In search of sustainability: what can we learn from the past?

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1. Introduction

> 'Concepts of past cultures have probably changed as much in the last thirty years as have ideas of the earth system. The two massive data sets await reconciliation.'(Gunn 2000:227)

The last decade the words sustainability and sustainable development have gradually become a modern equivalent of and complement to the Declaration of Human Rights which inspired so many people shortly after the devastating second European World War. Respected high-level business and government people have embraced the concept and hailed it as the foremost challenge for the new (21st) century.

Inevitably, these concepts have been broadened to the extent that they are now hosting a large variety of interpretations, objectives and proposals. These are intertwined with personal and collective values and perceptions (cf. De Vries 2001), which are, in turn, rooted in millennia of developments shaping the experiences, the knowledge base, the technical skills and the social arrangements and psychological traits of 'a culture'.

It seems only logical to ask whether we can learn something from the past in our search for the roots of [un]sustainable human-nature interactions [1]. In this paper we reflect on some of the lessons from a 3-year project sponsored by the Hollandsche Maatschappij der Wetenschappen in Haarlem in celebration of its 250th anniversary [2]. The topic was chosen, first, because historical analyses are a sine qua non in the search for a sustainable future, i.e. for a world in which the needs of the present are met without compromising the ability of future generations to meet their own needs (WCED 1987). Secondly, in the last decades a large amount of new scientific research results have become available, in particular from undertakings such as the IGBP PAGES and the BIOME 6000 projects. There is use and need for an overview. Thirdly, there have been novel insights and tools for a more in-depth, model-based understanding of the past which can help to synthesize disciplinary data, concepts and theories into a more coherent and transdisciplinary framework.

The project resulted in the book *Mappae Mundi: Humans and their habitats in a long-term socio-ecological perspective*. Given this background, it is not surprising that the team of contributing scientists has a varied background: archeology, history, sociology, geography, biology, engineering, climatogy, and that we use several ways of communication: myths – or stories, maps and models.

In the project, my co-editor Joop Goudsblom and I have attempted to sketch key empirical and theoretical findings about past evolution of socio-natural systems. It describes in a broad and impressionist way the transitions from the fire regime to the agrarian and industrial regimes. It reviews recent empirical facts and insights about palaeoclimatic change and its impact upon humans. It makes an attempt to understand some of the intricacies in human-environment interaction dynamics for particular eras and regions. By the time we had arrived at the European Middle Ages, we were running out of time as well as humbled by the complexity of our task.

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[1] In the present context, I will talk about socio-natural or socio-ecological systems to indicate the whole of humans living in their natural environment.

[2] B. de Vries and J. Goudsblom (Eds.), Mappae Mundi – Humans and their Habitats in a Long-Term Socio-Ecological Perspective: Myths, Maps and Models. Amsterdam University Press 2002, Amsterdam www.aup.nl.

It is my contention that the emerging, truly transdisciplinary approach of the evolution of socio-natural systems provides important clues to the 21st century challenge of sustainable development pathways for humanity. In this paper I address three broad questions. What can we learn from recent palaeo-climate and –vegetation reconstructions? Which insights have been gained from emerging, computer-based techniques such as complex adaptive systems modelling? And thirdly, which concepts and theories have come up to tell the 'Grand Story' of socio-natural system evolution? Three tentative answers are, in the form of statements:

the abundance of new scientific data on global change permits major advances in understanding the evolution of the material metabolism of peoples [3];

a number of environmental histories have been sufficiently investigated to propose and test scientific hypotheses about their socio-cultural dynamics; and

The new modelling tools and a variety of socio-ecological schemes – 'theories' – make it possible to tell several inspiring Grand Stories without sacrificing realism for oversimplicity.

Needless to say, I in no way claim completeness – nor in the sense of covering all relevant research nor in the sense of bringing in all integrating approaches.

2. An epistemological note

> "If it's hard to determine the function of things happening today under our eyes, how much harder must it be to determine functions in the vanished past! Interpretation of our past runs the constant risk of degenerating into mere 'paleopoetry': stories that we spin today, stimulated by a few bits of fossil bone, and expressing like Rorschach tests our own prejudices, but devoid of any claim to validity about the past." (Diamond 1992:82-83)

Using available methods and inference techniques, one can attempt to reconstruct 'scientific facts' about the past from what remains of it in the present. The methods to look into the distant past are still evolving. We see more and realize that what was 'seen' in the past was itself part of that past – which is also true for the present. Our knowledge, both in the form of data and concepts, came – and comes – through filters. 'Scientific' data and theories are biased accordingly. For one thing, the more advanced societies have left conspicuous and lasting material remains which naturally became the main focus of archaeology. Plant foods leave less traces than from animal foods, mud houses last for not more than a few generations. Changes in sea-level affect the use of marine resources and the ensuing archaeological records – numerous sites are likely to be below the present sea-level. Another bias stems from he larger part of historic and palaeo-climatic research having been done by European and North American researchers. This has resulted in more knowledge about certain places and times and in predominantly 'Eurocentric' interpretations. More in general, information about the past may have been or be distorted or withheld for geopolitical reasons.

Investigating past societies in recent (pre)history starts by examining patchy observations on material artefacts, food remains, vegetational traces and orally and written transmitted records. The observations are filtered and translated in

[3] The word metabolism is, by analogy, the transformation of material fluxes in the natural environment into usable 'goods' and their subsequent excretion, discarding and/or recycling. See e.g. Fischer-Kowalski and Haberl (1998).

descriptions of the system, for instance an evocative story or a set of differential equations. This process involves making associations and inferences to glue the patches together. There is filtering and selection, followed by complex cognitive processes which adds ‘meaning’ to the perceptions – or simply ignore them. To put it differently: observations have to be contextualized to become more than an incoherent sequence of material and mental objects.

Two more things to be said. One: human beings have gradually expanded the spectrum of sensory perceptions. After centuries of developing natural science, we are now aware of the narrowness of our ‘natural’ sensory apparatus. The human eye only sees a tiny part of the frequency spectrum of light – many animals see more or different parts. The same holds for sounds and smells – elephants can communicate across miles by stamping their feet, some fish are able to catch a prey using the smell of a mere few molecules. By now, humans have outperformed most animals in collecting and interpreting signals, by using tools such as telescopes and microscopes to extend their sensory limits. Beyond our immediate sensory experiences, with or without artificial extensions, we use inferences, hypotheses, speculations, conjectures and refutations as part of our genetic and acquired configuration. Concerning these – more subtle – thought processes, we are possibly only at the start of our potentialities and of our awareness of them.

Two: in the advance of science observations about one system are often used to infer hypotheses about another system – the use of analogues and metaphors. Spatial transference in which events in system A are given explanatory meaning in understanding system B and time transference in which events in system B at some stage of its evolution are understood in terms of observations about system A in a supposedly similar stage. This way of knowledge acquisition is helpful but may also be speculative and misleading.

3. Early humans: the threats and opportunities of a changing environment

As part of Global Change research, and in particular the IGBP- and HDP-networks and the PAGES- and BIOME-projects (www.pages.org), a large stream of satellite data and field data is being generated which allow [re]construction of present and past climate and vegetation characteristics. For some regions, based on investigations of ice cores, tree rings, sediments, stones and bones, rather detailed reconstructions of past climate and vegetation as well as of peoples’ diets and diseases have been made. As a consequence, new and refined hypotheses have been proposed for the transitions from hunter-gatherers to more sedentary forms and for the rise and decline of groups of peoples [4]. As a result, less speculative answers can be given to the questions about the when and where of early socio-natural system evolution.

The agrarianization process. In the first stages of expansion, human groups were confronted with changes in climate (temperature, precipitation) and, relatedly, vegetation. Some of these changes had a catastrophic immediacy such as earthquakes; others were slow but no less penetrating such as changing courses or drying out of rivers. The changes presented to human groups both threat and opportunity, both risk and challenge. In those situations human groups were largely dependent on their

[4] At this stage, human groups had already mastered the control of fire, which should be considered as a sine qua non for the onset of agrarianization (see Goudsblom 1992).

‘natural’ environment and many biogeographical traces have been found of how these ancient peoples lived (see e.g. Messerli et al. 2000).

In these early days of a still small and fragile anthroposphere, human groups will often have responded to signs of local resource scarcity with outmigration into new areas with better and new opportunities. Nomadic behaviour, like so many species. In some places the response will have been to increase control e.g. domesticate wild animals. The interaction between human groups and their natural environment intensified, with a more sedentary life and a loss of mobility. This coincided, in an chicken-and-egg way, with innovations in behaviour and tools and with sometimes drastic changes in organization. It may have induced group complexity as early as 15-30.000 yr BP [5].

