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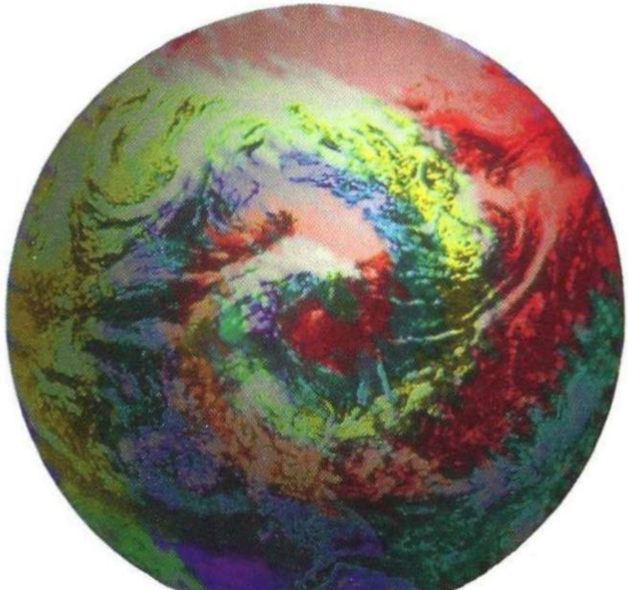
Global change – fresh insights, no simple answers



"Now that man has developed consummate skill in technology – the art of how to do things – can he develop equal ability to choose wisely which things are worth doing?"
W. Harman, An incomplete guide to the future (1976) .

19 GLOBAL CHANGE – FRESH INSIGHTS, NO SIMPLE ANSWERS

Bert J.M. de Vries, Jan Rotmans, Arthur H.W. Beusen, Michel G.J. den Elzen, Henk B.M. Hilderink, Arjen Y. Hoekstra, Marco A. Janssen, Louis W. Niessen, Bart J. Strengers and Marjolein B.A. van Asselt

19.1 Introduction

We know that the future is inherently uncertain, yet we are fascinated by insights into ways in which we may be influencing the planet. This interest is intensified because there is widespread perception that the world is changing at an unprecedented speed. Undeniably, many parts of the global system are accelerating or decelerating compared to previously observed, natural rates of change. For some people these processes of change may just look like more of the same. There are, however, underlying behavioural and structural changes at work which suggest deeper, more radical change in the longer term. Many of those long-term changes can be viewed as part of transition processes. Several of these are within the human system: from many to 1 or 2 children per family, twice as many older people per thousand compared to today, a factor of 3 to 5 less energy and water use per unit of economic activity, increasing pressure to cultivate more land and use it more intensively to feed the population. More gradual, but possibly of overriding importance, are the changes in the environmental system, such as the accelerating increase in the concentration of some atmospheric gases and increasing accumulation of pollutants in soils and water bodies which are the result of past and present practices. It is difficult to disentangle the human-induced, structural long-term changes from the natural changes, which makes it even harder to see where the world is heading.

For those involved, the changes are experienced and evaluated quite differently. In Chapter 10 the metaphor of a walk in a landscape is used to illustrate this situation. One may also use the metaphor of a huge ship which is moving at ever greater speed in an unknown direction. Some will find it an exciting experience, which offers all kinds of challenges and opportunities. Others get increasingly scared on this runaway trip. They try to slow things down, arguing that it will become more and more difficult to change course, should this prove necessary later on. Some focus on their responsibilities and use all available knowledge and controls to keep existing systems intact. Obviously there is no single, valid way in which one can interpret what's going on now and does formulate common goals for the future.

In this book we have presented a framework for analysing issues of global change and sustainable development. Using a systems orientation, the Pressure-State-

Impact-Response concept has been introduced to bring some coherence into this analysis. The notion of a family of interwoven transitions is used to put the many developments within the human and environmental system in a common context. The TARGETS1.0 model has been constructed with these concepts in mind. We have also attempted to deal with uncertainties in a novel and explicit way, recognising that many of the uncertainties in such a complex system cannot be resolved with the standard natural scientific method. These uncertainties have been framed as controversies and have been used to implement perspective-based model routes. This has led to the construction of utopian and dystopian possible futures, based on model experiments. In this chapter, we present a synthesis of the results of these experiments and some conclusions.

