnaya cherta (Abatis line) that extended for more than 1,000 km and included extensive earthworks and impenetrable belts of forest and scrub. Patterns of human activity across the globe share similarities that would indicate the evidence for local distinctiveness in human landscape interactions is rather weak. A cultural materialism that simply explains cultural differences with local differences of ecosystemic resources falls far too short. What is more, evidence for increased local and regional biodiversity that can be related to human social behaviour (Balée & Erickson 2006b) is not incompatible with a strictly systemic theory that follows the principle that humans arose as a part of nature and are still nature, and thus, are not freed from the laws and restrictions of nature. Historical ecology proposes that "*the human species is itself a principal mechanism of change in the natural world, a mechanism qualitatively as significant as natural selection*" (Balée & Erickson 2006b)—this is definitely true; therefore, nowadays, we even have to speak about anthropogenic global change.

Nature is objective, and unlike human cultural society, there is no value-based judgement, no sense of "good" or "bad". Thus, we do not search for the "*ecologically noble savage (Homo ecologicus, the idealized human species that is inherently custodial and nurturing of nonhuman nature) nor (…) the ecologically ignoble savage (Homo devastans, the idealized human species that is biologically programmed to destroy nonhuman nature)*" (Balée & Erickson 2006b). Nature plays out its role according to a set of laws and processes, including thermodynamics, evolution, and chaotic, indetermanistic disturbance patterns. Humans, by contrast, observe, rationalise, anticipate, plan, design, and change the course of outcome to suit their needs. In their work Delcourt and Delecourt (2004) integrate ecosystem theory with certain theories in social science to propose "Panarchy theory". This concept explains the complex interactions between humans and their environment as adaptive responses that result in self-organized hierarchical systems. *Homo sapiens* would have started to act as a keystone species in Pleistocene ecosystems, which were metastable, non-equilibrium adaptive systems. Aggregation of panarchical levels contributed to the establishment of increasingly complex social systems that continued to interact with the environment, and out of this relationship emerged new transforming strategies in ecosystem management (Delcourt & Delcourt 2004).

Common to all species and ecosystems, human social systems are subjected to the same laws and dynamics involving the exchange of energy, matter and/or information. Energy and material flows, are correlated with the size of the population. However, beyond a certain size and complexity of the anthroposystem energy and material flow also correspond to emergent properties which cannot be fully explained by the analysis of biological and ecological system characteristics. Thus, the anthroposystem starts to turn over more energy and matter than required for the maintenance of the biological system components—the individuals. On the one hand, the impact of the anthroposystem grows disproportionally, and on the other hand, its hypercomplex integration in practically all ecosystems on Earth and the globalization of energy, material and information flow makes these impacts ever more indirect and atopic—and thus less predictable.

Paradoxically, as social systems have become more sophisticated the interactions between the numerous subsystems have also evolved from a predominance of material exchange towards a more information-based process. Examples of this transition are found in most aspects of society. For instance, in the world's financial system and many other technologically driven business transactions between customers and providers involves the transference of information, much of it in virtual format. This seeming decoupling of social systems from ecosystem-imposed restrictions triggers an accelerating emotional and conceptual alienation of an ever increasing percentage of people from the ecosystems they depend on. The existence of highly evolved, abstract social systems, which are rather dematerialized, nourishes the fundamental misunderstanding that social systems can exist disconnected from the rest of nature and that further evolution (or even growth!) of the anthroposystem can be decoupled from energy and material flow in ecosystems.

The combination of various factors, detailed in the following points, contribute to this de-coupling and inevitably lead to unsustainability and environmental disfunctionality.

1. a tendency towards locally-simplifying, 'un-natural' (=cultural) and a static perception of the human environment in contrast to a complexifying world with exploding information and knowledge (complexity trap, knowledge trap and alienation-from-nature trap)
2. increasingly atopic, globalized uses and changes of ecosystems neither directly influenced by local action nor perceived locally (globalization trap)
3. strong systemic drivers that, for the sake of apparent system stability, growth and prosperity, reconfirm and enhance growth of energy and material turn-over of the anthroposystem that fuels non-linear changes in Earth's ecosystems (system trap).

We are convinced that the past and future evolution of the anthroposystem can be systemically analyzed and that any approach to sustainable human development must take into account the relevant system components and the system-inherent drivers and directions of change.

B.2.2.a A SYSTEMIC TOUR DE FORCE THROUGH EARLY EVOLUTION OF HOMO SAPIENS: BIOLOGICALLY DRIVEN ALIENATION FROM NATURE AS AN INEVITABLE COST FOR THE BENEFITS OF CULTURAL DEVELOPMENT

BIPEDALITY AND MEAT-FED, ESCALATING BRAIN GROWTH LEAD TO SYSTEMIC CONSTRAINTS FOR EVOLUTION

The origin of the genus *Homo* and the species *Homo sapiens* can be tracked back to pleistocenic Eastern Africa, where our ancestors evolved in a systemic play of changing habitat conditions and existing traits (McHenry 2009). Relevant habitat changes seem to be related with drying climate and the expansion of open savannahs which favoured further development of upright, bipedal locomotion (uplifted head and good overview over savannah, more efficient translocation; McHenry 2004a, 2004b). Other distinctive evolutionary developments included the loss of hair and the development of sweat glands, both prerequisites to an active, almost frenetic existence. The already habile 'great ape hands' then could be further developed allowing the evolution of handcraft skills. Increasing handcraft activities, and the development of technology demanded higher intelligence and ever more sophisticated thought processes.

The evolution of *Homo* out of *Australopithecus* is also related to a shifting of diet from a rather vegetarian nutrition towards more meat consumption, which may have started with cooperative stealing from other predators, scavenging and bone-cracking (Aiello & Wells 2002, Stiner 2002). Ungar *et al.* (2006) suggest that early *Homo* species developed dietary adaptations for flexible, versatile subsistence strategies that would have served them well in the variable African paleoenvironments. Definitely, there was a use of a variety of other food resources than just mammalian meat such as invertebrates, fruits, seeds etc. (Aiello 2002). However, increased reliance on mammalian meat and fat appears to have encouraged the development of both a larger body and brain. Aiello (2002) identify a diversion of energy towards brain metabolism at the expense of gut tissue. Inevitably, dietary changes towards higher dependency on energy-rich food led to increased costs of survival and reproduction. Furthermore, the same authors concluded that these increased costs would have been met by adaptations in energy stores such as increased tendency to store fat against leaner times; reproductive schedule; social interaction; changes in body form and leg length; and in foraging strategies favouring the evolution of division of labour.

SECONDARY ALTRICIALITY AND SOCIAL COOPERATION

Human infants have about 9% higher energy requirements than similar size apes, and increasing energetic costs have been related with the prolongation of growth rates and secondary altriciality (Foley *et al.* 1991). Human neonates are much more helpless than those of our ape relatives, and it has been suggested that they function more as a fetus rather than an infant (Rosenberg & Trevathan 1995). The increasing brain and head size of the neonates, in combination with decreased size of the bony birth-canal as consequence of the adaptation to bipedal locomotion, additionally contributed to the extreme helplessness of the neonates as well as the need for an assisted birth (Rosenberg 1995, Trevathan 1996). In fact, the evolution of bipedality and larger craniums contributed towards 'altruistic' behaviour during the birth process, and this, in turn, triggered social cooperation among group members and the elaboration of cultural systems (Trevathan 1996). Coqueugniot *et al.* (2004) concluded from the detailed analysis of a skull of *Homo erectus* that secondary altriciality was established quite late in the genus *Homo*, maybe in the common ancestor of *Homo sapiens* and *Homo neanderthalensis*, and that *H. erectus* was characterized by only a short period of brain maturation in the extramaternal environment. Bipedality and the birth-canal changes serve as good examples of how in the course of evolution evolved features, which themselves can start to act as systemic constraints and feedback-selection factors narrowing the corridor of future evolution. Thus, clearly, organismic evolution is not exclusively dependent on environmental factors of the ecosystems.

Extended parenting in humans not only originates from earlier primate behaviour but also shares similar characteristics with less developed primates. In humans this will have been another important factor for enhancing the formation of rather stable family groups or clans. Together with the increasing need for high-energy-dense food, the division of labour and the development of ever more sophisticated foraging and finally hunting behaviour was inevitable. Hunting in groups, as well as other evolving cultural interactions between members (such as assisted birth, education of children), contributed to the growing development of cognitive abilities and communication, especially language (Coqueugniot 2004). The rise of modern language, related to rapidly increasing cultural complexity, is thought to date back to approximately 40,000 yBP (Cunningham 1999). However, more recent findings that document the spread of humans across African and to the other continents suggest that the development of language started much earlier (Khoisan matrilineal ancestry: 90–150,000 yBP, out-of-Africa dispersal: 60–70,000 yBP; Behar *et al*. 2008). There is further evidence to suggest that Neanderthals shared with modern humans the same FoxP2 gene for language, and that there were many examples of material proxies for symbolic communication (Soressi & D'Errico 2007). This might push the date back for language development even further. Sophisticated oral communication revolutionized the development and transference of experience and knowledge between groups and across generations. It also represented a significant driver for greatly increased cognitive skills, in particular, the ability to reason, the very hall marks of *Homo sapiens* (which make us think that we are so different from the rest of species) (see also below).

Conscious and complex social cooperation that manifest in cumulative culture are among the most important innovative and autapomorphic features of *Homo sapiens.* However, these traits are rooted in the behaviour of earlier ancestral species. Clearly, cooperation in humans first evolved through natural selection within families and clans ("kin-selection"; e.g. Hamilton 1975, Axelrod & Hamilton 1981). The individual advantages of cooperation have been explored applying the approach of game theory by explaining how cooperation based on reciprocity can evolve. Of course, in the case of intelligent organisms, conscious game-playing develops into a very sophisticated form of behaviour involving complex memory, complex processing of information to determine the next action as a function of the interaction so far, a better estimate of the probability of future interaction with the same individual, and a better ability to distinguish between different individuals (Hamilton 1975). Simple reciprocity-based cooperation often proves to be a much more successful strategy than denial of cooperation and defection (Axelrod 1984). In social groups there is a reward for cooperation even in the absence of reciprocity: reputation. Cooperative people tend to have a positive reputation which indirectly favours cooperation through better positions in society and better access to resources and power.

The importance and relevance of power, leadership and reputation increased measurably with the development of larger and more complex social system, and as behaviour evolved reputation started to work as another motor of human socio-economic and intellectual development. Over time, status symbols e.g. related to ornaments without direct function as well as personal property and above-needs consumption emerged as a distinctive social trait. This particular aspect of the human character became an important driver of cultural development in the fields of design, arts, and architecture, and more recently, a trigger for the "industrious revolution" (de Vries 2009). When it became important to practice reciprocal cooperation and judge the relevance of reputation and status symbols cheating and lying were logical inventions. Thus, it was necessary to improve the abilities of discriminating interacting partners in order to decide if cooperation appeared to be promising or not (Hamilton 1975)—*en passant* fuelling intelligence and brain development. The detection of cheating cries for punishment because it violates the principles of societies based on cooperation. Clearly, here we can see the origin of morality, the definition of good and bad or false and wrong—and also the starting point of collective justice (Hamilton 1975).