In this early part of the agrarianization process there were two main routes. The first one was plant-food production, from wild plant-food procurement to crop production (horti-agriculture). The second was animal domestication, from predation to taming and protective herding to livestock raising and pastoralism. The dependence on wild plants and wild animals continuously decreased.[6] Climate and biogeography have played an important role.

Prior to ca. 15.000 yr BP almost all of the interior of South-West Asia was dominated by steppe and desert-steppe, dominated in part by grasses such as perennial feather grass. The steppe vegetation probably offered local foragers a diverse array of wild plant-foods “that could have provided not only carbohydrates, oil and proteins, but also vitamins, minerals and those miriad ’secondary compounds’ that are coming to be recognized as essential to complete human health.” (Hillman 1996:178). Some of these foods have relatively low energy costs of processing and thus a high digestible ‘net’ caloric value for humans. Recent data from pollen diagrams suggests that the life of early hunter-gatherers may not have been so bad – as assumed by Boserup (1966) in her explanation of rising land productivity and in Sahlins’ well-known book *Stone Age Economics*. Why then did the change happen?

Climatic and other environmental changes were almost certainly powerful forces in the inception and spread of agriculture and possibly of animal domestication (Hole 1996). The prevailing view nowadays is that agriculture probably originated some 12.000 yr BP in the so-called Levantine Corridor near the Jordan valley lakes in the form of the domestication of cereals and pulses. Within a millennium animal domestication took place: dogs, then sheep and goats. It is hypothesized that preceding hunter-gatherer populations lived in small refuges and that by this time the steppe vegetation started to become richer across the Fertile Crescent as a consequence of climate change. Soil moisture increased in the Late Pleistocene leading to woodland expansion in the northern Fertile Crescent and the spread of wild cereals and other herbaceous annuals. The invasion of annual grasses was followed by oak-dominated park-woodland and

> ‘increased dramatically the gross yields of plant-foods per unit area, particularly starch-protein staples, that correspondingly led to increased carrying capacity. It is suggested that these increases prompted significant extensions both in the storage of plant-foods and in sedentism, and that the ensuing increases in birth rate eventually

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[5] “Mellars has suggested that in the case of southwestern France a particular combination of ecological conditions led to population concentration and stable and relatively large co-residential units involving sedentism over a substantial part of the annual cycle, and that this was the crucial step in the emergence of more complex social structures.” (Doran et al. 1994 pp. 197).

[6] See [Mazoyer, 1997 #58; Harris, 1996 #8] for elaborate evolutionary classifications of plant and animal exploitation by human groups.

produced stresses on carrying capacity, which, in certain locations, led to the cultivation of cereals.' (Hillman 1996:195) [7].

This process of cereal cultivation started spreading to the south and east, accelerated by the increasing climatic seasonality and unpredictability coupled with the dry conditions. The spread of forest reduced the open range that encouraged territoriality and pre-domestication of animals by the protection and propagation of local herds (Hole 1996). Thus, climatic change affected human groups mainly through changes in the distribution and composition of vegetation, and by concomitant changes in the plant-food resource base (Hillman 1996). Figure 1 illustrates the point with a sketch of vegetation change based on recent observations and reconstructions.

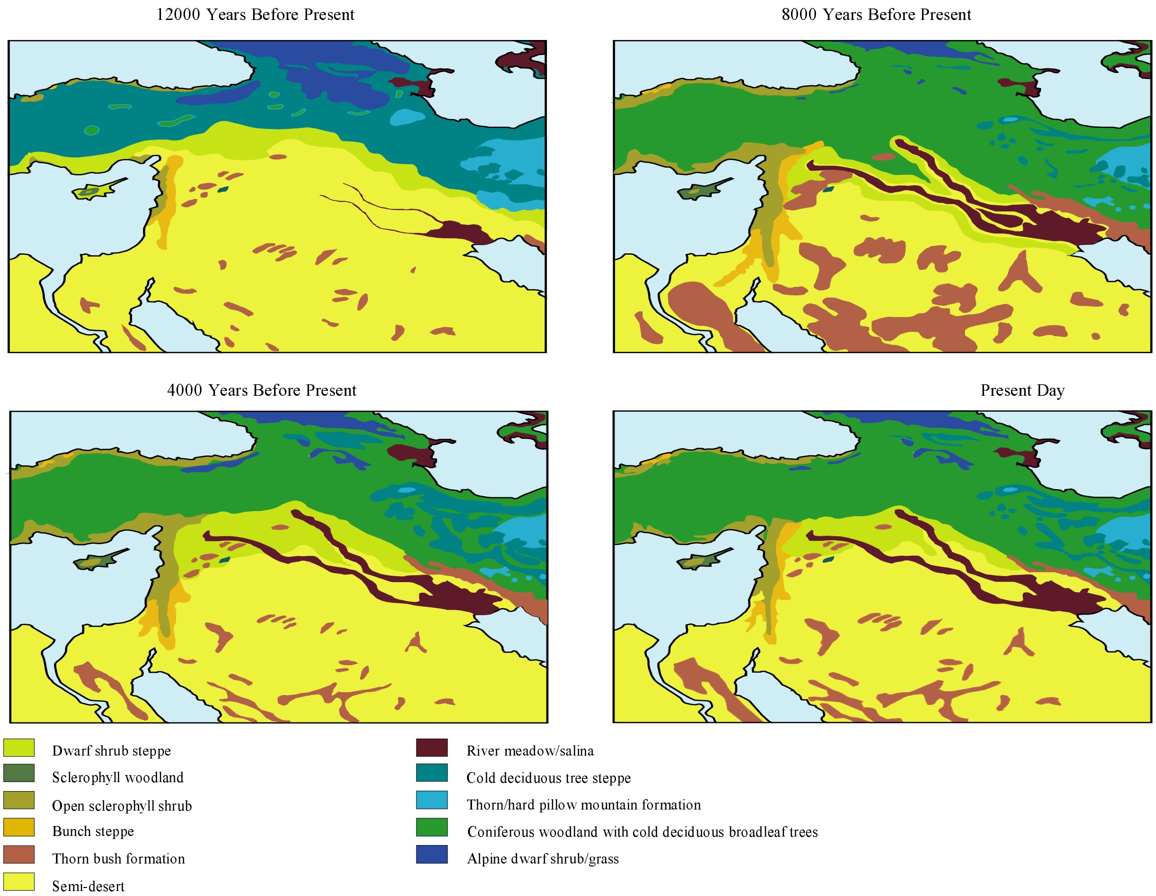

Figure 1 *Vegetation change in the Near East over the past 12.000 years, based on recent observations and reconstructions (Marchant and De Vries 2002)*

In this 'scientific story' then, agricultural cropping, animal herding and the use of trees for wood and fodder started as an apparently more rewarding alternative strategy because, overall, the dry cool steppe were places of low mean energy yield per unit of area – lower than in the later moister steppe, the woodland steppe with their grasses and the wetlands. Thus, it was at least partly a response to deteriorating conditions for a gathering-hunting way of life. In any case 'the' agricultural revolution has not been

[7] Climatically, the Near East is a highly complex region, conditions were continually changing in the early Holocene period and none of those conditions exist today anywhere in South-West Asia.

one momentous event – one of the reasons why we prefer to talk about agrarianization: a gradual intensification of the relationship between groups of humans, their environment and each other.

As so often, changes led to new changes – often not intended by the peoples who initiated the changes. A widely held hypothesis is that there was a reduced birth spacing as peoples became less mobile, causing higher fertility rates and in turn accelerating the agrarianization process. Net population growth may have hardly been affected due to another complementary (sub)mechanism: with rising temperature micropredators may have become more abundant and caused a rise in mortality, possibly reinforced by more intense human-animal contact. With sedentism the exploitation of the locally available resources (soil, water, trees…) became more intense, which may have accelerated degradation processes such as soil erosion. Figure 2 is a so-called causal loop diagram (or CLD) from system dynamics: it is a condensed semi-quantitative way of presenting some major dynamic factors in the agrarianization process [8].