19.2 Synthesis of the results

Social, economic and ecological capital

Economic activities are, along with population, the major driving force in the global human-environment system. It is driven by re-investment of a proportion of industrial output into agricultural and manufacturing production facilities. This process of economic growth feeds on a stream of productivity-enhancing innovations and the gradual unfolding of an infrastructure of roads, schools, hospitals, etc. Together, these comprise the stocks of economic capital. Adequate functioning of this 'economic capital' has to be complemented by other, less tangible forms of investments so as to maintain and enhance what is called 'social capital'. This refers to characteristics of the human population, such as social coherence, institutional arrangements and capacities and skills. The economic system can only be sustained by a continuous influx of energy and materials which are withdrawn from and again dissipated into the natural environment. This natural resource base constitutes 'ecological capital', also called 'environmental' or 'natural' capital. History has shown time and again that a proper balance between the use of these forms of capital is an important condition for human aspirations towards a fulfilling and prosperous life.

Recently, it has been proposed to frame indicators of sustainable development around these forms of capital stocks (Serageldin, 1996)[1]. As explained in Chapter 9, such indicators can help to communicate major trends and insights. The TARGETS framework permits a quantitative indication of the three capital stocks: social, economic and ecological (Table 9.1). For the present synthesis of the results, we make some basic definitions. Economic capital is the sum of industrial and service capital and the capital stocks for the supply of food, water and energy. The latter is

1 Serageldin (1996) distinguishes four forms of capital: man-made, natural, human and social. This is comparable to the categories used here, although there are slight differences in emphasis.

Definition of capital indicators

The economic capital indicators are only rough measures in view of our highly simplified description of the economic system. Social capital, defined here as the number of literate people in the age group of 15 to 65 years old, can be associated with the potential labour force. The ecological capital indicators are calculated for arable land, clean water and high-quality oil and gas resources and are referred to as Arable Land resource Index (ALI), Clean Water resource Index (CWI) and High-quality fossil Energy resource Index (HEI). Each of these is defined as the ratio of the unused resource base in terms of quality and size in year *t* and its value in year 1990. For arable land, we use the product of potential arable land and average soil quality (*Q* factor, Chapter 7) as a measure of the resource base. Hence, a decline in the ALI indicates that less of the potentially arable land is left unused which we feel is also a crude substitute for more complex quantities like forests and biodiversity. For water, we use the remaining fraction of the potentially usable, clean water flow (two highest classes, A and B; Chapter 6) as the indicator for the resource base. Hence, a decline in the CWI indicates that clean water sources are increasingly being tapped for human purposes. With regard to energy, we relate the resource base to the amount of oil and gas deposits which can be expoited at capital-output ratios less than 20 times the value in 1900 (depletion multipliers, Chapter 5). Hence, if the HEI falls, this implies that fewer cheap and accessible fossil fuel deposits remain. The composite indicator for Ecological Capital is a weighed average of the ALI, the CWI and the HEI.

dealt with explicitly and gives an indication of the relative importance of the food, water and energy-supply sectors discussed in Chapters 11, 17 and 18. As a first step, we associate social capital with the number of literate people in the age group from 15 to 65. Ecological capital is defined in terms of the size and quality of the remaining land, water and energy resource base. We confine ourselves to the 'source' side of the environment system; elsewhere indicators of the 'sink' side are presented (see, for example, the CYCLES state index in Figure 17. 11). One should also realise that changes on the sink side of the environment system such as a temperature rise do affect the land, water and energy resource indicators in our integrated model experiments.

Absolute amounts are not what matters here – it is the trends that are relevant. *Figure 19.1* shows the trajectories for the capital indicators for all three utopias for the years 1900, 1990, 2020, 2050 and 2100 normalised to the year 1990. Economic capital in the hierarchist and individualist utopia grows exponentially as a result of the assumption of exogenous GWP growth. The combination of a growing and structurally changing population and increasing literacy rates leads to an even faster growth in social capital. The capital stock needed to sustain the food, water and energy sectors grows much more slowly in the individualist utopia than in the hierarchist one. This reflects the individualist reliance on productivity-enhancing technology and a large, low-cost resource base. In both utopias, the ratio of economic to human capital keeps on growing during the second half of next century. This is most striking in the individualist utopia: it pictures a world which is inhabited by over 13×10^9 people, many of which are – and have to be – literate, skilled people who manage an increasingly man-made world. In the process, ecological capital falls roughly in a linear fashion over time. Here, too, the decline in the individualist utopia is slower because the resource base is assumed to be abundant.