SPEAKING, THINKING, PROSPECTING, BELIEVING AND THE DISCOVERY OF (UN-) SUSTAINABILITY

The development of language was the invention of a complex symbol system that required the capability of abstraction and reflection. It seems logical that another distinctly human characteristic, the ability for self-referential (autopoietic), and self-reflection emerged as complementary traits. The ability for deep self-reflection implied an awareness of the future and individual mortality. The human brain developed the capability to rapidly assimilate and rationalise substantial amounts of information gathered from observations of the surroundings. Furthermore, the mind had the capacity to convert these observations into complex abstracts and metaphors to suit cultural constructs; information was used to internal models of the external world which are fed by memory (past), perception (present) and simulation (future) (Gilbert & Wilson 2007). Neuroimaging studies show that both the prefrontal cortex and the medial temporal lobes are especially activated by prospection (Gilbert 2007). This is the same brain region, which made significant progress in *Homo heidelbergensis (*thought to be close to a common ancestor of *H. sapiens),* and also in *H. neanderthalensis,* which lived in Africa and Europe 200-600,000 yBP. This part of the brain is related to inhibitory control and goal-maintenance, abilities related to advanced social cooperation (Dubreuil 2010). More complex cognitive tasks such as perspective taking, complex categorization, or semantic processing have been related to changes in the brain's temporoparietal cortex; these occurred later in the evolution of *Homo sapiens*, when symbolism, art and cumulative culture arose (Dubreuil 2010). Recent findings also indicated that European *H. neanderthalensis* demonstrated behavioural modernity and the emergence of symbolism (Zilhao *et al.* 2010). Social cooperation, human cognitive abilities, language and culture are not the result of co-evolutionary processes peculiar to one species only but rather can be explained as emergent properties arising from a process of systemic escalation during hundreds of thousands of years (Dubreuil 2010).

The fact that humans started to predict the consequences of events they have never experienced by simulating those events in their minds, developing prospection and 'pre-experience' (Gilbert & Wilson 2007) can be considered a revolutionary cognitive innovation (very relevant for both unsustainable and sustainable behaviour). Unfortunately, human simulations of future events tend to be unrepresentative, essentialized, abbreviated and decontextualized and thus commonly lead to erroneous predictions (Gilbert 2007). However, the really important fact is that with *Homo sapiens*, for the first time in evolution, the (simulated) future started to have an impact on present decision-making and thus present events (Willke 2002)—a highly relevant emergent property of the anthroposystem.

Through a process of continual enquiry about the future and personal fate, early *thinking humans* were quick to recognise the paradox of knowledge and 'knowing', that enquiry reveals the extent and depth of ignorance (compare Socrates, in his apology, as echoed by Plato: "*I know that I do not know*")—an increasingly shocking awakening of self-consciousness, a real loss of 'innocence'. The awareness of non-knowledge especially related to death and life after death but also to manifold natural events and features. The sense of vulnerability born out of ignorance gave rise to spirituality and the development of religion that would provide answers and orientation in a frightening world. Sooner or later religion became an important driver of social organization and human development. Faith encouraged humans to extend intellectual and cultural frontiers. Alongside the norms of morality also came feelings of guilt and responsibility. Finally, motivation for social cooperation was lifted up to a completely abstract level of reciprocity and gain of reputation—humans aspired towards seeking acknowledgement in the eyes of god(s). Manifest in nurtured moralistic tendencies and behaviour is the ability to recognise *unsustainability*, and to incentivize individuals to practice ecological rationality.

EARLY BIAS TOWARDS SOCIAL SYSTEMS

Social cooperation and verbal communication laid the foundation for a completely new dimension of systemic interaction in the form of thought or spoken information. The door was open for the evolution of ever more complex social systems whose function was not genetically programmed and chemically regulated (as in social insects). The cooperation-based social systems benefited the individuals, kins and their fitness, and thus were reinforced by evolutionary feedbacks. As humans evolved as part of an increasingly complex social system, it was advantageous to the individual to focus on successful societal membership rather than invest time and effort on ecosystems. Membership of ecosystems was taken for granted, and threats arising from ecosystems—such as predators, food shortages or other extreme events—could be buffered and mitigated by social groups and technological development. This paper maintains that the development of the nature-culture antagonism and increasing alienation from ecosystems started very early in human evolution as a consequence of social and cultural capabilities, and that an individual's investment in developing social skills is under biological control. Clearly, the nature-culture antagonism became ever more relevant in the course of the Neolithic and especially the industrial revolution and was increasingly elaborated conceptually and culturally.

B.2.2.b SPREAD AND RISE OF THE ANTHROPOSYSTEM AND CHANGING INTERACTION WITH OTHER ECOSYSTEM COMPONENTS

DENSITY-DEPENDENT CULTURAL EVOLUTION

Social cooperation, culture and technology (especially the use of fire and later of clothes) allowed humans to spread beyond the limits of their original habitat. In fact, it was more than geographical expansion—it was the first time in evolution that a species was actively amplifying its ecological niche, despite the insignificant evolutionary changes to its genetic and biological make-up. In common with all other species, human reproduction and exploitation of the ecosystem follows principles of non-equilibrium thermodynamics, that is, energy turn-over maintaining individuals, populations, and social systems by utilising the energy stored in other species and parts of the ecosystem. Unless there is a restriction of energy or material resources (e.g., nutrients), in biological systems, reproduction tends to be accompanied by an increase of numbers of subsystems (multiplication of individuals and populations) and growth, i.e. increasing turn-over of energy and matter and of energy stored in biomass of the system. Proliferation of (sub)systems increases their density thus favouring interaction and complexity. Understandably, it took a relatively long time for humans to spread around the continents before reaching critical densities that would trigger the development of systems of higher order with new, innovative emergent properties.

Indirect genetic evidence indicates that sub-Saharan African populations fit models for population growth beginning in the Late Pleistocene which then would have facilitated the evolution of Late Pleistocene cultures (long before the development of agriculture; 41 thousand yBP) (Cox *et al.* 2009; compare Mellars 2006). The structure of early settlement dynamics in Africa implies the formation of small, independent human communities typified by delayed cultural development whilst African populations remained isolated from each other (50,000-100,000 yBP). It was not till later, once more favourable climatic conditions prevailed, that range expansion occurred and cultural development advanced more noticeably (Behar *et al.* 2008). The achievement of reaching critical population density marked a threshold or tipping-point triggering a new phase of cultural evolution after a long lag period without significant cultural progress. This is despite biologically determined modern cognitive capacities that evolved 100-150,000 years earlier. It has been demonstrated that demography is a major determinant in the maintenance of cultural complexity and that variation in regional subpopulation density and/or migratory activity results in spatial structuring of cultural skill accumulation (Powell *et al.* 2009). Thus, demographic factors can explain geographic variation in the timing of the first appearance of modern behaviour without invoking increased cognitive capacity. Modernity in this context describes technological and cultural complexity, including the first consistent presence of symbolic behaviour including systematically produced microlithic stone tools, grinding and pounding stone tools; improved hunting and trapping technology; it is probable that this cultural evolution should have led to a systemic positive feedback on population density (Powell *et al.* 2009). For instance, in South Asia, a significant demographic transition in the subcontinent, dating to 35,000–28,000 yBP coincided with a period of ecological and technological change, especially related to new diminutive stone blade (microlithic) technology (beginning 35,000-30,000 yBP) (Petraglia *et al.* 2009).

A CLEVER, OMNIVOROUS SPECIES WITH REDUCED VULNERABILITY AGAINST RESOURCE DEPLETION: THERMODYNAMIC SYSTEM EFFICIENCY DRIVES TOWARDS UNSUSTAINABLE HUMAN BEHAVIOUR

Advances in cultural and technological complexity together with an increase in population density marked a significant change in human impacts on ecosystems. Humans had already evolved unique hunting techniques that included deliberate selection of the reproductive core (prime adults) of ungulate populations (Stiner 2002). This unconventional strategy was potentially disruptive to prey population dynamics, but was locally feasible for omnivorous predators that were able to opportunistically switch to other food sources whenever the density of favoured prey declines from hunting pressure (Stiner 2002). Furthermore, range shifting/expansion was an adaptive strategy against consequences of local resource overuse.

These findings go some way towards explaining the rather sudden historical extinction of certain megafaunal species on all the main continents. The popular hypothesis holds that Pleistocenic megafaunal extinctions on most continents and islands could have been linked to the appearance of modern man (e.g., Martin & Klein 1984, Roberts *et al.* 2001, Alroy 2001, Brook & Bowman 2002, Steadman 2002, Delcourt 2004, Diniz-Filho 2004, Barnosky *et al.* 2004, Faith & Surovell 2009). However, hunting was not solely responsible for species loss everywhere; and at least in some regions an intersection with climatic change was a more likely reason (Barnosky 2004). Scientific evidence indicates that the period of elapse between human arrival and major faunal extinction events was highly variable on oceanic islands as well as on continents (Steadman *et al.* 2002). The more likely scenario for mass extinction of large fauna was a combination of hunting pressure coupled with a massive change in vegetation, mainly related to the human use of fire (e.g. for hunting purposes; "*overburn*"; Williams 2006).

Delcourt & Delcourt (2004) in their findings on the history of Pleistocenic Eastern North America nomadic hunters concluded that several factors contributed to the demise of mega fauna. In their analysis they demonstrated how "*natural ecological systems*" were transformed to "*culturally managed ecosystems*", "*shifting in balance through time and space from predominantly natural adaptive cycles to ones increasingly interlinked with anthropogenic activities*". Human cultures would have evolved as part of nature but became a unique ecological factor with long-term impact. With increasingly unstable late Holocene climates, prehistoric Native Americans also would have contributed to ecosystem degradation by over-exploitation of wood resources and by intensive cultivation of introduced crops.

Biological evolution seems to select for sustainable systems by default. The laws of thermodynamics, when applied at all levels, favour forms and functions in biodiversity (and wider environment), that are efficient at degrading or dissipating energy and generating exergy capital. However, this did not mean that abrupt dramatic system changes were autiomatically avoided. The perception is of nature operating in balance, with little evidence for stochastical changes in populations or of wholesale depletion of resources. In most cases the self-regulating forces are very effective in local ecosystems.

The ability demonstrated by *Homo sapiens*, to alter ecosystems in such a way as to 'cheat' the natural laws of carrying capacity and resource depletion might help explain why locally unsustainable patterns of behaviour continued unchecked through the course of human evolution. Improvements in hunting strategies as well as the development of technology made allowances for smaller sized hunting parties and this in turn triggered greater individual task specialization within cooperative networks (Stiner 2002). It was the emergence of increased efficiencies in transference of both energy and material, made possible through improved cooperation, which enabled humans to extend beyond their ecological envelope despite the biological constraints associated with their life history (Hamilton *et al*. 2009). Astonishingly, we clearly see a case of how increased thermodynamic system efficiency led to a feedback loop fuelling cultural evolution, system growth, increased resource needs and consequent unsustainable behaviour.

CULTURAL PROGRESS IN SESSILE CONDENSING POPULATIONS AND THE RISE OF HUMAN IMPACT ON ECOSYSTEMS

A dependence on meat not only asserted human claims as a top predator but also set limitations to population growth and abundance. This explained why most carnivorous Eurasian hominids were also the most highly dispersed (Stiner 2002). Early human societies partly resolved this problem by establishing settlements along coastlines where food was relatively accessible, in plentiful supply, rapidly replenished and diverse enough to ensure optimum foraging opportunities. Under these conditions humans were able to migrate rapidly along coastlines, even across to new continents (Walter *et al*. 2000). Coastal systems also acted as vital gateways to human movement and contact, from early hominid expansion to the rise of the coastal and riverine civilisations (Bailey 2004, Petraglia & Alsharekh 2003).