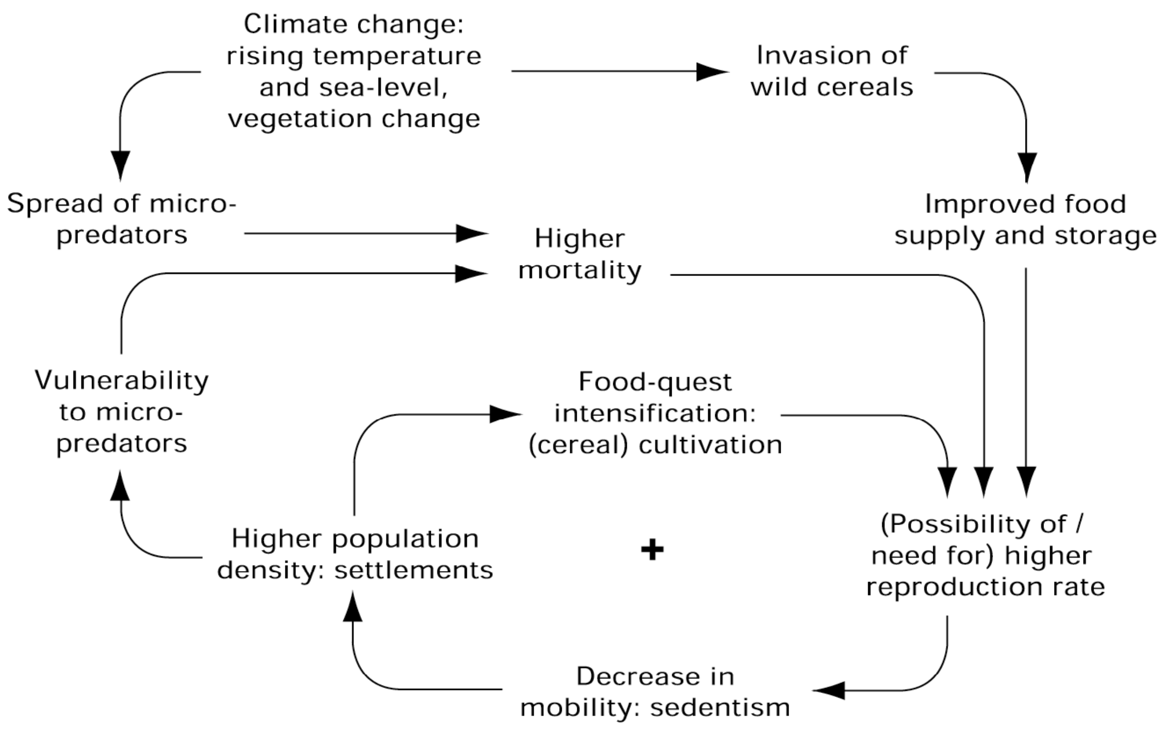

Figure 2 *A causal loop diagram (or CLD) presenting some major dynamic factors in the early agrarianization process*.

Outside the Levant there were also early agro-pastoral economies, for instance as long ago as 10.000 yr BP in the semi-arid areas surrounding the Iranian Plateau.[9] The recognition of the very early, probably independent origins of agriculture in China has been one of the important recent archaeological discoveries. Rice in south-east Asia was regularly cultivated at least 8000 yr BP, probably behind areas of seasonally receding floodwaters around lakes in the middle and lower reaches of the warm and

[8] It is similar to what is called 'figurational dynamics' by some sociologists.
[9] Agrarian settlements also spread over the entire Plateau itself, near places with accessible surface water [Christensen, 1993 #4].

humid Yangtze He region (Glover 1996). Millet was at the base of another origin of agriculture, in the northern Huang He area around 7000 yr BP. The early developments will no doubt have been influenced by significant changes in climate (Ge Yu 1998). Farming in the Guangzhong Basin in the north-west started some 7000 yr BP in warm and wet climate conditions. Recent research in this area shows that between 6000 and 5000 yr BP a rapid climate deterioration with intensive aeolian dust deposition took place, with widespread aridization and a remarkable decline in Neolithic culture (Chun Chang Huang 2000; Zhang 2000).

Other places in Asia and the Americas have probably been the locus of ancient beginnings too. The transition processes have sometimes been successful and enduring. Sometimes it broke off in complex interplays of environmental change and social response processes – as the expansion and contraction cycles of agricultural activity and population density some four to five millennia ago in the fragile Mediterranean environments of Europe show [10]. From the many narratives we choose one: the Hohokam people in North America.

4. An environmental history: emergence and disappearance of the Hohokam people in Arizona

> 'All mankind shares a unique ability to adapt to circumstances and resolve the problems of survival. It was this talent that carried successive generations of people into many niches of environmental opportunity that the world has to offer – from forest, to grassland, desert, seashore and icecap. And in each case, people developed ways of life appropriate to the particular habitats and circumstances they encountered… Farming, fishing, hunting, herding and technology are all expressions of the adaptive talent that has sustained mankind thusfar.' (Reader 1988:7-8).

An interesting environmental history has been constructed of early occupants of the desert region of central and southern Arizona (Redman 1999). Early in the 3rd millennium BP, maize farmers settled in the river valleys in places suitable for floodwater farming. Around 1250 yr BP this Hohokam culture had developed irrigation agriculture which tied households together into community networks, with ritual and belief systems. By 800 yr BP, larger villages with platform mounds were beginning to appear and canal systems were expanding, linking communities into larger networks. These and a variety of other cultural changes appear to be linked to downcutting and widening of the river valleys which destabilized the existing irrigation systems and everything else that was based on them, and precipitated the construction of new canal systems, and new ceremonial and political organizations. By around 550 yr BP the Hohokam culture had disappeared.

The Hohokam depended on the nutrients brought down in flood periods by the two rivers traversing the Phoenix lowland basin. Hundreds of canals led the water and sediments to the fields, thus regenerating soil fertility. The localized nature of accessible surface water and farmland, in combination with the need for labour investments in canals and rising population, made it disadvantageous to move around

[10] Agriculture has surely not been always and everywhere an obvious and rewarding alternative. The Jomon culture flourished in Japan from at least 9000 yr BP until about 2400 yr BP apparently without any fundamental changes to its economic hunting-gathering economy – nuts, fish, deer, boar – with pottery and sedentary settlements. Ingenious fishing tools were developed and there was trade in this 'Stone Age' society – but no stratified social systems or political structures evolved. The dry-field rice agriculture from northern China was known but more arduous than the Jomon hunting, gathering and fishing strategies. Only when well-developed wet-field rice techniques came in from overseas, full-scale agriculture quickly took over (Imamura 1996).

and forced them to take care of the productive potential of their immediate surroundings. The large empty surroundings provided a sustainable flow of wild food and material resources. Social institutions and community networks were instrumental in providing labour for canal construction and maintenance and in spreading the risks of food shortages.

The Hohokam lived in an unrewarding environment and their way of life – no domesticated animals, modest use of wood – tended to spare the vegetation. Nevertheless, despite a way of life apparently based on principles of sustainability, archaeological evidence suggests that the increase in population led to a scarcity of protein-rich food such as fish and rabbits. What, then, caused their disappearance [11]? The outcome of recent research allows a plausible reconstruction, as Redman (1999) convincingly shows. Three factors were at work: environmental change, irrigation strategies and social responses. Tree ring analyses indicate a rather high climate predictability in the period 1250 to 900 yr BP with modest variations in wetness – hence without extreme floods or droughts. Communities developed along the feeder canals that brought the water downstream to the distribution channels; population, organization and trade all increased. When in subsequent centuries flood variability became larger – as the tree ring evidence suggests – these communities were resilient enough to handle droughts and floods through storage, repair and trading. However, after 700 yr BP

> 'the climatic situation appears to have become even more erratic, with floods or droughts coming at least once every 10 years. This put tremendous pressure on the survival of the entire system. Crop production in the valleys was seriously diminished, and labour required to maintain the irrigation works dramatically increased… it is likely that the valley farmers overplanted in their good fields, extended planting to marginal fields, and cut back on fallow periods. All of these strategies would lead to decreases in soil fertility and subsequent productivity.' (Redman 1999:154).

Because the Hohokam remained in the same location, their activities unavoidably caused environmental changes such as increased runoff volume and velocity and subsequent soil erosion and canal silting. Although they maintained soil fertility through various conservation methods and by supplementing local food with goods brought in by exchange systems, '*when the climate entered a long period of greater variability, including disastrous flooding, it put an additional pressure on the Hohokam system that could not be easily sustained. Their response was to invest more labour in extracting the maximum from the land, but that made the system even more vulnerable to climatic extremes.*' (Redman 1999:155). Socio-political changes towards more centralized control and ceremonial activities may have further weakened the system's resilience. Their disappearance, it seems, was due to a dynamic interplay of environmental and social forces working on different time-scales.

5. Modelling the Neolithic transition: a global dynamic model

One way to investigate socio-natural systems is to study a particular place and time in detail, as with the previous narrative. Another approach is to draw the larger picture,

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[11] '*Each age, it seems, reads something different into the demise of the Hohokam. Not only does each age have an explanation, but each pushes into the shade explanations that had seemed reasonable to their adherents.* ' (Krech 2000:71).

in a more impressionist way: the *longue durée* and global scale. Computer-based modelling permits a more formal way of doing just this and a recent attempt to understand the spread of agriculture as a process of ecological opportunity and social exchange and innovation processes provides an excellent example (Wirtz and Lemmen 2002; De Vries et al. 2002). The transition process is modelled after microbiological dynamic processes. The simulation is highly instructive, putting many pieces of the puzzle into a theoretical frame with great heuristic value.