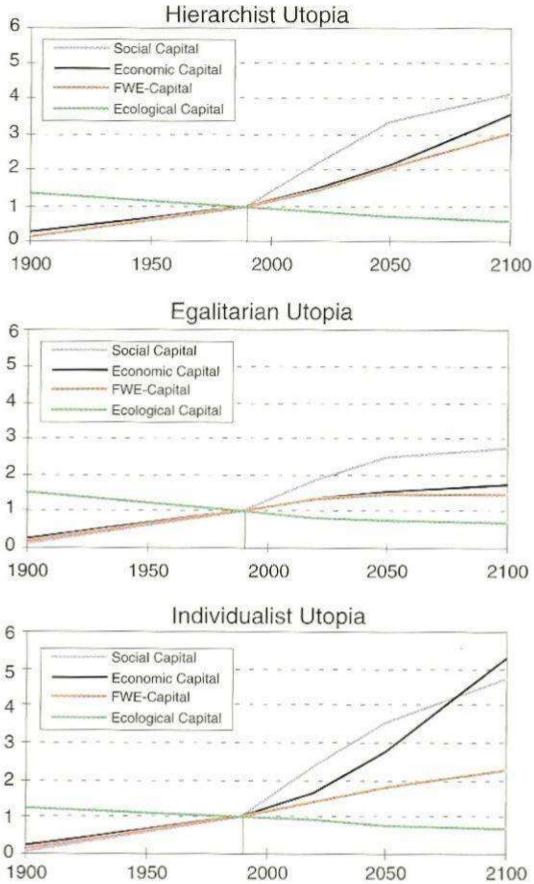


Figure 19.1 Development of four capital indicators in the three utopias.

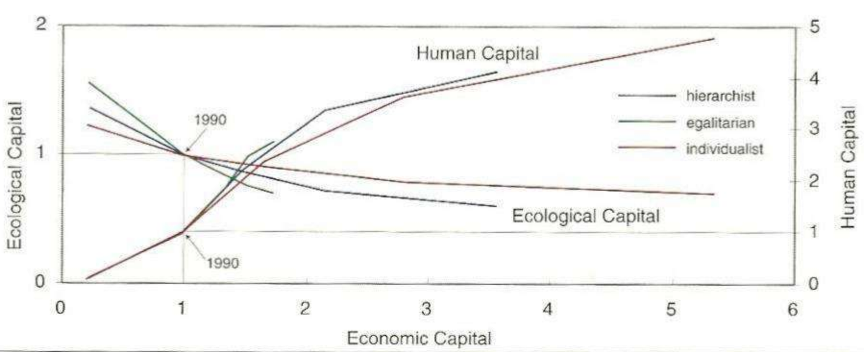


Figure 19.2 Development of human capital and ecological capital against the growth of economic capital in the three utopias.

The egalitarian utopia is rather different. Social capital increases the fastest, while growth of economic capital levels off. The resulting ratio of economic to social capital is only half the value of the individualist utopia by the year 2100, in a world with about half as many people and only one third as much machinery, buildings, roads, etc. Because the egalitarian world view has a conservative view of the possibilities of maintaining the resource base, ecological capital in this utopia also keeps declining, despite the much lower pressure. Indeed, it is at a lower level than in the individualist utopia.

A different way of displaying the same information is shown in *Figure 19.2*. The development of human capital and ecological capital against the growth of economic capital clearly indicates, at this high level of aggregation, the substitutability between ecological and economic capital on the one hand and the complementarity between human and economic capital on the other. The acceptability of such a trade-off is behind the difference in 'strong' and 'weak' definitions of sustainability. Our assessment suggests that substitutability and complementarity are strongest in a world which functions as the egalitarians suspect and which is managed according to their prudent style. As a result of emphasis on educating women, access to safe water and the like, modest economic growth goes with a significant increase in social capital. At the same, this modest increase in economic capital is still responsible for a noticeable decline in the stock of ecological capital, despite a reduction in the resource intensity of the economy. The individualist utopia presents the opposite picture. A large expansion of economic capital goes with a rise in human capital, albeit slightly less than in the less populated hierarchist utopia. This expansion creates major pressures on the environment, but less than in the hierarchist utopia which lacks the individualist high-tech orientation. Because of its underlying optimism about the natural system's resilience, it is still a world with plenty of good land, clean water, cheap oil and gas – and an abundance of the greatest resource of all: skilled humans.