Early coastal communities lived as hunter-gatherers, existing according to the 'rhythms' of nature and leaving little evidence of their activities from one generation to the next. However, this changed significantly at the onset of agricultural development. The establishment of agriculture in some regions, approximately 10,000-7,000 yBP, was possibly triggered by an improvement in climatic conditions and the coincidental domestication of crops and animals (Gupta 2004). This transition changed profoundly the trophic status of human society, and the relationship it had with the natural environment. Humans had, in part, broken free of the inter-dependency between populations and resource availability. Instead, cultures were able to select a wide variety of energy-rich food to cultivate and harvest. Furthermore, it soon became possible to generate a surplus to requirements, and this presented opportunities to provision for times of little. Those cultural societies that developed a crop-based form of agriculture, particularly in fertile regions, were able to build settlements and communities around the arable lands. In less fertile areas such as the tropical rain forests a more flexible system of shifting cultivation was practiced. Societies that chose a pastoral existence were required to move with the seasons and practice a typical nomadic lifestyle. In regions with infertile soils, like in the tropical rain forests, even farmers were forced to move regularly (shifting cultivation).

Despite the obvious benefits agricultural brought to many cultures, both hunter-gatherer and pastoral societies persisted throughout history, in many cases choosing not to adopt the more sophisticated agricultural lifestyle (Johnson & Earle 2000). One theory for this diversity of lifestyles is the concept of multilinear evolution where each kind of adaptive solution to a given environmental situation contains its own set of possibilities for further cultural evolution (Johnson 2000). It is plausible that in many cases the scarcity of natural resources and the relative unfavourableness of habitat impeded further social complexification (compare Diamond 1997). But it was not only the abiotic habitat and the availability of usable species. Each society had to adapt not only to the local ecosystems but also, increasingly to other neighbouring or invading social systems (Johnson 2000). What is certain is that the sessile agrocentric cultures would not have evolved as they did without significant interactions with nomadic pastoralists. For hundreds of years, nomadic peoples played a key role in historical processes, for instance, in Asia and Europe (e.g., Mirow 2009). They triggered warfare and miltary technological progress (see below), but also catalyzed the exchange of technological innovations between rather isolated sessile states.

In areas of high ecoregional and biological diversity, for instance in mountainous regions, a differentiation and specialization of cultures and land use types has been observed where different ethnic groups with separate backgrounds and economies persist in neighbouring ecosystems, exploiting different ecological, mostly altitudinally defined zones (e.g., in Pakistan, Johnson 2000; the Carpathians; and the tropical Andes). Often the agriculture-based, high-density groups excluded others from the prime lands, but allowed and benefited from vertical exchange of products (Johnson 2000, Murra 1972, VanBuren 1996).

It is probable that unsustainable ecosystem 'management', like overhunting ungulates, and subsequent resource shortage in many cases triggered technological innovations in attempt to resolve these problems (Delcourt & Delcourt 2004). Life-style changes that encouraged an increase in population density also prompted development in task and labour-sharing behaviour and this, in turn, promoted improved organizational development of the social systems in order to guarantee access to resources (and mitigate arising conflicts, see below). Often this process was achieved by the establishment of systems of higher order. Delcourt & Delcourt (2004) describe the various panarchical levels of human-ecosystem interaction and the related social complexification as well as the spatial expansion. The following levels largely correspond to their classification and terminology (which was also informed by the concepts proposed by Johnson (2000):

1. Foraging mode of subsistence of autonomous, local, mobile groups
(unlimited movements in vaguely defined home ranges minimizing competition; <100 persons/100 km^2)
⇨ increasing human density, intensification of food resource use, depletion, competition, semi-sessile lifestyle push towards a more complex organization ⇨

2. Forager-horticulturalist mode of sedentary villagers
(several hundreds of people in territories of 300–500 km^2)
⇨ sedentary human village groups adopt ownership sense of land tenure; ancestor-granted stakeholder rights and rituals bind people in their ecological neighbourhoods; intensification of land use and population growth lead to conversion of ecosystems at landscape and regional scales ⇨

3. Chiefdoms and national states
(thousands to ten-thousands of people in defended territories of up to 10^5 km^2)
⇨ local groups are more interlinked and are governed by more comprehensive institutions; arising social stratification; establishment of leading elites who control production and re-distribution of agricultural commodities; arising trade of high-status items; accumulation of material wealth; ideological direction of ceremonies and rituals; rising importance of military dominion and often conquest of new territories ⇨

4. Agrarian nation states and empires
(e.g., Maya state: 3–14 Mio. people, $1.6x10^5$ km^2, Inca empire: 8–14 Mio. people, $9x10^5$ km^2)
⇨ elaborated social stratification; states centrally controlled by ruling elite governed by military might, merchant class maintained economic control over rural agriculturalists.

This evolution and increase in sophistication of social systems has happened convergently various times through the early history of mankind. However, in nearly all cases the original set of environmental and social conditions of founder societies were unique. Recently, Spencer (2010) demonstrated, using archaeological data from six areas in the Americas and Eurasia where primary states emerged in antiquity, that there is a correspondence in time between the first appearance of state institutions and the earliest expansion of the state's political-economic control to regions lying more than a day's round-trip from the capital. It was apparent that state building and complexification was dependent on subsystem density, spatial extension and transport/communication technology. According to the territorial-expansion model the success of growing social systems and "*long-distance expansion not only demanded the bureaucratization of central authority but also helped provide the resources necessary to underwrite this administrative transformation*" (Spencer 2010)—here we find a feedback loop self-catalyzing state and nation-building once a critical mass of subsystems has evolved.

Apart from the well known complexly organized cultures and empires, especially those with prominent architectural testimony (e.g., Egyptians, Inca, Maya), many other chiefdoms and states also were able to significantly change ecosystems and biodiversity, even in landscapes commonly seen as virgin and untouched by humans (e.g., the chiefdoms of the eastern Bolivian Amazon and upper Xingu River, or the major polities along the Amazon River in late prehistory (Balée & Erickson 2006b). In some cases they may have persistently changed ecosystems that remained in states different from the one prevailing before the anthropogenic change, even after the dawn of the complex social systems, and this, as in Bolivian Amazon (Beni flooded savannas, forest islands), may even have been related to regionally enhanced geo- and biodiversity (Balée & Erickson 2006b)

INTERWOVEN CULTURAL FEEDBACK LOOPS: NATION-BUILDING, WARFARE, RELIGION, AND THE DEVELOPMENT OF GOVERNMENTAL AND LIFE-STYLE SYSTEMS

Agricultural development spawned a social revolution including changes in organization, cosmovision and religion. Improvements in social organisation and the development of economic constructs were relatively rapid and demanded political and regulatory frameworks if they were not to collapse. Population growth expanded dramatically around these social hubs putting pressure on local resources and setting off conflicts and warfare with neighbouring centres over territory and much needed natural capital. Humans are predisposed to aggressive behaviour within the species, a common trait shared by a close relative, the Chimpanzee (e.g., Wrangham 1999). Evidence of warfare in early and mid-Neolithic societies is rare (at least, there is very little reference to it in cave paintings) (Pericot 1961, cited by Hamilton 1975). However, as civilizations emerged out of settlements war featured much more prominently in recorded history (Hamilton 1975). In agrarian and sessile societies that developed concepts of value, reputation and status attached to the ownership of land and goods, stealing and robbing would have become a more rewarding business but at the same time would also have sparked off conflicts.

Social development towards more complex systems coupled with increases in population density, helped by a change in diet, introduced new threats and vulnerabilities, particularly to agrarian societies. For instance, the fortunes of farmers were much more dependent on climate, weather and soil conditions. In some densely populated parts of Eurasia certain sectors of society suffered from nutrition-related health problems and this was reflected in individual stature (Stiner 2002). Furthermore, the political and economic status of individuals also changed, creating a social diaspora between the rich and poor. In extreme cases famines started to influence political events and the course of history, a problem that has persisted through to modern times (e.g., French revolution, emigration from Europe to North America, famines and economy-motivated migrations across sub-Saharan Africa). In China, dynasty changes have been seen to coincide with internecine wars which were often triggered by famine or density pressure (Chu & Lee 1994). Thus, in densely populated states the re-distribution of agricultural commodities and the management of arising scarcity, poverty and potential unrest, especially in the lower strata, became a crucial issue of overall system stability fostering more and more authoritative and suppressing systems of governance. Societies or the ruling subsystems of societies needed to protect themselves against threats: social parasitism, internal disorder and external aggression of ever closer co-existing communities. This explains the rise of chiefs and finally kings protecting ordinary people by managing more and more organized armies. From the early beginnings of chieftains and principalities emerged larger feudal systems, in some cases, empires, that offered some measure of protection to the population masses. These asymmetric systems developed the first resource protection policies, and in some cases they were related to the establishment of hunting reserves for the elites—a conservation theme that appeared in various cultural contexts and until recent times. Biodiversity conservation, here, was a by-product of asymmetric resource allocation.

It was not uncommon for young feudal systems to develop their own dynamics and logics and even decouple from the processes responsible for their emergence. Consequently, warrior chiefs and kings strongly influenced the development of social systems without necessarily supporting the needs of the people or the overall sustainability of the community. In fact, the industrious activities of the community were exploited as a source of wealth for the ruling members (Williams 2006). Population was even managed and shifted within the landscape for the sake of power and socio-economic 'progress' (e.g., *mitima* policy of the Inca [Wachtel 1982], immigration policy of the Chinese Ming dynasty to create a densely-settled core of the country [Williams 2006], or the Great Elector's policy of inviting immigrants in order to re-establish a viable state of Prussia after depopulation through the 30 years' war). For as long as these feudal states existed in relative isolation a certain degree of stability persisted across regions. It wasn't until the development of more effective transport and information communication systems that the relative stability of these states became more fickle. Ironically, technological advancements in both fields propagated warfare and conflict, and in some cases societal organization, advancement and complexification were actually retarded by violence (negative feedback).

Large scale warfare had a significant impact on local and regional ecosystems. In some cases, population down-turns following war led to the recovery of degraded ecosystems (e.g., in depopulated Europe after the 30 years' war, although the war itself had fuelled degradation, such as in Pomerania where the Swedes cut down large areas of forests; Williams 2006). However, under different circumstances, for instance in northern Vietnam during the late Holocene, it was warfare rather than agriculture that contributed to fire regimes and subsequent landscape degradation (Li *et al.* 2009).

The selection pressure for the advancement of military technology and warfare was strong in all agrarian states. On all continents, in all periods of history, it were the efficiently armed, warlike nations that succeeded conquering or even eliminating the more peaceful and less armed ones (from warlike Bantus largely replacing the khoisaniform peoples [Hamilton 1975] to the Inca conquering Aymara cultures in the Central Andes, or to Europeans destroying or seriously harming indigenous cultures in Africa, America and Asia). In fact, all the sub-global or intercontinental European empires arising in the 16th century were "gunpowder empires" McNeill (1993), cited by Osterhammel & Petersson 2007).

The processes of social evolution that led to the development of settlements and later feudal systems existing in conflict were a natural phenomenon free of any value judgement; it was neither good nor bad. Neither biological nor cultural evolution lead to the 'survival of the fittest' but rather to comparative advantages for systems that under given conditions can grow and use resources more efficiently and rapidly than others. However, this does not mean that these systems are well adapted to change of conditions or will be more persistent than others. Rather, there are sufficient examples that show that systems' evolution can regularly drive into dead ends, extinction and collapse (see below).

In some cases feudal oppression itself, once decoupled from the motifs related to the distribution of commodities and system stabilization, led to sociopolitical unrest (e.g., European Peasants Revolt of 1524; Williams (2006). Consequently, there was strong pressure for the elites and especially the chiefs, kings and emperors in the more advanced states to fortify and justify their authority and suppressing action. Oppression was not the only means of exerting influence on the masses. Evidence from around the globe indicate that leaders also engaged with religion thus combining the development and integration of state and religion to varying degrees of influence. In some cases rulers established positions of deity or divinity thus sealing their complete authority over the people. The interwoven feedback-loop of religious, governmental and life-style systems became a powerful driver for cultural evolution. Commonly, the kings of agrarian nations promoted themselves as divine representatives or deities, often related to the notably most important power, the sun. This invited public loyalty to the both the state and its rulers, to the extent that enormous efforts were made towards the construction of various monuments and effigies, as well as building up military operations. These efforts did not necessarily have a direct or short-term benefit, such as improved access to (food) resources.