First, a world map of 196 land units or regions ('ecozones'), constituted from 0.5 x 0.5 degree grid cells and each comprising about 10^5 to 10^6 km^2 has been constructed. For each of them, the potential to provide hunting-gathering and agricultural subsistence is estimated from environmental conditions that are supposed to be inherent to the mid-Holocene distribution of vegetation types. The latter are to that end projected onto two quantitative biogeographic characteristics: the net primary productivity (NPP) and a temperature limitation index that is zero at permafrost conditions and unity in warm climates. They serve as a bridge to two other indicators acting much more directly on the Neolithic transformation. First, the local natural food extraction potential (FEP) becomes a linear function of the temperature limitation index and a parabolic function of NPP, reflecting the low caloric return achievable in marginal ecozones as well as the notion that the amount of unusable biomass increases when going from temperate zones to the tropics. Secondly and akin to the development stages suggested by Boserup (1966), each regional NPP is transformed to the number of locally available agricultural strategies. This quantified agricultural potential represents the natural occurrence of domesticable plant and animal species in a habitat and, thus, peaks in open woodlands while approaching zero at either marginal (low NPP) or too densely forested (high NPP) ecozones. Moreover, faunal and floral differences between continents have been accounted for.

With appropriate parametrization, the model simulations give a fascinating view of the spread of agricultural strategies and population density. They show where and when the local Neolithic transitions and their first order effect on the human population occurred, and how agricultural subsistence strategies diffused from the independent centres. In the early Holocene period, nowhere does the population density exceed the level of 0.08 people/km^2, which is characteristic for hunter-gatherer communities. Some 2000–3000 years later, it has increased considerably to a range of 5–10 people/km^2 in several Eurasian regions. By 3500 yr BP large parts of the Eurasian continent have reached the levels of population density associated with the Boserup stages 4-7. Prominent pioneer areas are North China and Near East/Mesopotamia, later followed by the western Mediterranean, Central Mexico, two Andes regions and the Pampas. Except for the latter region, and in some respect also the Mediterranean one, the correspondence between these simulated farming kernels and current palaeo-biological and archaeological knowledge are striking [12]. Of particular interest is the emergence of a corridor around the Silk Road, with dense populations oscillating and migrating between China and Europe, mirrors some of the destiny connected to early nomadic invaders. We can hence speculate that the model might have hit relevant key processes acting on an aggregated level in real prehistory and can be useful in guiding further research.

Obviously many questions need to be raised about this complex model, for instance about model initialization and parameterization. There are still a number of

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[12] An interesting 'error' in the simulation is the Indus valley. This can be explained by the absence of any exchange via sea routes and by the strong influence of geographical barriers.

difficulties with the biogeographical maps arising from, for instance, the compilation of input maps and the many local uncertainties therein. Nevertheless, filling the gaps of *terra incognita* brings the advantage that many world regions that are sparsely investigated by scientists or for other reasons offer a small amount of finds are now treated the same as prominent zones such as the Mediterranean or the south-west of North America. The outcomes of the model have to be interpreted in the light of the spatio-temporal scales for which it has been constructed. Short-term outbreaks of non-adaptive strategies such as the maintenance of a large urban and associated negative feedback loops on wealth and development are clearly filtered out.

The global dimension of the simulation study should be understood as an extremely hard test of the model's generic nature. Parameters, initial values and evolution equations do not carry site-specific modifications. One question arising from these simulations is whether commonly attested world-wide patterns of human-environment interaction during the Holocene period can be reproduced by means of a deterministic rule system and whether they lose their "contingency". No clear answer to both questions is presently ready for presentation, However, the model provides a clear context for raising these questions and reflects the growing possibility of linking theories of the macro-evolution of humanity to models which in turn can be more easily subjected to a critical validation using the increasing amount of archaeological and archaeobotanical fragments.

6. The rise of social complexity: environmental risk and social organization

> 'The normal sense of a satisfying explanation in archaeology is that it makes a set of facts in some sense intelligible by demonstrating that they seem "natural" when viewed from the perspective of a certain framework of thought.' (Cherry 1985:44)

In the previous paragraph the natural environment has been described as a background against which the first steps into the second, agricultural regime were made. However, a concurrent process was the further unfolding of social complexity – an equally essential component in understanding and interpreting the human-environment relationship. Is there evidence that human-induced environmental change played a significant role in the rise and decline of social complexity? Can variation in the environment explain the nature of social organization? To what extent was the perception of environmental resources and risks a major determinant of how social complexity evolved?

Our answer floats around two observations. First, with the intensification of the human-environment interactions environmental risks tended to change from short-term event-based to long-term process-based. Secondly, the corresponding expansion of the anthroposphere with rising population density and intensification of the human-human interactions caused socio-economic differentiation and stratification which in turn affected the ability to cope with exogenous and human-induced environmental risks.

Environmental feedbacks and risks. The tale of the Hohokam and of other societies e.g. Easter Island and Norse settlements in Greenland, suggest that combinations of environmental change and resource exploitation may well cause the collapse of human societies. However, we should beware of simple environmental determinism: reality is more complex than most anecdotes suggest. Along the lines of the 'triad of basic controls' proposed by Elias, Goudsblom (1996) distinguishes between dangers coming from the extra-human world – droughts and floods, wild beasts and pests, earthquakes and volcanic eruptions; from inter-human relationships – hostile neighbours, invading warriors; and from mismanagement due to intra-human nature – negligence, ignorance, lack of self-restraint or discipline. Here I focus on the interface of the first and the last: human-induced environmental change and mismanagement in the sense of failure to cope with the unintended – and possibly misconceived – consequences [13].

There is much evidence that more intense exploitation of the local resource base caused environmental change. In some cases it was rather local and, for the interested observer, direct and visible. Such was for instance the case with erosion from deforestation and/or overgrazing or salinization from irrigation. Even then, however, it could take centuries before the impacts would show up in the form of abandonment or collapse. A reconstruction of the decline of early 9th millennium BP villages in Jordan suggests that lime use for plaster and goats destroying the vegetation caused deforestation and subsequent abandonment (Rollefson 1992). Although the extent and mechanisms are still debated, there is general agreement that environmental deterioration – mainly in the form of salinization – played a role in the collapse of the later Ur dynasties in the Mesopotamian plain of Euphrates and Tigris in the 5th millennium BP (see e.g. Pollock 2001). Deforestation as a result of woodcutting for domestic and industrial hearths, with further destruction by goats, was another detrimental force in many places. A well-documented environmental collapse concerns Maya settlements in Guatemala. Analysis of lake sediment and soil show a causal sequence of population growth, deforestation and soil erosion during the period 3000-1000 yr BP, leading to the abandonment of most Mayan upland and southern lowland settlements (Redman 1999).

Human-induced environmental change will also have operated over longer space- and time-scales and more indirectly. An interesting and for over a century discussed question is whether human-induced changes in land cover affected the Mediterranean climate around 2000 yr BP (Thirgood 1981). Reale and Shukla (2000) have recently attempted to simulate with a climate model the impact of humans in the Mediterranean area during the Roman Classical period. They have organised all available archaeological and historical information into a coherent history of climate and vegetation. It was found that North Africa was wetter than today and that the Mediterranean had experienced a continuous trend towards a "drier" kind of vegetation. A general circulation model was run to explore the impact of human-induced change in land cover – mainly deforestation – on the climate (a vegetation change experiment). The result suggests that the action of land clearing might have contributed to a positive feedback loop affecting climate and resulting in a drift towards drier conditions. Although such endeavours are still full of uncertainties, they can give an impression of when and how human interaction with the environment started to result in larger-scale feedback loops. Recent investigations in southern France seem to confirm the existence of anthropogenic degradation of the regional climate (Leeuw and De Vries 2002).

If environmental change happened as a consequence of human activities, how will peoples have responded? This is a much harder question to answer. One may phrase it in terms of the control and dependency loop shown in Figure 3. The rise of social complexity is closely related to the efforts to control the (natural) environment. A key

[13] There are many 'collapse' myths and theories related to earthquakes, volcanic eruptions, floods and droughts etc.. These are not discussed here.