In another attempt to synthesise the mass of results, we make use of the multi-dimensional star or 'amoeba' representation (*Figure 9.3*). The first step is to select sets of indicators for each of the four parts of the Pressure-State-Impact-Response (PSIR) chain. We have sought a compromise between the desired characteristics of indicators (Chapter 9) and what the model can provide. A total of 21 indicators have been chosen. The first six are considered representative of the pressure on the system, and are extensive: the larger the more. The second set of five indicators are a measure of the state of the human and the environmental system. These are closely related to the capital stock indicators presented in the previous paragraph. The third set represents a selection of indicators that are associated with impacts identifying aspects related to the quality of human life. They are intensive and their value ranges from some biological or technical lower limit to some upper limit, which in some cases is also related to biological or technical considerations. The last set is a – quite limited – selection of variables which can be associated with response actions in the form of prices, taxes and technology. Because the outer circle is normalised to the maximum value in the three perspectives, this representation is primarily a comparison. The globe in the middle is the unit circle representing the situation in 1990. The formulation of the indicators is such that outward expansion corresponds with 'more': the more pressure, the more depletion of resources, disturbance of the climate system, affluence, and the more drastic responses.

The multi-dimensional star, or amoeba, representation

The starting point are five concentric circles which are associated with the levels 1 (inner circle) to 5 (outer circle). The indicators used are defined as follows. We first calculate the ratio of the value at time *t* to the value in 1990. Next, we scale the resulting normalised indicator in such a way that 1990 is on the unit 1 circle and the maximum value of one of the three utopias is on the outer, unit 5 circle. Hence, the position along the five concentric circles represents the position of the indicator in between its value in 1990 and its value in 2020, 2050 or 2100. For instance, life expectancy is presented as the number of years ranging from 66 in 1990 (unit 1 circle) to 88 years, which is the maximum (unit 5 circle). The list of indicators and range of values is given in *Table 19.1*.

We have arranged the indicators according to the PSIR chain discussed in Chapter 2. Pressure refers, in general, to those quantities which are the driving forces behind the exploitation of natural resources. The state variables reflect changes in the size and quality of natural resources, usually related to source depletion and sink accumulation. The impact variables are important quality aspects of the reservoirs and fluxes in the human and environmental system. There are lower and upper limits for these quantities, beyond which they are considered to be inhuman or impossible. Finally, the response indicators represent a few of the endogenous response mechanisms within the TARGETS1.0 model. Many of these indicators are discussed, in varying degrees of detail, in Chapters 12 to 16.

Pressure	State [b]	Impact	Response
GWP	*1/ALI* (1-5)	*GWP/cap* (4030-41300 $/cap)	*water price* (4-220 ¢/ton)
Population *POP* ($5.25\text{-}13.3 \times 10^9$)	*1/CWI* (1-5)	Life Expectancy *LE* (66-88 yr)	*energy price* (5-16 $/GJ)
Food Demand *FD* (X14.2-56.5 Gton CCE)	*1/HEI* (1-5)	*Food/cap* [c] (2720-3940 kcal/cap/day)	Health Services/GWP *HS/GWP* [d] (8.6-12.9%)
Water Demand *WD* (4.1-14.9 Tton)	CO_2 *con*centration (352-727 ppmv)	*Water consumption /cap* [c] (0.8-1.28 kton/cap)	*GWP/emissions* [e] (1-2.75)
Energy Demand *ED* [a] (177-843 EJ)	*tem*perature Change (0.3-3.6 °C)	*Energy /cap* [c] (34-71 TJ/cap)	
CO_2, SO_2 and NO_x *emissions* [e] (1-4.4)	sea-level rise *slr* (0-120 cm)		