The transition from hunter-gatherer societies to agrarian systems very often[44] led to the decrease in the number of deities and goddesses. This suggested that a significant part of nature ceased to hold any reverence in the minds of people (e.g., plants and animals). Agrarian societies developed dependence from other components and processes of the ecosystems, especially those related to soils and weather. After overcoming pantheistic worship through a de-coupling process with nature, the focus on human self-awareness and self-importance was sharpened. New representations of gods took on human qualities but also with a functional role in controlling the various forces of nature such as sun, seasons, weather, earthquakes, flooding, earth's fertility etc. Increasingly, societies adopted a functional aspect towards nature, dividing it crudely into "useful" and "harmful." This provided the necessary justification (even spiritual) to tame the beast in nature, remove all unnecessary obstructions to progress including the "wilderness" (wild woods, wetlands and scrub). Farmers started to intentionally manage and reshape ecosystems according to their needs, building mounds, hills, canals and terraces, and expanding open grasslands at the cost of forests. The shaping of landscapes marked a new era in the relationship between humans and nature. With new technology at hand the comparative ease at which change could be affected instilled a sense of power and ownership over nature, once the force that dictated human survival. Humans had now elevated themselves to the status of "god's stewards". Fortified by a moral imperative to secure and preserve the needs of human beings, societies around the world embraced the responsibilities of pushing back the frontiers and instilling a new kind of order, a human order, on the natural world.

The most advanced reduction and abstraction of god(s) has been achieved by the related but competing religious cultures of the subtropical Near East region. These religions were built on earlier concepts of oligo- and monotheistic religions of the region: the Jewish, Christians and Muslims, the three 'book religions'. In all three cases, God, is no longer confined to specific elements of nature but rather takes on an "all-present" persona, unconstrained by space, time or matter. The immediate interpretation of this is that all creation is the action of god. In the case of the Christian faith, "all life and all elements on earth but also beyond are the loving action of God, who continues to care for all aspects of existence". Jesus is quoted as saying, "Are not five sparrows sold for two pennies? Yet not one of them is forgotten by God" (Luke, 12:6–7). This belief is also echoed in the Islamic faith, "To him belongs every being that is in the heavens and on earth" (Qur'an: 030.026). However, interpretation of these preachings has been characteristically selective, if not corrupted to suit the needs of the elite. For instance, in medieval Europe, interpretations of Christian doctrine emphasised the importance of civilizing of so-called barbaric cultures that followed more animistic and less abstract religions, and with the 'domestication of nature'. Religion served as an important societal cement, fostering nation-building and the motivation of defence against multiple invasions by aggressive nomadic peoples.

The medieval story of European colonization and deforestation was tightly related to the mission of religious actors—"*the Benedictines, and then later the Carthusians, Premonstratensians, and particulary the Cistercians, were the shock troops of clearing*" (Williams 2006). In Europe up till the period of enlightenment, religion and governmental organization of social systems were inseparable. While the Christian church on the one hand hindered scientific progress (for instance, trying to prohibit revolutionary Copernican ideas), on the other hand, the significant infrastructural and intellectual resources of monasteries and churches supported further European cultural evolution. The technological creativity of medieval Europe has even been related to the ideological power displayed by Western forms of Christianity (White 1978). The multiple feedback relationship of population growth, complexification

44 But not always and automatically; e.g., compare Iftekhar Iqbal (2008): "In Western traditions, the forest has often been considered the hostile "other" of civilization, but this was not the case everywhere and at every historical stage. In the Hindu pantheon, for instance, the forest has a "character"; there have been numerous forest deities who keep the kingdom of the forest alive, and in the forest live the sages who cater to the spiritual and social needs of the people. Moreover, forests were a place to retire in later life of the Brahmin. Material forces of deforestation do not neutralize such popular perceptions of the forest as a pristine provider of both material and immaterial well-being. In fact, the idea of deforestation rather than the forest itself was alien to many communities in the tropical world".

and urbanization of medieval society as well as the religiously supported aspiration for power, expansion and (economic) growth laid the foundation for a process of ever accelerating and globalizing ecosystem degradation led by the so-called 'Western civilization'.

INTEGRATION, INTELLIGENCE AND INNOVATIONS

The emergence of urban centres greatly increased demands for material and energy but also altered the spatial configuration of the landscape (Mirow 2009). The networking between state systems referred to the trade of goods, political contact and cultural exchange. For instance, states in the Near and Middle East and Northern Africa were linked by a network of trade; goods were transported from the Mediterranean to the Baltic sea and vice versa. In some cases considerable distances were covered. The Olmecs travelled 500 km north and south to gather commodities which were not available in their territory (Mirow 2009). Right across Eurasia and Africa large extensive trading routes were established including the trans-Saharan route and the Silk trail.

Trade and commerce should have triggered cultural (and maybe even biological) evolution: "*Mercantile operations (…) need complex models in the minds of their operators, just as military ventures do. The main difference is in more emphasis on prudence and less on daring. It is probable that civilization has given steady selection for the intelligence needed for this mercantile kind of preparatory modelling. The intelligence that gives a good appreciation of the real principles involved in a new technology, as opposed to seeing it as a kind of magic, is probably also constantly favoured, since improvers of a technology avoid the arrows of contempt and penury that face pioneers and can do very well*" (Hamilton 1975). Possibly more important than biological selection for 'mercantile intelligence' was the increasing exchange of ideas and technological innovations. Some innovations, and especially those in the field of information technology (information documentation, storage, diffusion, communication), were very effective in feedback-fuelling the process of innovation generation.

Technological progress enabled urban centres with high population densities to grow. In part, this was made possible by a combination of improved food production; the reduction of impacts of density-dependent diseases (medical treatments, finally even vaccination), and a dramatic development in transport and communications. Information technology brought more and more ever better educated people together allowing exchange and fusion of ideas, leading to innovations. Rapid cultural evolution followed the same principles as that of biological evolution: 1. replication, 2. multiplication, 3. diversification, 4. densification and finally 5. complexification. Innovation and cultural progress can be seen as density-dependent processes with intellectual subsystems that are partly refreshed by travelling, reading, and interactions with other communities. In several cases throughout history, the scientific and technological status of certain civilisations grew substantially as a result of immigration (e.g., Russia, USA). The injecting of new life into society through intellectual exchange and immigration of talented individuals is an essential component to the development of civilisations. "*when starved of access to a large "collective brain" by isolation from trade and exchange, people may experience not just less innovation, but even regress*" (Ridley 2009).

The emergence of numerous centres of civilisation across a diverse global landscape, each operating semi-independently, led to the inevitable diversification of traditions, language, and ultimately culture ("cultural mutations", Ibisch 2010). These "cultural mutations" also include small technological changes and deviations—partially occurring as mistakes or recombination of practices (as in biological evolution), and partially intentionally, because humans with their prospective capacities invent changes (and these changes do not have an analogue in biological evolution). Cultural mutations are assessed by selection, just as are biological ones. Rogers & Ehrlich (2008) provide meaningful evidence (in the case of Polynesian canoes) of two sets of related cultural traits, one tested against the environment and the other not. Both evolve at different rates in the same populations. Natural selection apparently slows the evolution of functional structures that are relevant to the survival of the canoe users. On the other hand, symbolic designs diversify more rapidly. The authors conclude that cultural change, just like genetic evolution, can follow theoretically derived patterns.

A number of authors compared technological innovations with biological mutations, and others concluded that there were no suitable biological analogies (e.g., Mirow 2009). However, this paper maintains that *innovations* also exist in biological evolution, but normally do not depend on single mutations. Rather, it is about the combination of traits, a consequence of cumulative mutations, which from a certain critical point, an evolutionary tipping-point onwards, leads to new emergent properties and non-linear evolution of the biological or cultural system. Examples of this phenomenon include fundamental innovations such as feathers and wings, lungs, oral language, or boats and metallurgy. A significant difference in cultural evolution is that innovations can easily be exchanged, facilitating a reticulate evolution, which does exist only to a certain degree in plant evolution. Successful social systems of higher order, such as empires, more or less systematically 'forage' for innovations in order to maintain growth and expansion.

As in biological evolution, the combination of certain traits that could be called pre-adaptations (which originated for another purpose, but then became fitness-relevant in another context), together with selective pressures has a strong potential of producing convergent results. Evolutionary convergence provides strong evidence for the systemic nature of evolution and corresponding system-immanent mechanisms, without the existence of a higher plan, and thus leading to comparable and more or less projectable patterns. The phenomenon of cultural convergence used to be rarer in the past. However, important cultural achievements such as agriculture, writing or state-building were produced independently on several occasions through history. It is also a well-known phenomenon that certain ideas and theories arise periodically, and under a certain intellectual climate. An example of this is the theory of evolution developed twice and dependently by Darwin and Wallace. Today, thanks to intensive networking and excellent access to existing information coupled with very high densities of educated, idea-developing people, convergent evolution of ideas is a common outcome of modern society. The modern age of open information access has created the paradox of the 'parallel innovation syndrome' that is to say, the discovery of a new concept, theory or principle by one scientist in isolation and ignorance of the identical discoveries by another or others elsewhere. This growing phenomenon has raised the levels of competition between innovators and this in turn has acted as a feedback mechanism in accelerating scientific and technological evolution. "*The capacity for ideas to have sex on the Internet is likely to accelerate cultural evolution still further*" (Ridley 2009).

DISTRACTING MULTIPLE SYSTEM MEMBERSHIP AND A RECORD ALIENATION FROM NATURE

Cultural and technological evolution led to the creation of ever more interconnected subsystems of the anthroposystem. Relatively 'smaller' systems do not only connect to each other, forming systems of higher order, such as clans organizing themselves in states, and states working together in confederations, but also parallel systems evolve and interact in a complex way. At another level, individuals can simultaneously act as members of ecological and social systems. Here we have to distinguish between mandatory and facultative membership (Ibisch 2010). Mandatory memberships are fundamental and refer to being part of an ecosystem with its energetic and material constraints or of a biological population belonging to the species *Homo sapiens*. Facultative membership can be temporary and extremely multiple. It refers to the participation in actual or virtual (internet-based) social networks, in schools or companies, in sport clubs, in professional associations etc. Likewise, social systems of higher orders can form part of various kinds of systems; for instance, states can be members of trade organizations, political and military treaties, of conventions or formal supranational unions with state-like structure such as the European Union

In earlier societies, membership in social systems was quasi-mandatory. For instance, medieval craftsmen had no chance to leave behind the membership in guilds and their rules. In some stratified societies it was (or still is) extremely difficult or impossible to change the stratum, classes or castes. As it is, industrialization and later fossil-energy-fuelled democratization and liberalization have increased the number of facultative individuals. This has made it much easier in modern times for individuals to opt out of basic social systems that were for a long time a mandatory part of social life. Individuals now have the option to withdraw their membership from various social orders such as political parties, dedicated professional bodies or even from the family. The freedom of choice, thanks to cheap energy and transport of goods and persons (for people with above-average to economical resources) is enormous and comprises the selection of places of where to stay as well as the consumption of ecosystem goods produced everywhere in the world (Ibisch 2010). The globalization of the anthropo-subsystem, in the sense of expanding networks, both at the institutional and the individual level, has greatly increased concerns of achieving and maintaining sustainability. Historical boundaries between communities, cultures and civilisations are dismantling and bringing about de-territorialisation (Scholte cited by Osterhammel & Petersson 2007) and atopia (Willke 2001). Apart from the acceleration of energy and material turnover within ever larger and more complex systems, the psychological effects on the participants of these systems are significant. A combination of freedom of choice and loosely defined membership to various social structures has fostered a perception of individual liberation from systems of higher order. In particular, members of the social elite such as the policy makers, industrialists, scientists, economists, and even the "intelligencia" move between continents without any need to leave the culturally sterile environments of airports, air-conditioned offices and hotels. This fuels notions of a sustainability that is dependent on the functioning of economical and financial systems (Ibisch 2010).