'material' factor has been the size and reliability of a food surplus and the means and infrastructure for distributing it. A large and stable surplus was a precondition for the rise of urban settlements. The increased productivity was only possible with investment, i.e. stored labour efforts or 'capital goods'. To increase food yields, tools were constructed and terraces and canals were built. To provide protection and distribute and trade food, storage rooms, roads and transport equipment, defence works etc. had to be constructed. These investments did not only increase the food surplus but may also have improved the management of short-term risks related to frequent events, such as those related to variations in rainfall. A flood or drought, for instance, could be survived by trading with other regions or empty the storerooms.

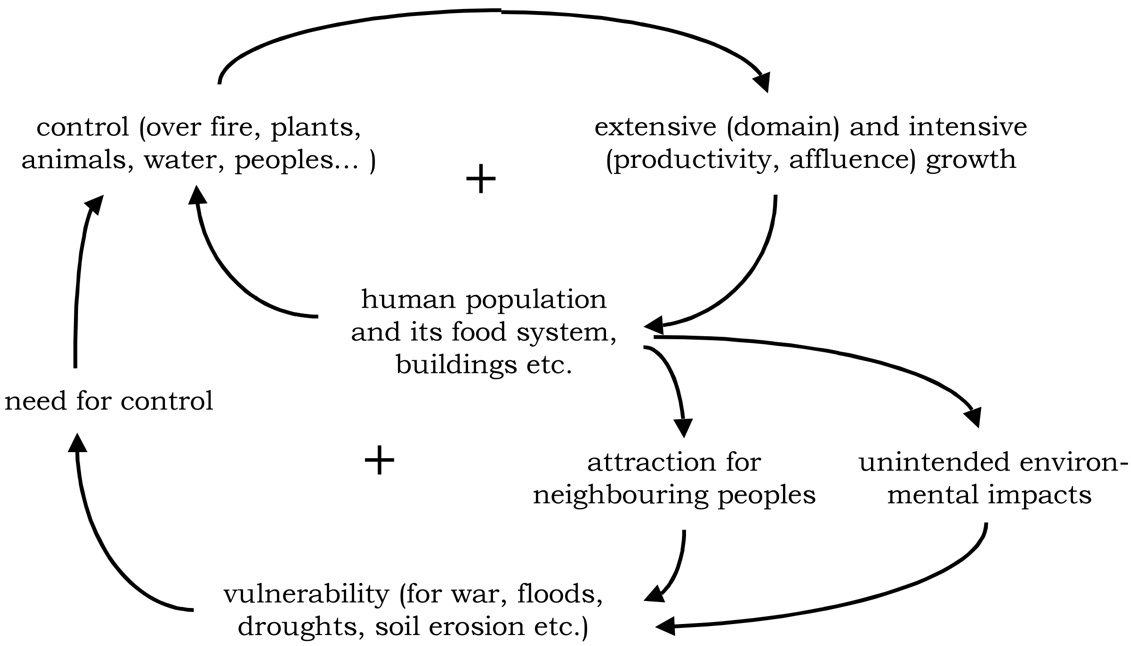

Figure 3 *The control and dependency loop*

However, it also introduced new risks and vulnerabilities. Capital goods were particularly susceptible to deterioration, catastrophes or destruction. When a society made great investments to control the environment, it became at the same time more dependent upon its proper functioning. Hence, the associated vulnerabilities had often a more insidious and long-term character: invasions by other peoples, destruction by raiders, disappearance of survival skills and knowledge. The new techniques and practices also introduced new and unknown longer-term impacts and could, with an improper or incomplete understanding of environmental processes, accelerate negative feedback loops. Learning to cope with these longer-term and less frequent or more erratic events is more difficult. The 'escape space' narrowed, the risk spectre broadened. Thus, new dependencies and vulnerabilities show up as the corollary of increased (food) productivity, processing, exchange and interaction. This makes it so difficult to understand adaptation and/or collapse: the values and perceptions of a society, its organization and technical knowledge base, even its past responses to environmental challenges and its capacity to learn from it are all part of the human response.

7. The rise and fall of socio-cultural complexity: system's concepts

> 'To read what the 'ecologists' write, one would often think that civilised peoples only ate, excreted, and reproduced; to read what the humanists write, one would think civilisations were above all three, and devoted all their energy to the arts.' (Flannery 1972:400).

Specialization and stratification. Can we relate the various forms of social organization to the regional biogeography without falling into the trap of simplistric environmental determinism? One may hypothesize that the increase in social complexity occurred in response to the need and wish to bring forth food, water and shelter from an exacting and unpredictable natural environment. Each group was confronted with different environmental opportunities and threats – including neighbouring groups – and evolved in a continuous adaptation process. With increased capabilities to use animals, store food and manage water supplies came a surplus of food exceeding the needs for bare survival. Some groups settled down and developed forms of agro-pastoralism that developed into large-scale land clearing and irrigation efforts; others never settled down remaining mobile nomads with large animal herds. This was largely biogeographically determined.

However, the social processes of differentiation – with corresponding organization and civilization – started to be an increasingly important factor in the adaptation dynamics. *Specialization* in certain skills began – fishing, hunting, stone quarrying, house building, pottery, metal- and tool making, boat construction. Trading along trade corridors evolved, marketplaces became nodes in an emerging transport infrastructure. Trade was often one of the more feasible and successful strategies to reduce risks – of famine, for instance, and of war – but it also made individual households and villages more dependent upon each other, as has been discussed above.

A concurrent process was social *stratification*. In the ascent to complexity, bands with familial bonds and common residence evolved into communities with land- or property-holding social units and elaborate ceremonies and rituals. Social ranks with differentiation in ownership and access to resources appeared: the chief was born with acclaimed noble birth, a special relationship with the gods and the right to community support and tribute. These chiefdoms often already had large populations with thousands living in villages. It was only one more step towards the state. At this point came the classes of soldiers, priests and kings, of merchants and administrators, who were given part of the food surplus as a reward for real or imaginary talents: physical superiority for good (protection) or bad (extortion), sacred knowledge necessary for rituals, divine ancestry, goods and means of transport for exchange, procedural or informational power. An urban-rural divide started to develop, with larger variations in population density. As with the spread of the fire regime, almost no peoples have remained untouched by the process of agrarianization. The generation of food surplus gave agrarian societies increasing control over their environment – including other human groups. War, trade and migrations intensified. Thus, complexity manifested itself in increasing spatial interaction, social stratification and demographic and cultural heterogeneity.

The rise of social complexity can be related to the risks early agrarian communities faced (Goudsblom 1996). Priests fulfilled a mediating role between ordinary people and the extra-human world but they also played a pivotal role in inducing the self-restraint required for a farming life of hard work and for the exigencies of food storage and distribution: '*...rites conducted by priests helped to strengthen the self-restraint which could keep people from too readily drawing upon* *their reserves.*' (Goudsblom 1996:42). Harvest feasts and sacrifices are social institutions to manage the pressures of frugality. Priests are resource-managers *avant-la-lettre* – not a strange idea when one knows about the rules in Christian and Buddhist monasteries.These priest-led – religious-agrarian – regimes were probably first but came almost everywhere in competition with warrior-led – military-agrarian – regimes. The latter usually won, a dominant but not universal trend. The emergence of a warrior class, that is, of professional killers and pillagers, should be seen as one stage in the monopolization of violence and cannot be explained solely in terms of their discipline, equipment and organizational skills. It can be argued that the most crucial force behind it was the bonding of warriors and peasants:

> 'The warriors needed the peasants for food, the peasants needed the warriors for protection. This unplanned – and, in a profound sense fatal – combination formed the context for the great variety of mixtures of military protection and economic exploitation that mark the history of the great majority of advanced agrarian societies…. wherever in agrarian societies rural settlements developed into city-states which were subsequently engulfed by larger empires, the priests became subservient to the warriors. ' (Goudsblom 1996:59).

Transition dynamics. The previous reflections on social complexity stem largely from the scientific disciplines of sociology and anthropology. Other disciplines such as ecology and demography as well as the more generic approach of system analysis have also attempted to deepen our understanding. For instance, in ecology and demography there is the well-known logistic growth curve along which a population grows to some carrying-capacity. Using this ecological concept of 'filling a niche', one may see the human evolution as a series of transition processes with increasing spatial interaction and enlargement and interiorization. Each transition had its pinnacle after which the forces conflicting with the prevailing techniques, institutions and belief systems became too strong and decline set in. A new transition process would start in which both spatial scale (extensive) and complexity (intensive) took on new configurations and had new potentialities.

Figure 4 sketches such an evolutionary process. Whereas the x-axis can be associated with time, chronological or phaseological, the y-axis is some indicator of the size and extent as well as the complexity and intensity of the socio-natural system. In the upswing of each transition, a population was expanding by 'occupying' a food producing potential. The new techniques and institutions could sustain a larger population density and physical and social dehomogenization became possible: urbanization. In certain places and times, leaders, craftsmen, merchants and others started to concentrate around fortified villages which extracted part of the food surplus from the agricultural population, either by trade, tax or take. In-between two transitions, one may assume that human groups lived in subsistence mode – as most of them did most of the time anyway.