[a] use of commercial, secondary fuels
[b] the ALI, CWI and HEI are the environmental capital indicators discussed previously
[c] primary energy supply, water use (withdrawal plus re-use) and food intake per capita, respectively
[d] health service investments
[e] the sum of 0.5 × indexed CO_2 and 0.5 × indexed SO_2 and NO_x emissions

Table 19.1 Indicators used for amoebas

Let us first look at the utopias, indicated for the years 2020, 2050 and 2100 in *Figure 19.3a-c*. In 2020 the hierarchist and the individualist utopia differ less than 15% with respect to all but 6 indicators. These 6 have to do with a more optimistic assessment of water resources and climate sensitivity and technical progress in food and energy provision. The egalitarian utopia differs more than 15% from the hierarchist one for 13 out of 21 indicators. The difference is mainly in the form of lower pressure and lower affluence levels and yet less remaining resources and a larger climate impact. The low estimate of the potential arable land and the negative impact from climate change shows up in the state part; the high carbon tax in the response part. By the middle of the next century all these differences have become much larger, with the exception of emissions where technology in the individualist utopia does for emission reduction what the carbon tax and technology do in the egalitarian utopia.

By the end of the next century, the differences between the three utopias have become quite marked. Whereas the individualist utopia has the highest pressure and the highest impact values for the selected indicators, the climate impacts are least and water and energy prices are lowest. This is a world of abundance and resilience: , land, water and energy resources are huge and the environment system is rather insensitive to human disturbances, although the cheap oil and gas deposits are largely depleted. The egalitarian utopia shows the opposite picture: at much lower pressure and impact levels, and despite rather radical response measures, some aspects of the environment – notably land and climate – are in worse shape. The hierarchist world is somewhere in between these two extremes, with the exception of the energy-related indicators.

The three pictures give a useful visual impression of possible future shapes of the planet Earth. However, these utopias are the rosy part of the picture. There are numerous less utopian futures, a few of which have been explored with our model (see Chapter 18). To give an impression of such dystopias for the year 2100, *Figure 19.4* pictures the amoebas for the six dystopias which are generated if management style and world view clash[2]. If the medium growth 'Conventional Development' or 'Business-as-Usual' trends continue, but as it turns out that the world functions according to the egalitarian world view, humankind's ecological capital is in a disastrous state (*Figure 19.4, upper, green curve*). There are serious, negative feedbacks on human well-being; the lower population leads to a lower pressure, but technical progress falls far short of slowing down environmental degradation. In the high-growth world of the individualist, the confrontation with a small resource base and a vulnerable climate system would lead to a similar, catastrophic situation (*Figure 19.4, lower, green curve*). Already in 2050 the world would be confronted with significant climate change and, partly as a consequence, with serious food and water shortages. The major transitions are slowed down or reversed: life expectancy

2 The GWP trajectory always corresponds with the management style.

Figure 19.3 Multidimensional star, or amoeba, representation of the state of the world in 2020, 2050 and 2100 for the three utopias. The shaded blue area represents the state of the world according to the hierarchist utopia. The globe in the middle represents the situation in 1990.