The urban masses have also become divorced from the local ecosystem surrounding them. Cities are designed and constructed to accommodate the socio-economic needs of a technocentric society. In all cases the urban fabric is made up of processed material that is then structured and ordered to create a microtypology that appears distinct from the surrounding landscape. Towns and cities behave very differently from the surrounding ecosystem, often supporting a unique assemblage of species (many introduced), and also a distinctive microclimatic. Opportunities for native biodiversity are limited under these conditions, and in most cases urban environments export problems to the surrounding ecosystem. Much of the urban green space is either gardens or parks with very little remaining of the original landscape. Even rivers are grossly engineered to fit in with the urban fabric. The green space typology is the spatial metaphor for cultural and artistic expression; it does not necessarily need to have any environmental function. Consequently, less importance is attached to the biodiversity needs or ecosystem services of these sites despite the potential they might offer. This metaphoric and abstract representation of nature identifies one of the levels of apparent de-coupling between culture and nature. However, there are examples of a more extreme level that go beyond reshaping landscapes and genetically engineering nature. The use of artificial vegetation including turf, potted plastic foliage and flowers offers something nature cannot—a sense of permanency, perpetual flowering, all year ground greenery, a quasi-utopic environment. This form of cultural extensionism is rather more than just a de-coupling from nature; it also represents elements of a schism between reality and a fantasy world, another "Avatar." The ultimate frontier is the creation of spatial representations of computer-generated virtual worlds—variations on the theme of Disney World. In some of the most recently built urban-architectural spaces of the last decade, dominated by concrete and glass materials, nature has been reduced to a very minor role, or is superficially cited by artistic elements rather than really displayed.

The development of media and broadcasting technology has re-introduced nature into the lives and houses of the masses. This very detached and virtual exposure to nature introduces an element of naivety into the relationship, it presents nature as benign and unthreatening, a "cosy" and safe nature. Furthermore, it also widens public appreciation of the diversity and forms of nature that they would not normally encounter in the local environment—polar bears, tigers, Komodo dragons, and killer whales. These species very quickly inherit iconoclastic status that ranks them in importance above other forms of biodiversity. Watching charismatic 'beasts' and wild nature under controlled conditions in many cases may even reconfirm the nature-culture antagonism.

The rapid expansion of urban culture and its various manifestations has generated a society of 'omnipotent creators', modern city planners with access to energy and technology that allows them to go beyond former limits. The desire for humans to create artificial environments free from the constraints of nature is responsible for the generation of bizarre structural phenomena including buildings almost a kilometer high, artificial islands (The Palm Jumeirah, Jebel Ali, World Islands), or airconditioned beaches[45], all to be found in Dubai, as well as the plan to establish an energy-efficient model city in a hostile desert ecosystem: Masdar City, Abu Dhabi, "*the world's first carbon-neutral zero waste city*", head-quarters of the *International Renewable Energy Agency (IRENA)*[46]. Conservation and development actors, such as WWF, praised the initiative: "*Masdar City is fast developing into a global showcase of sustainable development in action, and a driving force for the world's renewable energy sector. The City is a focal point for the global sustainability community, a place where the world's leading minds and experts meet and connect to advance renewable and clean technologies. It is hard to imagine a more appropriate location for an international agency concerned with promoting renewable energy*" (Goncalves 2009). Technologists and technocrats are making an obvious statement that the replacement of fossil energy by renewable sources will be the panacea for all problems on Earth, leaving behind all restrictions defined by ecosystem boundaries and properties.

The process of urbanization has not just generated enormous environmental problems and costs but also contributed to the unsustainability of the global anthroposystem. Specifically, socio-psychological effects and combined political consequences of urbanization have impacted heavily on the well-being and welfare of individuals and populations. In other ways, urbanization of much of the world's population has skewed public opinion on issues of global sustainability and biodiversity conservation. Urban voters are predominantly responsible for steering policy in all matters to do with the environment and society (Ibisch 2010). In other words, those furthest removed from nature have the strongest voice, and may over-rule the opinions of rural communities on issues about the environment.

The rapid transition towards a globally modernised society has left behind just remnant populations still living in or near 'wilderness'. These last remaining refuges have been adopted as the new form of recreation for the privileged and educated few in the industrial states. As the number of middle class grows around the world rural countries and regions are targeted as travel destinations. In a short period of time these landscapes and cultures develop the venire and qualities of a tourist resort. Any legacies of the natural system are soon lost and replaced by more induced or artificial aspects of nature.

Urbanisation has also removed large sections of the population away from the living landscape, the agricultural lands that provide food for the cities. In the minds of city folk the connections and relationships between food on the plate and 'life in the field' are fuzzy. The detachment of city dwellers from the source of all the goods and services provided by the surrounding landscape and beyond has been compensated for by the development of a sophisticated transport network. It is possible to import all the necessary goods into a city including clean drinking water. It is common for ordinary lower or middle class people of industrialized countries to consume food that has originated from various continents. Even the ingredients of single products commonly represent a mixture of ecosystem products from various biomes and ecoregions. Dietary habits are no longer influenced by seasonality or local scarcity. In all industrialized countries, thanks to container-shipping and controlled-atmosphere storage, it is now possible for supermarkets to offer fruits like strawberries or apples all year round. Similar changes have even taken place in many developing countries, where in the last 10–20 years the culture of supermarkets has been established, and where at least upper middle class people have been integrated into subtle global trade and material flows. Increasingly, even lower-income people are more dependent on

45 "*Chill out, you beautiful people, the Versace beach is refrigerated*" (J. Leake, The Sunday Times, December 14, 2008).
46 www.masdar.ae

intercontinental trade systems of staple food such as rice. This inevitably raises the vulnerability of these sectors of society to sudden and unpredictable shifts in either the production or transport of food as witnessed during the rice crisis of 2008 (Boris & Crépu 2009).

Many of these life-style changes that have happened in the last 30–40 years have gone unnoticed by many because of the speed and apparent seamless transition of progress. The acceleration of wealth for many has set new standards of living which in turn have greatly raised demands for material goods and services beyond traditional expectations. Fuelled by ever more sophisticated marketing strategies of self-maintaining commerce systems, consumption 'wants' have become the most powerful single driver of societies' complexification, globalization and economic growth. A global scale aspiration towards a middle class life-style has put untold demands on natural resources. At one level, it has accelerated technological innovation, and contributed towards the evolution of a more complex global society. However, it has come at a high price to long-term social sustainability and biodiversity.

THE ERA OF NATURE-NEGLECT AND NEOCLASSICAL ECONOMICS

Economic and financial systems have gradually evolved away from the influences of the political system. Internationally operating organizations and business companies have evolved into transnational bodies, which in the globalizing world, have turned out to be powerful "*lateral world systems*" (Willke 2001, 2003). This aspect of globalization has materialised from the interactions of both individuals and groups that have eventually created networks within growing numbers of organizations; it is a phenomenon which is based on various processes that have a long history (Osterhammel & Petersson 2007). Everything began locally with agricultural surplus, subsequent urban condensation, and an increasing division of labour, with people adopting different professions as well as expanding mercantile exchange. In various cultures, these processes, convergently, led to quantum leaps in the development of symbol systems: letters, writs and money. The division of labour, together with the invention of money, also initiated new subsystems of the states; among their emergent properties there was 'economic growth' and laboral dependence, with significant feedback impacts on governance systems, technological progress and ecosystems.

To effectively serve a global economy transnational and (sub)global financial systems have emerged. These systems, like most others, have evolved their own dynamics and system-immanent logics, leaving behind the original *raison-de-être*—a phenomenon especially addressed in the course of the end of the current decade's financial and economic crisis. Current, sophisticated elements of financial systems have adopted a more virtual form, being nothing else than the transaction of information but still with meaningful impact on economies. For example, the performance of financial systems driven by share holder interests or other mechanisms even more decoupled from original function can have a strong influence on the availability of investment money for either intervening in ecosystems or either protecting them. In fact, 'virtual economics' appears to operate independently of the real material-based systems, but still influence the judgement and behaviour of people. This level of sophistication marks the preliminary end-point of the evolution of the neoclassical economical systems that appear to function detached from natural capital and ecosystems services.

The economies' of prehistoric cultures depended exclusively on the use and extraction of natural resources, nowadays called natural capital. The only man-made capital was represented by some hunting implements (Czech 2000). Over time, the division of tasks and increased exploitation of the ecosystem increased the value of human capital. An economic culture centred on community-based activities kept the focus on agricultural land produce, associated technology, craft, and labour (Czech 2000). The simple equation was more land use by more labour applied by more people led to more growth. As Brian Czech (2000) pointed out, "*somewhere in the transition from classical to neoclassical economics, capital was added to the list, so then we had 'land, labour, and capital'* ". This capital formed the economic infrastructure, tools and machines made available through the processing of natural resources and the consumption of exergy stored by ecosystems (such as wood, coal or finally especially oil). This infrastructural capital became so abundant and dominant in the direct environment of working people that at a certain point it appeared to be a decisive factor for production and economic growth. It was the generation and accumulation of implements and tools that caught the interest of the early neoclassical economists. These artifacts came to represent the new commodity at the expense the land and natural resources. Ultimately, this new found capital together with labour formed the basis for commercialisation of the economy (Czech 2000). Advanced forms of capitalism demonstrate how production and earnings can be achieved virtually, without labour, using exclusively man-made capital, or in the case of modern financial tools such as derivates and futures, symbols of capital only. However, the complex and abundant flows within the finance system forget that this "abstracted economy" (Kunstler 2005) represents nothing other than movements and re-distribution of values that ultimately are (or should be) backed up by real material resources.

The apparent multiplication and decoupling of financial values from natural resources—which has been understood by many people for the first time when the recent global financial and economic crisis gained momentum—are possible because the corresponding values do represent only the option of purchasing natural resources. If all financially wealthy people at once wanted to withdraw their bank savings or even purchase real land, wood or food for their money, it would instantly expose the mismatch of virtual economic commodities, actual money, and existing resources. However, history has proved several times the vulnerability and fragility of current economic models. For instance in times of hyperinflation money loses any significant worth, sophisticated neoclassical economies collapse, and even 'valuable' things such as gold or diamonds become extremely cheap in the face of diminishing natural resources such as food, timber and water. In extreme cases of collapse populations quickly revert back to bartering with food and 'tools of the trade' (agricultural seeds, livestock, implements and so forth).

The hidden costs to the environment and the masked inter-dependency between economic and natural systems have set new challenges to re-engage both systems by accounting for natural capital. This task has become the new frontier of *ecological economics,* a very different brand of economics from the more conventional model of environmental economics that simply assigns economic value to natural resources (Czech 2000). The recent emergence of new models for evaluating biodiversity, in particular global ecosystem services (Costanza *et al.* 1997) has stimulated interest and activity across a broad spectrum of society not just within the conservation community. This recent development spawned the TEEB-study (*The Economics of Ecosystems and Biodiversity;* TEEB 2008, 2009). The first TEEB report included a critical discussion of economists' attempts to assign monetary values to biodiversity. The problems are particularly related to the expectations and value-judgements of future generations about goods and services. For this purpose economists developed the habit of discounting, based on assumptions that any product or service will lose value over time as technology finds ways of replacing them, and as economic growth leads to higher incomes and increasing purchasing capacity. The phenomenon could be a called a kind of "*colonization of the future*" (Leggewie & Welzer 2009). There are obvious difficulties with the application of this principle to renewable, evolving natural resources. Actually, future generations may assign higher values than we do to certain resources such as clean water and wood-producing forests, as they begin to diminish. Correspondingly, negative accounting rates have been suggested for taking into account the changes in value of diminishing resources (Ehrlich 2008, Ehrlich & Ehrlich 2009).