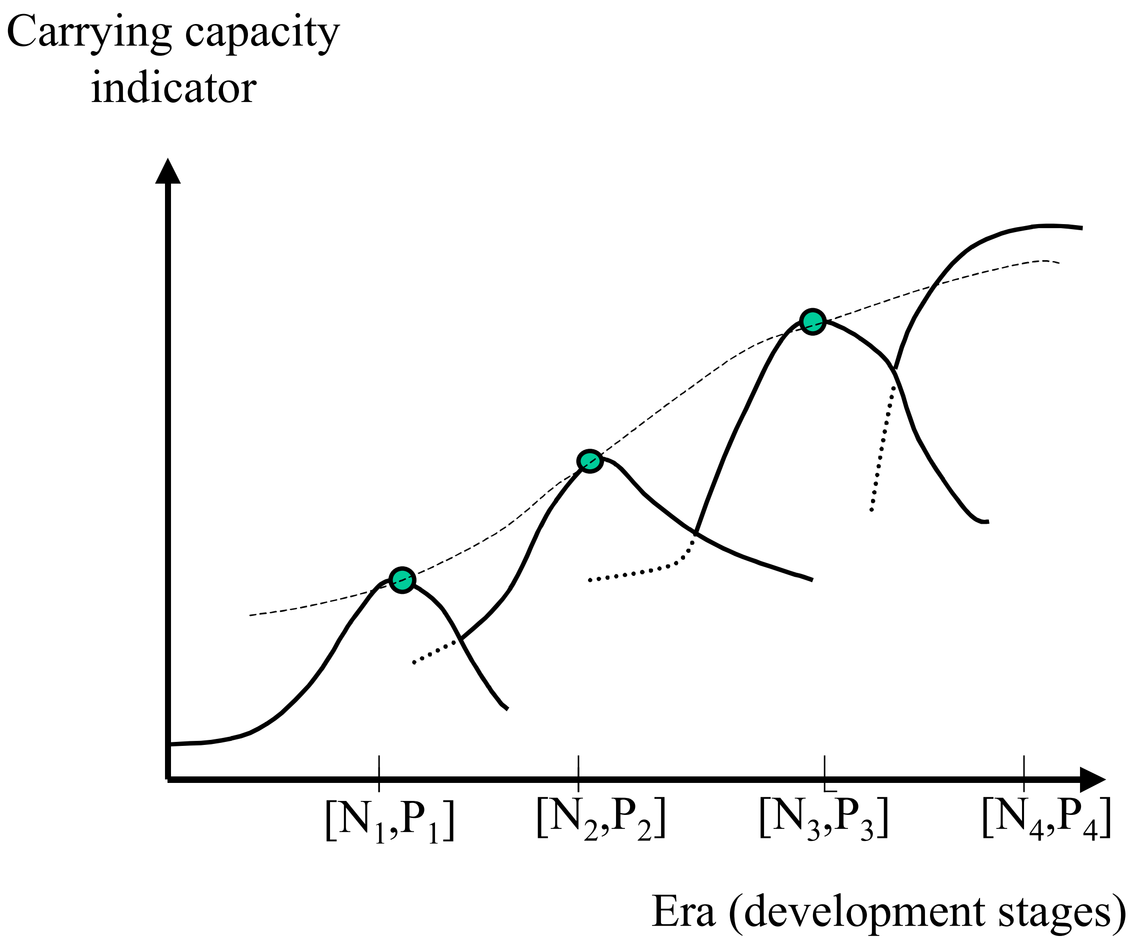

Figure 4 *Transitions in the process of extensive and intensive growth*

An example of such sequential transitions in a later stage is given in Figure 5. It portrays the course of the human population in France between 1000 and 1800 AD. Detailed analysis of agricultural practices and techniques reveals an increase in the sustainable (or potential) population density (Mazoyer et Roudart 2001). Between the far north (too cold) and the far south (too dry) Europe could support in early medieval times less than 30 person/km^2, with wide local fluctuations and often less than with slash-and-burn agriculture (20-30 Mediterranean, 8-15 Mid-North Europe). This gradually rose to a European average of 30-80 person/km^2 around 1250 AD. Whereas in 900 AD the survival needs for a 5-person family are an estimated 16 (Mediterranean) to 34 (Mid-North Europe) ha in a cultivated-fallow winter cereals system, it dropped to an average of less than 9 ha with the advent of winter and spring cereals systems and better ploughing techniques. Then, a series of famines and wars set in – one possible determinant may have been rather sudden drops in temperature (dotted curve in Figure 5). The concurrent fall in population freed up large amounts of space and after the crises, with improved fertilization strategies (animals, meadows) and tools (horse-drawn plough), the population quickly recovered to a new plateau with sustainable population density levels of up to 160 people/km^2. This period in European history is a dramatic illustration of a cycle of rise and decline and of the simultaneity of both natural and social forces at work.

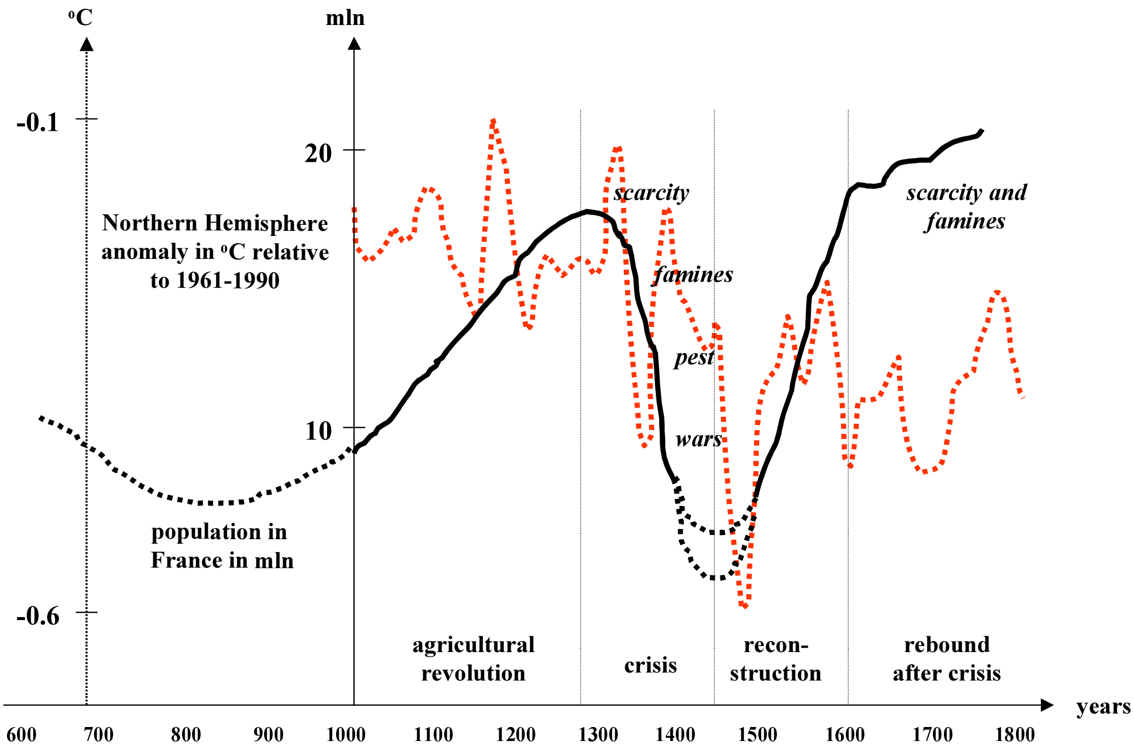

Figure 5 *Rise and decline in a socio-natural system: population in France and average Northern Hemisphere temperature relative to the period 1961-1990 (Mazoyer et Roudart 2001, IPCC 2001).*

Systems theory approaches. Archaeologists have tried to get more in-depth understanding of the past processes of organization and civilization. One of the earliest attempts to use system dynamics principles was made by Flannery (1972). He identified increasing differentiation and specialization of subsystems (segregation) and increasing linkages between the subsystems and the highest-order controls (centralization) as the driving processes. Within these he proposed to distinguish several mechanisms:

promotion: a special-purpose institution rises in the hierarchy to a higher level, becoming a general-purpose institution. For instance, military institutions often seized power in this way; and

linearization: lower-order controls in the system are repeatedly or permanently bypassed by higher-order controls. An example is when local irrigation is increasingly regulated by a higher-level institution in order to facilitate information exchange and reduce the risk of harvest failure.