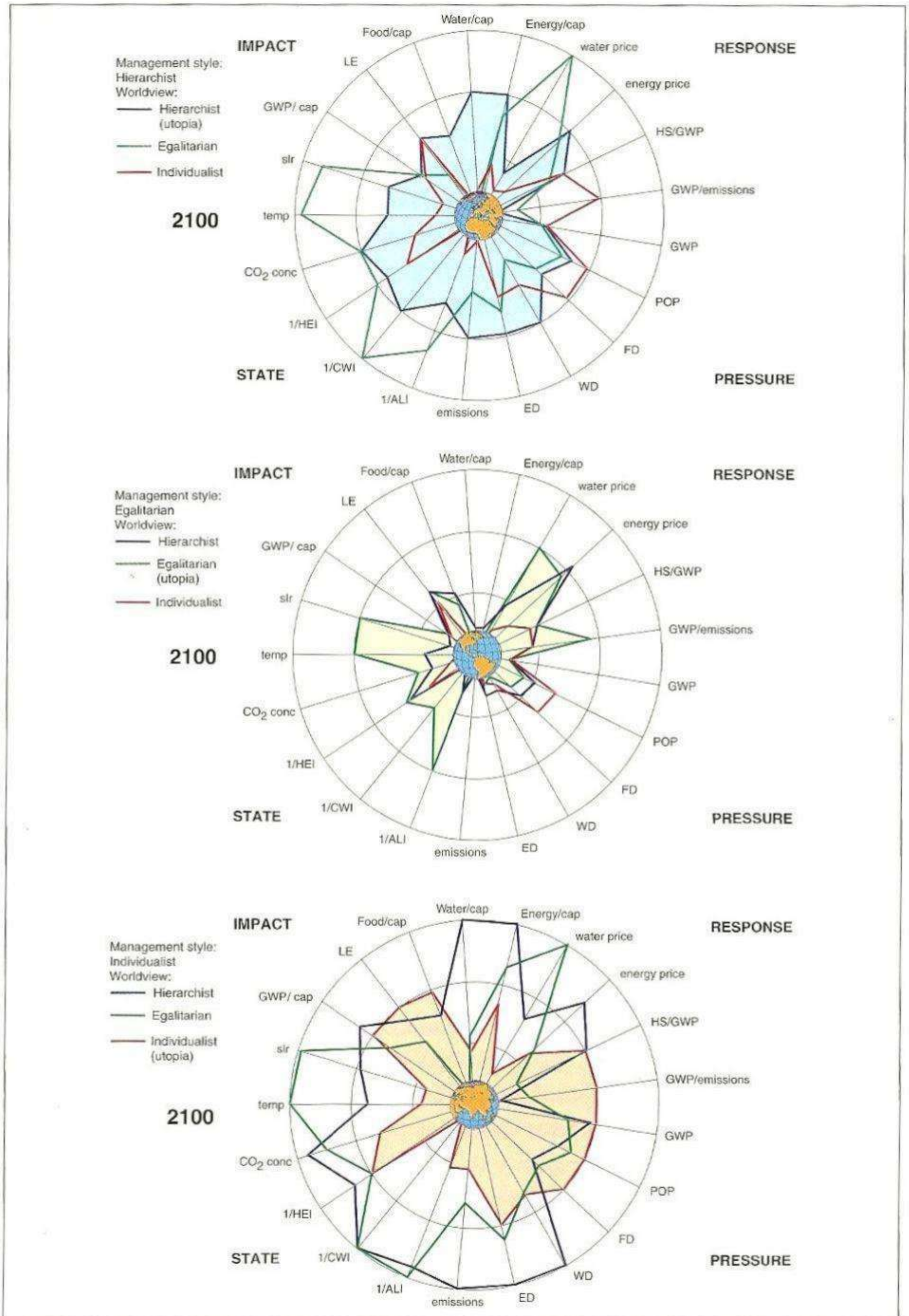


Figure 19.4 Multidimensional star, or amoeba, representation of the state of the world in 2100 for the dystopias which evolve when a certain management style is confronted with a world view which does not match. For reference, the utopias are indicated in the form of the shaded coloured areas. The outer circle is level 7.5, not 5 as in Figure 19.3.

increases much less, the resource base is squandered and welfare and health are even more unevenly distributed. These outcomes reflect the experiments described in Chapter 18 where it is also found that the most catastrophical future is one in which an egalitarian world view is combined with medium to high growth in population and economy and a hierarchist or individualist management style. Or, as egalitarians would put it: a future in which a vulnerable world is ruled by myopic materialists. The main conclusion here is that governments should heed the warnings of environmentalists if they expect – and, as is often the case, promote – an individualist style of government. Indeed, it is because of this risk that environmentalists advocate strong, not weak government.

The mirror image of the above disquieting dystopia is also interesting: the combination of an egalitarian management style with an individualist world view (*Figure 19.4, middle, red curve*). Or, as individualists would say, a low growth world run by anxious and frugal prophets of doom whose risk averseness has spoilt huge opportunities. Climate change is hardly noticeable, but there are more people and they are less affluent and have a lower life expectancy than in the egalitarian utopia. Because of the failure of technology, the resource base is in worse shape. If we call the previous dystopia an egalitarian nightmare, then this one might be called the individualist regret.