Concerns for the needs of future generations introduce an ethical dimension into economic modelling. All measures of fiscal worth used in socio-economics become invalid under considerations of collapsing global ecosystems. If the loss of regulating ecosystem services, such as carbon sequestration, pushed the climate system towards a tipping-point beyond which dangerous run-away climate change would happen, then the value of the corresponding systems would be infinite. Existing economic and development models that promote accelerated loss of natural capital and that trigger processes that may lead to downward turns in the status of the Earth system are arguably unethical. In this scenario biodiversity conservation would be locked into a perpetual process of crisis management of treating problems generated by ongoing activities of unregulated economic growth. There would be an end-point to this scenario and that is the final collapse of all functional ecosystems.

There are limits to growth on a planet that is already heavy populated and utilised, and with much reduced availability of resources (as suggested by the milestone study of Meadows *et al.* 1972, compare also Meadows *et al.* 1992). However, more realistically, it is the likely loss of ecosystem services that will impact most severely on economic growth and sustainability rather than the scarcity of resources itself. "*The conventional response to the dilemma of growth is to appeal to the concept of 'decoupling'. Production processes are reconfigured. Goods and services are redesigned. Economic output becomes progressively less dependent on material throughput. In this way, it is hoped, the economy can continue to grow without breaching ecological limits—or running out of resources*" (Jackson 2009). Unfortunately, there is no evidence that it is realistic to achieve an absolute decoupling of economic growth from energy turnover and material throughput. For instance, "*despite declining energy and carbon intensities, carbon dioxide emissions from fossil fuels have increased by 80% since 1970. Emissions today are almost 40% higher than they were in 1990—the Kyoto base year—and since the year 2000 they have been growing at over 3% per year. (…) The truth is that there is as yet no credible, socially just, ecologically-sustainable scenario of continually growing incomes for a world of nine billion people. In this context, simplistic assumptions that capitalism's propensity for efficiency will allow us to stabilise the climate or protect against resource scarcity are nothing short of delusional. Those who promote decoupling as an escape route from the dilemma of growth need to take a closer look at the historical evidence—and at the basic arithmetic of growth. Resource efficiency, renewable energy and reductions in material throughput all have a vital role to play in ensuring the sustainability of economic activity. But the analysis* [done by Tim Jackson] *suggests that it is entirely fanciful to suppose that 'deep' emission and resource cuts can be achieved without confronting the structure of market economies*" (Jackson 2009). A detailed analysis of the flaws and myths of current neo-classical models of economics are presented by several authors, including Herman Daly (e.g., Daly 1972, 1996).

Still, many conservationists seek to reconcile economic growth and biodiversity conservation; compare: "*The larger challenge is to allow human society to meet its potential and share the fruits of economic growth while sustaining a biosphere that not only sustains full ecological functions but retains its living diversity*" (Adams *et al.* 2004). But: "*Even 'green growth' is not sustainable. There is a limit to the population of trees the earth can support, just as there is a limit to the populations of humans and of automobiles. To delude ourselves into believing that growth is still possible and desirable if only we label it 'sustainable'" or color it 'green' will just delay the inevitable transition and make it more painful*" (Daly & Townsend 1993). From an ecological perspective it is simply impossible to envision alternatives to steady-state economy or even degrowth[47]. A macabre but organic metaphor of putting monetary value to Earth's biodiversity for the sake of permanent growth of the anthroposystem is the discussion among cancer cells in a body that assess the economic value of brain cells, the lungs or the heart.

The myth that economic growth and technological progress can provide the ultimate solution to all problems of modern society is understandable if naive. Undeniably, in the short term, economic growth has improved the well-being of many but selected numbers of individuals. From an *ex post* perspective, history provides evidence for repeated technological solutions in times of social and economic crisis; humans have designed and planned their way out of trouble. There is little substance to this argument as in many cases in the past, complex human societies degraded or collapsed when they were challenged by serious problems such as epidemical events, severe conflicts and wars or (anthropogenic) environmental changes (see below). Often the solution to density-dependent problems that led to starvation, disease

47 The debate about degrowth and alternatives to GDP growth rates as indicator of development is gaining momentum, even among (inter)governmental institutions and in high-ranking scientific journals (compare, e.g., Degrowth conference Barcelona 2010—www. Degrowth.eu; EU-Initiative: http://www.beyond-gdp.eu/; Editorial Nature 2010; see also Fournier 2008).

outbreaks, armed conflicts and mass killings, was not technology, but simply emigration—nothing else than increasing use of natural capital/land. In fact, emigration has been a common and repeating theme throughout human history. The development of fossil fuel technology transformed the human-nature relationship by removing many of the constraints and dependencies on landscape resources. The result was a rapid increase in population numbers tied in with a technologically-driven so-called 'green' revolution. A more assertive population in control of its own food supply and powered by technology triggered off an expansion in global trade; mobility; and information systems. It also brought about a profound change in social psychology—a new found dependency, self-confidence, and a belief that the world could be shaped and designed to accommodate the needs and wants of society beyond the boundaries and constraints once set by nature. Humans had finally moved from a position of being merely another species existing according to the laws of nature to one of master of his own destiny and governor of the system.

Belief in progress as a synonym of technological advancement and economic growth is thought to represent a secularized monotheism, a continuation of the old tradition of belief, a predilection in divine mission (Gray 2010). In this sense, society has found justification through religious belief to excuse themselves from the laws of nature. Whether religion in all its form is seen as a destructive force that plays on human intelligence and drives humans further from their evolutionary ties is debatable, but it is clear that it provided the necessary material and social glue for human cultural evolution.

Significant numbers of today's society have woken up to the problems and potentially destructive forces of unbridled technology and modernity, and are now seeking a means of 'cleansing' themselves from all the ailments it has brought with it, an alternative way of life. Understandably, many are turning back to traditional cultural pathways including religion. In a number of cases the strength of feeling about modern life issues and problems is producing religious zealots, extremists and ideologists, often creating backlashes and problems of a different kind. Religion is an essential part of human culture, but it needs to evolve and enfold many of the complex issues that represent modern society. There are some attempts of dialogue between the main faiths and the scientific community. This partnership needed to build into a more effective theoretical and practical framework that is better able to address problems of population explosion, resource depletion, valuing of other life forms and natural systems.

GLOBALIZATION OF THE ANTHROPOSYSTEM, INCREASING SYSTEM OPENNESS AND THE GLOBALIZING BIODIVERSITY AND DEVELOPMENT CRISIS

Social evolution led to the formation of systems of higher order on the local, regional and finally the global level. The ultimate establishment and condensation of worldwide networks that has given rise to socioeconomic globalization has been described as "space-time compression" (Harvey 1989, cited by Osterhammel & Petersson 2007). Pre-modern societies did not exist in total isolation but at the same time could not be described as globalized. The globalization of political and economic networks did not arise simultaneously[48]. Similarly, other aspects of culture such as religion that spread across the world and eventually united occurred, sometimes hand in hand with economic and/or political development, but other times independently. Either way, the partnership between religion, politics and economic development was an essential development to the success and persistence of emerging empires. In cases where this alliance did not really exist such as the Mongolian empire, collapse followed after a short while (Osterhammel & Petersson 2007). That said, the most powerful form of global integration was the migration of people and the exchange of goods and services. This form of integration was particularly relevant to the status of global biodiversity.

48 E.g., first impulses of continental integration, e.g., expansion of the Islam and Mongolian expansion; establishment of the Spanish and Portuguese worldwide empires since 1500; multilateral interdependence between Europe, Africa, Asia and America until the middle of the 18th century; strongly deploying trade interlinkages especially with the rise of the industrial revolution, but contraction and dissolution of European empires; export of European institutions in the 19th century; world and globalization crises because of the world wars, and finally the evolution of world-politics and policy in the 20th century (Osterhammel & Petersson 2007).

Human travel and trade marked the beginning of the atopization of ecosystem use. Communities no longer depended exclusively on local ecosystem goods and services. Through trade, systems with limited resources and opportunities tapped into other more productive ecosystems thus increasing inflow of material and energy. It was mainly the wants of the elites that facilitated spatial integration of state systems. Today, even staple foods are transported intercontinentally.

Globalization, together with urbanization, has contributed to the de-coupling between culture and nature: "*escaping from the natural constraints to energy flows*", that has significantly increased the exosomatic metabolism flow of the society[49] (Giampietro & Mayumi 2009). „(…) *The food system consumes ten times more energy than it provides to society in food energy. However, since in the U.S. the exo/endo energy ratio is 90/1, each endosomatic kcalorie (each kcalorie of food metabolized to sustain human activity) induces the circulation of 90 kcalorie of exosomatic energy, basically fossil*" (Giampietro & Pimentel 1993). The pre-industrialized societies represented relatively closed systems with the sun providing the main source of energy. While the maximum density of energy input obtained from biomass harvested from agro-ecosystems has been calculated at about 0.05W/m^2, the typical energy use for a city (including residential, retailers, industry) is in the order of magnitude of 10-30W/m^2 (Smil 2003), cited by Giampietro (2009). Energy budgets of food production illustrate how deep societies are caught in a 'fossil energy trap'; e.g., in the United States, the energy input-output ratio of wheat, is 1: 2.57 calories, with about 90% of the input being fossil-energy-based (Pimentel 2009b). Similar ratios apply to other crops such as corn or potatos.

Modern trade is completely exosomatic, and a mainly fossil-fuel-dependent driver of economic growth. By the late 19th century, world trade started to decouple from world production, growing much more rapidly and leading to increasing openness of more and more local and regional systems (Osterhammel & Petersson 2007). Between 1948 and 1958, world production grew by 5.1%, and between 1958–1970 even by 6.6%. In the corresponding periods trade grew by 6.2% and 8.3% respectively (Lewis 1973, cited by Osterhammel & Petersson 2007). If a comparison was to be made between *global ecosystem production* and trade, the decoupling would be even more striking. Only a minimum increase in global net primary production (amongst others, as consequence of global warming) can be expected. Clearly, the ecosystem-based agricultural production has problems catching up: for instance, the world exports of merchandise and commercial services between 2000 and 2004 grew by 9%[50]; in the same period the world rice production virtually stagnated without any growth[51]. Global food production is steadily increasing but at a much slower pace than economic growth, and at the cost of primary production in natural ecosystems such as forests (that have to be transformed to agro-ecosystems). There are clear limits to growth based on net primary production of plants because of the limited availability of space, nutrients and water. Economic growth, in an era of industrialization, has been decoupled from the productive capacity of ecosystems by the increase of exosomatic metabolism flow and the transformation of stored exergy of the Earth's system (e.g., chemical industry based on oil).

Countries such as Germany that are strongly integrated into economic globalization generate an enormous flow of commodities, including ecosystem products. For instance, Germany, in 2007 exported 6.7 million km^3 of timber (90% to Austria and China), and at the same time imported about 4 million km^3 of timber (42% from Sweden and Czech Republic)[52]. Economic growth, in this case, does not mean anything else than increasing mobility of products, which is made possible by the use of (fossil) energy with more social systems participating in material and energy flows.