These mechanisms may erode a system's resilience when institutions increasingly serve only their own interests rather than those of society. The associated pathologies may cause stress which in turn may accelerate disintegration:

usurpation occurs when a subsystem's purpose starts to dominate the objectives of the larger system. This is a corollary to the promotion of the military class and is evident, for instance, in periods of the Roman Empire;

meddling is the other way around: higher-level controls take over what ordinarily is best regulated locally. Stifling controls on trade have been proposed as an explanation for the inertia of the Sumerian and Chinese empires;

too great a degree of subsystem coherence leads to *hypercoherence* which may, in Rappaport's words, be as lethal as too little coherence. Nepotism resulting from marriage alliances between ancient Akkad and Classical Mayan urban centres may have caused such hypercoherence.

This list is not exclusive. These social mechanisms and pathologies are hypothesized in many of the environmental histories told. For instance, the environmental history told by Earle (1988) of the tobacco and cotton farmers in south-eastern parts of the United States of America is a stark example of meddling: he shows that science – introduced from above-and-outside and judged superior to local practical wisdom – has been a force in destroying farming practices which were in the context of long-term agro-economic cycles rather sustainable.

Renfrew (1985) has focussed on the role of *interaction* and suggests a linkage between ecological diversity and exchange and, in particular, information exchange. Peer-polity interactions have been proposed as a compromise between pure exogenous and pure endogenous explanations of structural change towards larger complexity [14]. Some of such interactions to be considered are (Renfrew 1985:8):

warfare, which may intensify both resource use and social stratification – unless catastrophic warfare results in total collapse;

competitive emulation, a process in which polities compete by means of displaying wealth and power, using "Great Buildings", symbols of deterrence and the like;

symbolic entrainment, not unlike the previous two but now in the realm of symbolic systems where the more-developed one absorbs or influences the less-developed one;

transmission of innovation, during which a specific invention becomes accepted and henceforth imbued with social or religious status;

exchange of goods which are part of the more general process of economic growth with concomitant phenomena such as the rise of a merchant class and specialized skills.

In the present context, the relevance of these socio-political processes is that they often have a large bearing on how environmental resources are used. Warfare has been a perennial phenomenon in the early civilizations in the Middle East and Greece and often led to accelerated deforestation:

> 'During campaigns, wood foraging parties were sent out. An extreme example was at the siege of Lachish, in 588 BC, by Nebuchadnezzar, King of Babylon. After 2500 years, layers of ash several metres thick still remain, higher than the remains of the fortress walls. The hills for miles around were cleared of trees. The wood was piled outside the walls and fired. Day and night sheets of flame beat against the walls until eventually the white-hot stones burst and the walls caved in.' (Thirgood 1981:58-59).

One consequence was often a decline in population – which somewhat alleviated the pressure on the forests – and an increase in pastoralism as populations sought refuge in the more secure mountainous areas – which could further degrade the environment if intensive grazing occurred. Competitive emulation may have featured in – and exhausted – Megalithic and Meso-American cultures, with Easter Island as a probably

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[14] In Meso-America Blanton (1993) and colleagues found ecological diversity to be a key element in understanding state-market interactions.

prominent example. Cultural, technological and economic diffusion, exchange and invasion processes have affected almost every civilization in its incipient stages.

If decline happens and collapse threatens, societies have had a variety of responses. Setting up or expanding trade, technical and social innovations, a change in environmental management practices, migration and conquest and a mix of all these have sometimes postponed, sometimes reverted and sometimes accelerated the processes of decline and collapse. If disintegration occurred, new shoots on the tree of human civilizations got a chance (cf. Figure 4). Tainter (1988) analysed explanations of collapse of civilizations and lists them under eleven headings which can be categorized in three groups:

- Resource- and environment-related changes, fully exogenous or partly endogenous in the sense of human-induced;
- Interaction-related changes in the form of conquest or other, less penetrating forms of invasion; and
- Internal changes in socio-political, cultural and religious organization and worldview, diminishing the adequacy of response to external events.

This classification coincides roughly with Goudsblom's categories of extra-, inter- and intra-human change introduced previously. Tainter (1988, 2000) finds nearly all explanations unsatisfactory: they are either cyclical or superficial or both. He views the introduction of complexity as a primary problem-solving strategy and the use of increasing energy subsidies as an important means to sustain it. The complexity itself is the result of a societal problem – such as diminishing productivity of resources or physical or mental labour. Its rise is an incremental process. He suggests that ultimately diminishing returns to complexity are at the root of decline and/or collapse. It shows up as increasing cost to support complexity: the energy, labour, time and money to create, maintain and replace the institutions and information and distribution networks necessary to deal with the complexity.

Tainter illustrates his thesis with the decline of the Roman Empire. Van der Leeuw and De Vries (2002) tend to see the declining marginal returns on further investment as an effect, not as a cause. They consider the economist explanation incomplete: the collapse of the Empire was due to the fact that the structure itself weighed too heavily on the Empire's capacity 'to think the unthinkable and do the undoable' when that was required. In any case, the capacity of institutions to have requisite variety – or be 'clumsy' in Thompson's phrase (Vries et al. 2002) – and use the knowledge available at all levels is an essential aspect of a system's capability to transform itself structurally, i.e. its resilience.

Modelling: the Complex Adaptive Systems (CAS) approach. Most scholars would now agree that the decline and fall of complex societies can never be explained by a single cause-and-effect chain. Instead, such systems will be in constant structural transformation during which thresholds, non-linear behaviour and feedback loops make their trajectory in time and space a unique series of interconnected, irreversible events. Causes and effects operate at various time- and spatial-scales, each with their own dynamical characteristics. Anyone studying real-world socio-natural systems is well aware of the huge simplifications in many of the early formal models derived from analogies with the physical sciences (De Vries 2003). It is clear that 'history matters' – which leads to the exploration of models with path-dependence (ergodicity) either from non-linearities or stochastic processes or both (see e.g. Castaldi and Dosi 2003). The search is for stable attractors to which a process will tend and, as a next step, for changes in the very landscape in which one walks due to exogenous influences as well as the very walking (epigenetic). The analogies are no longer provided by the physical and engineering sciences, but by biology, ecology and technology dynamics.

A ‘formal’ approach along these lines is the Complex Adaptive Systems (CAS) theory, essentially a collection of seminal investigations into the dynamic behaviour of non-linear and stochastic processes and originally conceived as groups of agents engaged in a process in which adaptive moves by individuals have consequences for the group. The availability of powerful simulation tools has stimulated a focus on modelling individuals with their motives, habits, rules and forms of co-operation and conflict. The resulting models – also called multi-agent models – are interpreted as “worlds” that can deepen our understanding of past and present “real” worlds because they supposedly resemble them in useful respects. Under certain circumstances they may exhibit remarkable abilities for self-organization. Whether these should be interpreted, in the case of human beings, as macro-behaviour without internal hierarchy or implicit class structure remains an open question.

One of the more detailed and interesting analyses along these lines is about the causes and consequences of the contraction of community territories noted for the Pueblo III period in the Mesa Verde region in the final 400 years of pre-Hispanic agricultural society (Kohler 2000). Patterns reconstructed from archaeological excavation and survey data have been used to construct and calibrate an agent-based model – in which households are the agents – that generates these same patterns working from the first principles of human adaptation in conjunction with the climatic conditions reconstructed for this period and the subsistence technology that was available. Such first principles of human adaptation are: minimization of energy expenditure, population growth responsive to resource conditions, and the possibility of subsistence intensification. Of the many observations drawn from this preliminary work, one of the most remarkable is the tendency, known from archaeological records, for the latest occupations to be concentrated in a small portion of the apparently farmable area – based on the simulation. Although this could be due to an error or omission in reconstructing potential maize productivity from tree-ring data, it is also possible that some other cause not included in the model, such as widespread violence, was responsible for this dramatic contraction.

In general, there appear to be three very important and related roles for models in such situations. The first is to suggest hypotheses that can be tested by other means. The second is to examine the effects of varying agent behaviours, such as the exchange of maize, that are difficult or impossible to view directly in the archaeological record but which ought to have measurable effects on settlement behaviours that *can* be seen in the records. Finally, there is the sense that we get much closer to an explanation of phenomena such as settlement behaviour when we can generate or “grow” it, working from a small set of rules and boundary conditions and acting through low-level agents, than when we derive statistical, systems-level correlations between, for example, agricultural productivity and the density of households.

Did biogeography and natural or human-induced environmental change play a role in the social organization processes, and if so, how? Let me present a modest effort to find some larger patterns and formal models to get at more in-depth descriptions.