19.3 World in transition

In the previous chapters, we have explored population, health, energy, food, water, and environmental change issues on the basis of current controversies. The issues behind these controversies can be summarised in a single question: *Can we provide a future world population with enough food, clean water and energy to guarantee a healthy life, while safeguarding our natural resource basis?* The fundamental uncertainties in the functioning of the Earth system and human behaviour do not permit an unambiguous answer to this question. Outspoken and often controversial views on the above question are published regularly, fuelling the debate. Many assessments have either an apocalyptic or a sanguine character. They adhere to the (neo-)Malthusian view that mass starvation is unavoidable as the human population already exceeds the carrying capacity of the Earth (Pimentel *et al.*, 1997). Or they anticipate an overshoot and collapse future which is triggered by a continuous degradation of natural capital (Meadows *et al.*, 1972; 1991; Barney, 1980, 1993; Brown and Kane, 1995). In striking contrast to these warnings of doom are a growing number of global studies which propagate an optimistic future for humankind. Well-known is Simon's 'The Ultimate Resource' (1981). There are some more recent examples: 'The True State of the Planet' (Bailey, 1995), which is a positive response to the 'State of the World' report of the Worldwatch Institute, and 'A moment on Earth' (Easterbrook, 1995). A more balanced picture emerges from the recent 'Global Environmental Outlook' (UNEP, 1997). Many analyses of the longer term future do not even mention the natural system, at least not explicitly; the focus is on current liberalisation, globalisation and technological trends (Petrella *et al.*, 1994; Shell Planning, 1996). Obviously, there are as many ways of viewing the need to interfere with current trends and formulate policies for a more sustainable future as there are in these views themselves. The picture is further obscured by the fact that many transition processes are occurring simultaneously and that some of these are scarcely discernible now but may become dominant factors of change as a consequence of emerging technologies, insights and attitudes.

In our global assessment we identify three interrelated transitions (Figure 17.6-9). The first is the health transition, which comprises the demographic and epidemiological transitions. The second is the economic transition which represents the shift from a largely agricultural to an industrial economy, followed by a shift to a service and information-oriented economy. Thirdly, there is the environmental or ecological transition during which material and energy intensities, after an initial upturn, start to fall. The associated emission intensities follow a similar pattern. These major transitions are often associated with minor ones which are sometimes a precondition and sometimes a consequence and have also a cultural component. For food, for instance, there is the trend towards a higher proportion of meat in the average diet and, in agriculture, towards more intensive farming. For water and energy, the trend of increasing intensity-of-use with the onset of industrialisation is reversed once service and information-oriented activities start to dominate. This reversal is supported by the wider use of more efficient equipment.

The combined dynamics of population and economic growth and these transitions determines the demand for food, water and energy (Figures 11.3 and 17.1-2). The resulting forward projections of food, water and energy supply provides an indication of the use of important natural capital stocks and flows: arable land, water reservoirs and fluxes, and energy resources and fluxes (Figure 19.1-2). This is mediated by all kinds of pressures on the environment such as the use of fertiliser in agriculture, which results in water pollution, and the emissions of various substances into the air. Will the Earth be able to sustainably meet humanity's demand for these resources? And if not, why not, and what should we do about it?

Focusing on the physical level (Figure 2.6), current trends suggest that there is reason for concern. The supply of food, both for humans and animals, will cause a further increase in the area of land use for cultivation and of consequent erosion. Use of inputs per hectare may steadily rise too, leading to higher yields. Effluents to land and water, especially nitrogen compounds, will increase. Great demands on water resources lead to an increase in the average costs of water supply and to a decline in the available groundwater resources. The supply of energy in various forms will cause a decline in the fossil fuel resource base. Supply costs are expected to increase as the high costs of new deposits are no longer compensated for by innovations.

Fortunately, new sources and technologies slowly penetrate the market which will, in combination with abatement measures, tend to slow down or reverse the trends in emissions of carbon, sulphur and nitrogen compounds. Some changes in environmental capital directly affect the functioning of human society; others have a more indirect impact in the sense that they necessitate changes in activity and investment patterns.