49 The differentiation of endosomatic and exosomatic metabolism has been especially proposed by Lotka (1956) and Georgescu-Roegen (1975). Both kinds of metabolism are related to flows of energy and material transformed by humans with the socioeconomic process—endosomatic metabolism is mainly defined by the energy transformation by the human bodies, and the exosomatic metabolism refers to energy transformation by people and social systems that use machines and burn various energy sources.

50 WTO International trade statistics 2005, www.wto.org/english/res_e/statis_e/its2005_e

51 www.beta.irri.org

52 Federal Agency for Statistics—Statistisches Bundesamt (www.destatis.de).

The globalization of markets and trade creates and multiplies its own selective pressures on people and states. In the case of many developing countries and transformation countries the degree of openness towards global markets correlates with the socio-economic situation of the inhabitants. At the same time, higher rates of trade liberalization, system openness and participation in financial systems are rewarded by more subsidies and support by the international finance system, a positive feedback loop (Bodenstein 2006). Following the collapse of communism, central European countries such as Poland and the Czech Republic were able to rapidly integrate into global markets. Consequently, these states demonstrated higher rates of economical development and growth than neighbouring countries such as the Ukraine that for various (political) reasons maintained a more closed economic system (Bodenstein 2006; compare Geyer *et al*., B.1.2.b. in this document). The communistic countries of central and Eastern Europe contributed about 30% to global economic production but participated in global trade only to an extent of 4% (Oatley 2004, cited by Bodenstein 2006).

In the currently 'transforming countries', rapid integration into global markets and trade has lead to: (a) more material wealth of an increasing number of individuals, (b) improved food security, (c) liberalization of individuals with ever more options for both consumption and mobility, as well as (d) independence from scarce and insecure local biodiversity services. There are only a few remaining cultures or political systems that have remained closed to globalization. Amongst the transformation states of central Europe the effects of global trading and internationalisation of the economy has also imported familiar problems of ecosystem degradation and biodiversity decline. Additionally, economic growth has been achieved partly at the cost of externalization of environmental costs by the import of products demanded for consumption and production. The development of international trade in animal and dairy products is a typical example of structural changes that have occurred in the older EU countries and which are now also repeated (much faster) in the new accession states. Originally, cattle were produced in a rather extensive way using vast local areas for grazing and hay production. The intensification of productivity (per animal and per farm) forced the farmers to industrialize animal production by introducing indoor breeding programmes, and purchasing of mixed provender produced from crops imported from other continents, such as soybeans from South America[53]. As a result of modernising agricultural systems, the traditional small farmer was replaced by fewer but much larger agro-industrial facilities. This also had a profound effect on the shape and character of the landscape. Especially in mountain regions, such as the Alps or the Carpathians, this process lead to the expansion of forest or tree plantation areas (often related with the loss of species diversity in cultural landscapes); in regions with better soils pastures were converted into cropland.

Those transformation states that have not experienced a meteoric growth in economy have also not managed to integrate effectively either into global markets or into regional (political, military and economical) treaties. Consequently, they show a poorer performance in social welfare development and economic growth, but retain greater biodiversity across the landscape. Furthermore, they do not export less environmental costs to other countries, an example being the Ukraine (compare Geyer *et al*., B.1.2.b. in this document).

The socioeconomic changes in transformation and developing countries have lead to abandonment of rural areas and increasing urbanization. Apart from the socio-psychological and social consequences of creating the growth of a poor urbanized strata with people who lose their connectedness to nature and local cultures (see also above), this phenomenon also has ecological relevance because it contributes to fuelling energy use and material flows. Poor urban people have a much higher ecological footprint than rural dwellers, because they increasingly have to use motorized transport, rely on fossil energy for domestic use, and consume imported staple foods such as rice produced on other continents instead of eating locally produced food.

53 This change of production regimes and continued globalization of agricultural markets has created an enormous dynamic in several production countries that take over a considerable portion of the environmental costs of consumption in the industrialzed world. E.g., in Bolivia from 1992 to 2007 the soybean production grew about 400% while population in the same period increased only by 53% (data from FAO, http://faostat.fao.org/,and INE, www.ine.gov.bo/).

Poor (rural) people in 'less socio-economically open' countries continue to depend more directly and more profoundly on local biodiversity than relatively better off in 'well-developed countries'. Consequently, some authors consider biodiversity dependence of the poor as "*a form of last resort, in the absence of alternatives*" and suggest "*that the poor may need to break their dependence on biodiversity in order to improve their livelihood outcomes*" (Vira & Kontoleon 2010). Evidence from transformation countries, indicate that whenever local people escape from subsistence economy and the dependence from *local* ecosystem services, and integrate into globalized material and energy flows they tend to be better off (unless they end up in urban slums). Global economic development has compensated for the (total) local loss of ecosystem services, and also externalized all environmental costs of individual and community lifestyles. However, any notion that global development has unshackled societies from the constraints and limitation imposed by nature is grossly misunderstood. The concept of ecosystem services defines the profound reliance of humanity on biodiversity that without it there would be no past, present or future.

The externalization of environmental costs implies that the negative consequences of the (over)use of ecosystem services is exported to other territories. Environmental problems including contamination, ecosystem degradation, fragmentation and conversion manifest in landscapes beyond the boundaries of origin but may not impact on systems until some time later once critical levels of tolerance have been exceeded (e.g., in post-second world-war Western Europe, compare acid rain in Scandinavia caused in industrial areas e.g. in Germany). For instance the environmental (and social!) impacts of intensive and large-scale sugar, fodder or biofuel production were exported by high-consumption countries to remote areas, such as Amazonia or Indonesia (where people were and are anxiously seeking entrances to globalized economy). Tragically, arising awareness of environmental problems and natual resource shortage is compensated by the export of environmental costs instead of developing locally and globally sustainable solutions (compare also Freudenberger *et al.*, B.1., in this document). Developed countries with a high population density and a "respectable" cover of remaining semi-natural ecosystems buy their national 'sustainable' development from countries, mostly in the south. E.g., Germany is covered by forests to an extent of about 30%. This is possible, in spite of high consumption rates, thanks to intensive fossil-fuel utilizing agriculture and the import of agricultural commodities produced elsewhere. In China, currently, it is possible to observe enormous efforts of halting deforestation and forest over-use; afforestation is strongly promoted, and protected area managers in some regions see improving conditions for biodiversity conservation because of rapidly increasing rural exodus and urbanization. Of course, the consequences of this structural change of agriculture and forestry production are exploding demands regarding the import of ecosystem services and products—triggering ecosystem degradation elsewhere.

In the last few decades there has been an accelerating change to the world's ecosystems, global environmental change including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems. These changes are likely to alter the capacity of the Earth to sustain life (US Global Change Research Act, 1990). Global change has always existed and was driven mainly by astronomic and geological forces. The globalization of the anthroposystem in the last few centuries, and especially in the last number of decades, has led to anthropogenic global environmental change made of manifold facets and processes that are increasingly interlinked. Most of the corresponding processes are the result of small local actions that can give rise to measurable global impacts:

1. **Change of atmospheric composition** mainly by the use of exergy of the Earth system stored both in living organisms (wood) and in fossil sediments (coal, gas, oil) (especially impacting 2, 3, 4; especially impacted by 2, 3, 4).
2. **Land cover changes** mainly by deforestation in forest biomes and the spread of agricultural production systems (especially impacting 1, 3, 4, 5; especially impacted by 1, 3, 4).
3. Subsequent **climate change** caused by changed atmospheric composition and land cover (especially impacting 1, 2, 4, 5; especially impacted by 1, 2, 4).
4. **Changes of ecosystem functionality and extension by the reduction/elimination of system com-**

ponents (e.g., species, forests, soils) and by reducing the extent of ecosystem types (including energy dissipation, exergy storage, hydroclimatic cycles etc.) (impacting 1, 3; impacted by 1, 2, 3, 5).

5. **Reduction of the evolutionary potential of biodiversity** by the loss of genetic and species diversity (directly impacting 4; especially impacted by 2, 3).

The compounded effects of global environmental change result in complex and multiple impacts on human development. Anthropogenic climate change is generating feed-back loops, for instance, globalization of socioeconomic subsystems have led to anthropogenic global environmental changes that will have knock-on effects for future generations and the environment. The dramatic release of stored exergy in the form of oil, coal and gas has the potential to trigger a shift in the global ecosystem system to a new operating point. Earth has not only become "*hot, flat and crowded*" (Friedman 2008) but, on top of that, also biologically impoverished, thermodynamically inefficient, socially unbalanced and unfair. The anthroposystem is facing a complex environmental crisis at a time of increasing scarcity of critically required resources. These issues and problems are surfacing at a time of social change. The world is divided along strong politic and religious lines as well according to economic zones. Social and political tensions can only add to mounting environmental problems, particularly as the two are inextricably linked. Solutions to environmental problems must not only take into account the planetary boundaries (Rockström *et al*. 2009), but also factor in social structures and complexity. Climate change can be also understood as cultural and political crisis (Leggewie & Welzer 2009). And it is not the only one. As in all systems synergies and non-linear changes are relevant phenomena; definitely, there are cultural and political thresholds beyond which multiple stresses in social systems can lead to runaway political chain-reactions.

It is important to understand the complex nature of all "*converging catastrophes*" (Kunstler 2005). All aspects of human well-being are vulnerable, in particular, the availability and security of food and water. All lessons learnt from human history indicate that heavily stressed social systems will respond in unexpected and non-linear ways. Increasingly, scientists warn of social perils triggered by global environmental change (e.g. Welzer 2009), and first systematic and quantitative analyses of history show strong correlations of socio-economic processes and temperature changes. In a recent study by Zhang *et al.* (2007) they show that "*long-term fluctuations of war frequency and population changes followed the cycles of temperature change*", and even that "*worldwide and synchronistic war–peace, population, and price cycles in recent centuries have been driven mainly by long-term climate change*". They identify an additional dimension to the classic concepts of Malthusianism and Darwinism. Other authors such as (Burke *et al*. 2009) have confirmed these findings in studies that indicate that historically there have been strong linkages between civil war and temperature in Africa, with warmer years significantly increasing the probability of war. Work by Burke *et al* (2009) presents quantitative estimates for armed conflict increasing by as much as 54% by 2030 (an additional 393,000 battle deaths if future wars are as deadly as recent wars). However, this extrapolation is not taking into account other parallel stress-provoking processes that may further exacerbate the problem.

The most relevant lesson we have to learn in the face of global environmental change is that all humans depend on ecosystem services that are not just produced locally. In the short run, the most important challenge is to address problems of climate change in order to avoid catastrophic events that are likely to effective the survival of human civilization. The conservation of global regulating ecosystem services, especially those related to hydroclimatic processes, is at least of equal importance as the maintenance of the local provisioning and supporting services. All communities, settlements and nations are reliant on local, regional and global ecosystem services. A subsistence farmer in Africa should be equally concerned about preserving the carbon banks in the boreal forests of the north as they are for the neighbouring forest that provides wood, food and medicine.

ABOUT COMPLEXIFICATION, DEVELOPMENT, COLLAPSE AND SUSTAINABILITY OF SOCIO-POLITICAL SYSTEMS

"*We can learn much about our own predicament from the interactions of the four thermodynamic principles, Energy, Entropy/Exergy, and Quality. In our culture, quality is increasingly embodied in sophisticated matter-energy systems, rather than in inherited cultural forms. Our civilisation thus depends on massive throughputs of energy, transformed at a frantic rate by an enslaved technological quality, and producing entropy at an accelerating pace. This latter manifests partly in the lower, material hierarchical dimensions, as the 'wastes' or 'pollution' that threaten to poison or choke our industries, cities, and selves. It is also there in the higher hierarchical dimensions as the loss of 'quality of life', a staleness of social existence, the creation of profoundly alienated masses, and of a constantly threatening degeneration of the functional quality of the support systems, both material and social, on which we all depend. The injections of exergy, in the form of ever more complex systems intended to prevent or remedy these structural ills, carry their own costs, and can eventually overload the societal system and contribute to its collapse, as in the case of declining civilisations like Rome*" (Funtowicz & Ravetz 1997).