8. A fragment of a theory: ecocultural dynamics

Ecocycles and Cultural Theory. In the past decades ecological observations have led to several interesting theories which may help understand socio-natural systems – after all, humans are (still) an integral part of ecosystems. Well-known is the 'ecocycle' theory proposed by Holling and colleagues (Holling 1986; Gunderson 1997). From empirical observations it has been found that ecosystem succession is controlled by two functions: exploitation, in which rapid colonization of recently disturbed areas is emphasized, and conservation, with an emphasis on the slow accumulation and storage of energy and materials. The species in the exploitative phase have been characterized as exploring *r-strategists* and in the conservation phase as consolidating *K-strategists*. The latter live in a climax community, the former in a pioneer community. Revisions in ecological understanding indicate that two additional functions are needed to adequately explain ecological change. One is a stage during which tightly bound biomass and nutrients that have become increasingly susceptible to disturbance – overconnected, in system terms – are released. The resulting debris is then reorganized in a series of soil processes, which makes it available again for a renewed cycle of exploitation. In other words: the complex system becomes compost, which in turn undergoes renewal into low-level energy enclaves, which are the seeds for the rapidly expanding pioneer communities.

Although this "ecocycle theory" is a simplification of the complex processes in real-world ecosystems, it provides a helpful scheme for thinking about complex system dynamics. For instance, the parallel with economic and political systems is an interesting one. The entrepreneurial market represents the exploitation phase, with innovations, conquests and rapid expansion – on horseback, ship or whatever. Nature is seen as essentially boundless, not unlike some early hunter-gatherer tribes. With rising expansion, specialization and stratification, an administrative and bureaucratic hierarchy emerges: this is the conservation phase during which states and empires are moulded. Nature or, more adequately, the socially constructed environment has now become part of the conscious worldview and is something to be managed within the confines of past experiences and the resulting insights. The release phase is one of "creative destruction" – a term borrowed from the economist Schumpeter – and of decline and fall in a historical context. In the subsequent phase of reorganization and restructuring, complex societies decompose into small bands some of whom are absorbed in coping with their own situation – the fatalists – while others start a new cycle by grasping the opportunities that always go along with the threats – the egalitarians and individualists. The dynamics is highly non-linear, consisting of nested cycles, each occurring over its own range of scales and resulting in an ecosystem hierarchy in which each level has its own distinct spatial and temporal attributes.

Cultural perspectives. Thompson et al. (1989) have proposed that human beings can be classified according to four worldviews, each associated with a certain way of structuring the relationship between man and nature and between fellow men. According to the societies and individuals involved, this is expressed in quite different judgements about technology, environmental risks and the distribution of prosperity between now and the future and between here and elsewhere.[15] Together these four

[15] The basis of Cultural Theory in anthropology is work done by Douglas (1978) in which peoples' belief systems are interpreted as reflections of social relationships; in ecology Holling's work (1986) on the stability of ecosystems and the cycles within them. A fifth worldview, that of the *hermit*, is postulated outside the plane of the grid-group axes and not considered here despite its possible

"myths" of the world form multiple rationalities. The two axes differentiating the four worldviews are the group axis and the grid axis.The group axis is associated with the (non)existence of a collective, shared set of values. The grid axis represents the degree of ranking and stratification in a society. The resulting four perspectives are related to their position along these two axes: hierarchist (high on both), individualist (low on both), egalitarian (high in "group", low in "grid") and fatalist (low in "group", high in "grid"). Needless to say, it should be borne in mind that people seldom express these paradigms in their extreme form - nor should one give in to the temptation to make caricatures.

Each worldview tends to maintain a related explanation of the world. Whereas the hierarchist places the emphasis on control and expertise in order to guarantee stability within a world of limits, the individualist is convinced that the world has inherent stability and abundance. The egalitarian emphasizes the fragility of nature and the probability of irreversible destruction. The fatalist experiences the world as determined by pure chance. These two constructions of human nature and (the perception of) the natural and human environment mirror the hierarchical state-empires and the market-oriented trade regimes. In the fringes of empire, millions have been living as fatalists whereas egalitarianism is found in political and religious revolt as well as in common property regimes.

These four paradigms interact dynamically and none of them can exist without the other three. Individuals alter their worldviews when they are no longer reconcilable with their experience. On the collective level this leads to fluctuations in how events are interpreted and responded to, excessive swings to either side being corrected – although with differing time delays and "hidden costs". Such complex institutional arrangements can be recognized in the narratives of emergence and decline in previous chapters. Excessive hierarchism leads to legalism with ever lower marginal returns, containing the seed of decline and eventual disintegration. Extreme individualism ends in perpetuating conflict and marginalization, which feeds the desire for social stability and justice. Egalitarianism, arising from the desire to purify society from extortion and greed, destroys itself in sectarian self-righteousness and religious wars if pursued to its extremes. Fatalists are always at the disposal of the other three worldviews, as converts for the egalitarians, as cannon fodder for the hierarchist or as cheap labour for the individualist. There is an interesting parallel between this theory and the previously discussed ecocycle theory. Both theories have also a remarkable similarity with the theory of collapse proposed by Tainter and the ecological and economic notions of increasing instability and subsequent creative destruction of complex hierarchical systems discussed above.

I will end this paper with a speculative thought. With and as an expression of rising social complexity, peoples organized themselves. The hierarchist state emerged. According to one school it arose out of the needs and desires of individuals and subgroups of a society: governing institutions are essentially coercive mechanisms to resolve intra-societal conflicts arising out of economic stratification. They exist to maintain the privileged position of a ruling class. Another school argues that complexity in all its manifestations arose out of the needs of society: governing institutions came into existence to centralize, co-ordinate and direct disparate parts of complex societies in response to stresses.

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historical relevance. Interpretations of complex phenomena such as discussed in this book can often be traced at least partly to a prevailing worldview and an associated scientific discipline (see e.g. Keyfitz 1993 and Section 5.2).

Is the evolution from simple, tribal to complex societies a one-way evolution? Is biogeography a determinant in whether a hierarchist or an individualist orientation evolves? Are the cycles of rise and fall most characteristic? Surely complex societies were preceded by tribal societies in which

> ‘Leadership … tends to be minimal. It is personal and charismatic… Hierarchical control is not institutionalised… Equality … lies in direct, individual access to the resources that sustain life, in mobility and the option to simply withdraw from an untenable social situation, and in conventions that prevent economic accumulation and impose sharing… Personal ambition is either restrained from expression, or channelled to fulfil a public good….’ (Tainter 1988:24-25).

Evidently, tribal society imbues the low-level enclaves with egalitarian tendencies. Investing the civilizations in Mesopotamia, Egypt, Aegean Greece and several other regions, I hypothesize that human societies have evolved in similar ways as ecosystems. Within each environment human groups had to design [survival] strategies to cope with environmental opportunities and threats. The local/regional biogeography reflected and constrained the successful strategies including the resilience in terms of allowable fluctuations (Leeuw and De Vries 2002). In the process of rise and decline new strategies evolved, sometimes in confrontation with other human groups. Some crystallized forms may have been the hierarchist and individualist forms described in cultural theory; other and more peripheral forms are the fatalist and egalitarian forms.

In particular, one can relate the dynamics of extraction and control in the rise and fall of the ancient Mesopotamian empires and of more or less successful responses to Nile floods and droughts in ancient Egypt to the efforts at sustaining complexity in hierarchist regimes. The two empires had a similar biogeography: a large and fertile river plain and surrounding valleys, although there were important differences in the details. They were also hierarchist, with their large and centralized bureaucracies and social and military startifications (‘grid’). Quite different though was the Aegean biogeography where, one might hypothesize, trade was a risk-reducing strategy *par excellence*. Hence, this civilization had more individualist traits of which the famous Greek π ο λ ι σ testifies. In the ‘fringes’ of religious-military and trade empires – during but also before and after – egalitarian forms of organization could sustain themselves. It is tempting to associate these with what has been called ‘common property regimes’ by Ostrom. Written accounts show that peoples all over the world have developed institutions which have lasted over 1000 years in some cases and have survived droughts, floods, diseases and economic and political turmoil. Most of these regimes were in highly variable and uncertain environments and resource systems. The appropriators, that is, the individuals who use the common pool resource, have ‘*designed basic operational rules, created organizations to undertake the operational management of their common property regimes, and modified their rules over time in light of past experience according to their own collective-choice and constitutional-choice rules*.’ (Ostrom 1990:58). These self-organizing groups solved the problem of commitment and mutual monitoring – among them the avoidance of free-riders and effective sanctioning – without resorting to centralized power exercised by external agents or to competitive market institutions. Maybe, it is in these ‘fringes’ that real-world resilience and sustainability is hiding…

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