According to the preceding sections we can summarize that development of societies is rather an open-ended process of *evolution* following systemic rules, rather than a deterministic *development* towards a prescribed state. Analogous to biological evolution, the subsystems of humankind, regularly experienced growth, multiplication, diversification and finally condensation, complexification and self-organization in systems of ever higher orders. This process was normatively perceived as progress, especially when apparent limits to growth were overwhelmed by spatial expansion and/or technology and individual access to resources was achieved. In a spatially restricted context, earlier or later, growth of systems leads to competition with other systems that demand similar resources. Once a critical population density was achieved, human history started to be shaped by conflicts about space and space-dependent resources and corresponding warfare. The systemic escalation of environmental factors that allowed higher population densities and higher densities of competing political systems, which was accompanied by high investments in warfare technology (together with the availability of correspondingly required resources such as iron/steel; compare Diamond 1997), led to the situation that some nations arrived earlier at the point where they were able to conquer other political systems and trigger political and economic globalization. This evolution of complexifying and globalizing political systems was fuelled by the use of fossil energy, especially required for the facilitation of interactions in the form of exchange of material, information and individuals. Concentration of people, division of labour and increasing efficiency of the overall economic systems led to social inequities and corresponding unrest. Revolutions became systemically unavoidable (compare Fulcher & Rochow 2007), commonly promoting individual rights and opportunities. Individual freedom and mobility together with ever increasing opportunities for multiplication, reproduction and storage of information caused an explosion of information and knowledge. In a feed-back loop, information-driven technological progress and complexification of people and social systems trigger ever higher turnover rates of individual energy and material use and also political change. The permanent increase and acceleration of resource use by the globally condensing and complexifying social system, in the last decades, allowed a historically outstanding technological progress which almost made one forget that social systems can also decomplexify, de-grow or collapse.

Collapse of systems of higher order is nothing else than a form of reorganization, and mostly allows system evolution to continue towards higher thermodynamic efficiency. There is even programmed collapse of systems, such as the death of organismic individuals, which has evolved in the course of natural selection. In biological evolution, decomplexification of ecosystems and (mass) extinctions regularly led to re-organization of the global Earth system, and always, the direction towards higher thermodynamic efficiency was picked up after more or less extreme events, which humans tend to normatively call 'catastrophies'. As explained above (see Hobson & Ibisch, B.1.1. in this document), the adaptive cycle of complex systems includes a phase of more or less significant revolt, instability and degradation before entering the phase of reorganization. Comparable phases can be identified in the development of abiotic, biological, ecological and social systems. A corresponding phenomenon has been described by historians and archaeologists, normally without referring to complex system theory.

For instance, Stanish (2001), who studied the processes of first-generation state formation in South America, supports the theory of earlier authors such as Marcus & Flannery (1996) or Feinman & Marcus (1998) who suggested a dynamic model of periodic expansion and collapse of archaic states. "*State polities emerge through the incorporation of other groups* (…). *As one polity peaks and begins to break down, former lower-level settlements regain their autonomy, after which the process of consolidation, expansion, and dissolution continues again*" (Stanish (2001), referring to Marcus (1998)).This dynamic cycling, for instance, happened in the Maya area, as well as in the Titicaca basin, where the Tiwanaku culture followed the Pucara one, showing four cycles before the Inca conquest (Stanish 2001). We can also find examples from other cultural contexts, such as the process of German state and nation-building. Everything started with rather diverse autonomous and culturally different states that started to interact more intensively and were brought together under different systems of higher order such as the Holy Roman Empire of the German Nation, the German Confederation, the German Empire, the Third Reich or the Federal Republic of Germany. Each phase of (re-)organization and integration was preceded by a phase of crisis and disintegration. In the course of historical development of the systems of higher orders, the subsystems do not stay how they used to be, but evolve influenced by their own traits as well as by systemically interacting environmental factors moderated by the functional context of the systems of higher order they work in.

Whether an abrupt loss of organizational complexity is called 'collapse' or 'deregulation' might be a simply semantic question. Recently, various researchers (see McAnany & Yoffee 2010) questioned Jared Diamond's popular collapse monography about failing societies (Diamond 2005). On the one hand, Diamond shows that human societies under various ecological conditions and in different historical-socioeconomic contexts faced severe systemic crises and that they often did not respond adequately. On the other hand, the collapse sceptics provide evidence or theories that in some cases the collapse was less absolute than claimed by Diamond (e.g., on Easter Island), they show contradicting approaches proposed in Diamond's earlier works—e.g., an apparently deterministic development approach with few options of choice as explained in Diamond (1997), versus inadequate responses to crises—and they argue that cultures that still partially exist, e.g. through their language, such as the Mayas, cannot have collapsed, rather they simply would have changed and adapted to changing conditions (McAnany 2010). From a systemistic perspective many of the identified contradictions are not absolute or even not valid. Cultural attributes such as language can persist as emergent properties of systems of lower order; their maintenance cannot be used as an argument against the collapse of a system of higher order such as an empire. "*We today, who face similar problems* [as those societies that collapsed or suffered from severe decline] *and could face similar fates, will not be consoled by the thought that our grandchildren might exhibit resilience*" (Diamond 2010).

In many cases in history socio-political systems had few chances of really choosing to fail or persist, because they simply are complex systems with decision-making driving on the border of chaos, and order being influenced by the interrelated interactions of very high numbers of subsystems. Some empires such as Napoleonic France or Hitler's Germany collapsed because of stressing to many other neighbouring systems and, in the latter case, the rarely arising (sub-)global political system of interacting states on different continents. Other empires, such as colonialistic Spain, Great Britain or Soviet Union, did not collapse to non-existence, but were degraded to much smaller relic states—they simply overgrew without being able to centralistically dominate the enormous diversity within the large empire comprising manifold social, cultural and political subsystems. Other non-imperialistic processes of continental confederation building instead followed evolutionary, self-organizing and efficiency-driven complexification and growth; good examples might be the United States of America and the European Union. However, this peaceful process of self-organization does not mean that these political constructs are not vulnerable against disturbances and change. Currently, in 2010, the EU is providing an example of the potential negative consequences of complexification and the building of systems of higher order: the economic crisis of single small member states such as Greece is challenging the stability of the common currency and even the political integration. Complex or even hyper-complex systems arising by self-organization can function more efficiently, but suffer from increasing vulnerability against disturbances that may occur only in a few subsystems. Thus, degradation and collapse are always an option. This leads back to the arising risks for the current informationally, politically, economically, financially and especially environmentally globalizing and hyper-complexifying human society on Earth. As the globally interlinked society produces emergent properties that can be categorised as global environmental change and that establish ever more linkages between socio-economical development of more and more states as well as environment and development, efficiency of the whole system decreases and vulnerability grows with non-linear tendency, especially as critical tipping-points of environmental systems are approached.

It is important to point out that stressed systems of higher order rarely decomplexify in a gradual way and without abrupt changes. Normally there are reasons of energetic and functional efficiency that do not allow a smooth return to lower complexity and lower energy turnover. In the case of the agricultural societies, due to the achieved relatively high population numbers and densities and the corresponding changes in the supporting ecosystems, it was completely impossible to return to a state of hunter and gatherer communities—although it might have been desirable for a majority of malnourished individuals. If a more or less highly-developed agricultural state collapsed, falling apart into smaller and less complex subsystems, at least at some times in history, this has meant reduced agricultural production and re-distribution of commodities or loss of protection against aggressive invaders—and thus, a decrease of population with fatal consequences for many individuals.

On the other hand, it was only in times of expansion, growth and complexification that social systems could provide or realistically promise a wealthier and safer future to their members. Thus, the individual demand for a better and more secure access to resources immanently has always driven human societies to growth whenever the conditions allowed it. In history there does not seem to exist any evidence that human societies willingly decided to deregulate and decomplexify. Actually, this describes the growth trap the globalized society is caught in while the limits to further material and energy consumption or turnover cannot be ignored any longer. "*A long time we could not take note of the meta crisis, which has been mounting up in the background of our apparently undamaged living environment, because our, in comparison to the rest of the world, relatively comfortable and safe living conditions saved ourselves from being confronted with the existential problems of the present*" (Leggewie & Welzer 2009[54]).

THE RECONCILIATION OF SOCIAL SYSTEMS WITH ECOLOGICAL SYSTEMS: A HOLARCHICAL ECOSYSTEM APPROACH

Arguments in support of the widening rift between nature and culture are compelling and have been covered in this paper. Equally, the growing mismatch between socio-political systems and ecosystems (e.g., Freudenberger *et al*., B.1.1. in this document), as a result of exporting and importing ecosystem products, have contributed to the widening gap between society and nature.

The understanding of interlinkages between biodiversity conservation and human development is a result of recent research (e.g., Fisher *et al.* 2008, Roe & Elliott 2010a). Modern studies also focus on the spatial overlap between poverty, ecosystem services and biodiversity loss (e.g., Sachs *et al.* 2009, Turner *et al.* 2010, Roe & Elliott 2010b). Still, there remains an urgent need to investigate problems relating to global change and human development. Often it is argued that conservation activities designed to meet *local* people's basic needs deserve more attention (e.g., Kaimowitz & Sheil 2010). Equally important is

54 Citation translated into English by the authors.

the need for special priorities for conservation action that targets the functionality of the overall *global* system.

The combined effects of ecosystem alienation—'problem of the fit', and the globalization of resource use (Folke *et al.* 2007, Cash *et al.* 2006, Cumming *et al.* 2006) do nothing for "*reconciling human existence with ecological integrity*" (Westra 2009). This reconciliation must begin conceptually accepting that the whole anthroposystem, comprising all social and economic subsystems, is part of and supported by the global ecosystem. Likewise, human subsystems can be embedded in subsystems of the global ecosystem, but depend on atopic ecosystem services provided outside local or regional territories.

The identification of real system boundaries is relevant beyond academic theories. Too often managers and even scientists describe for instance protected areas, as *socio-ecological systems* in terms of compartmentalised and discrete units although they might simply represent overlapping parts of greater systems which are holarchically nested within larger entities. Rather less, if anything, is made of the behaviour of the collective system. Consequently, socio-ecological management units do not coincide with real existing complexes of interactions. This can cause management failure because of an oversight or neglect of external influencing factors generated beyond the boundaries of the managed area. Thus, it is an important principle of the CBD's ecosystem approach that ecosystems shall be managed within the limits of their functioning. However, world-wide globalization of ecosystem uses and environmental threats complicate attempts to resolve all the environmental problems throughout the world. Ethical, political and technical frameworks for valuing environmental and social systems that also deal with complex interlinkages and interdependences across all system scales and dimensions are a prerequisite to an effective solution to global problems. The principal aim of this holarchical framework would state the desire for the effective functioning of the global ecosystem above all other concerns. Existing economic and commercial measures of achieving objectives and outcomes towards this aim are inadequate and should not obstruct or hinder more ideal-seeking behaviour towards protecting ecosystems and their services. A commitment to meeting this ultimate aim goes beyond values of "*global public good*" (Crabbé & Manno 2009) that can be purchased, used and taxed, and "*far higher than the value (or sum of values) of its components*" (Crabbé 2009). It is about the priceless evaluation of a planet that ensures our own survival. The promulgation of an Earth ethic should be a key enterprise of biodiversity conservation (compare Pimentel 2009a). A seriously implemented, more radical Ecosystem Approach can bring us closer to this kind of ethic and to effective conservation (see Ibisch *et al.*, A.2., in this document).

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