There is also a broader aspect which involves behavioural and cultural dynamics; the medium level in Figure 2.6. Throughout these transitions and as part of them, there will be human response behaviour. Declining productivity of land is counteracted by additional fertiliser use; rising marginal costs to supply water require additional investments; depletion of fossil fuel resources induces energy conservation and the exploitation of renewable energy sources. Much of what is called 'current trends' is actually rooted in human behaviour at the local scale and determined by factors such as traditions, habits, markets and prices, governance and trade structures. The three cultural perspectives we distinguish in this book express part of this behavioural richness.

The highest level along the vertical axis of Figure 2.6 refers to values, beliefs and ideas. At this level, belief systems about Nature and Man are constructed to be able to act coherently and meaningfully – such as the three world views formulated in this book. One of the basic differences in world views is whether human history is seen as a series of 'rise-and-fall' cycles or as steady progression (Kahn and Wiener, 1967). The dominant, western view has been that the future will be better than the past. This vision is increasingly challenged, not in the least because of the growing awareness that humankind faces unprecedented global threats to its well-being or even to its survival. It is in this context that the notion of sustainable development has emerged as a vision which may help development along desirable transition pathways.

Of particular importance is the observation that the less developed regions in the world aspire to follow a path similar to the one that the developed regions have followed over the last century. If this process unfolds without an acceleration of the health and ecological transitions described above, the world will most probably be confronted with increasing pressure on both local and global resources. This will lead to increasingly intense political conflicts about food, water and fuels. A leap towards advanced technologies is required, because humankind can no longer afford the luxury of 19th century inefficiencies. But technical fixes are not sufficient; they have to be complemented by sustained, long-term population, income and price policies. One of the most precious – and scarce – resources for this undertaking is that most intangible of the capital stocks: 'social capital'.

With regard to the controversy formulated above, there can be hardly any doubt that continuation of current trends will increasingly confront societies with physical limits to growth. The interesting question is whether we anticipate the approach of such limits and whether the responses, both precautionary and adaptive, will be timely enough to avoid major overshoot and collapse situations. A key factor is the rules which govern human behaviour – there may be social and psychological limits to the rate and extent to which these can be changed. This, in turn, is at least partly a matter of perception and vision. If leading groups in society develop a coherent and convincing image of a sustainable and fair future, the probability that it will be realised will increase significantly. In this respect, much still remains to be done. In the wordings of the recent Global Environmental Outlook: 'progress towards a global sustainable future is just too slow. A sense of urgency is lacking' (UNEP, 1997 p.3).

19.4 Epilogue

At the end of a book like this, one faces the question: what has been our contribution? We have presented a number of concepts and constructed a simulation model. Such a model is a tool, like a telescope or a microscope: you hope to see new things or to see things more clearly. Which new insights can be gained from our research? The past 25 years of global forecasting have shown that dogmatic predictions about the Earth's future are misleading and unreliable, even politically counterproductive. With hindsight, world developments have turned out to be more complicated and more surprising than anticipated. Many problems identified in earlier doom scenarios persist but they have not overwhelmed the planet. Some threats, such as fossil fuel depletion, have receded; others, such as industrial pollution, appear susceptible to determined policy intervention. Unfortunately, new and unexpected threats have emerged: depletion of stratospheric ozone, resurgence of infectious diseases, anticipated global climate change, increasing scarcity of fresh water, land degradation.

Our model-based analyses add at least three elements to the more speculative statements about the future of the globe. First, our quantifications of future trends are based on numerical consistency and on a variety of 'stylised facts' and insights which are at the core of the sciences. Although this offers no guarantee that the future does not hold surprises which may make such consistency and insights irrelevant, it nevertheless complements less quantitative, fiction-like analyses of the future. Moreover, several of the submodels have quite novel elements too. Secondly, we look at these future trends from a more integrated perspective than is usually the case. In particular, we investigate some of the most important feedbacks between the human and the environment system. This increases the plausibility of the resulting images of the future because it provides a consistency which is absent from many more narrowly-based analyses. Thirdly, the use of perspective-based model routes contains a clear invitation to others to participate in the search for more sustainable futures. We do not hide behind scientific expertise when such a position cannot be defended, given the range of views expressed in current controversies. This explicit inclusion of values and beliefs gives our endeavour an open, process-oriented flavour which we feel is essential in the context of an enquiry into nothing less than the future of the planet. In this sense, the TARGETS project extends an invitation to people with a broad spectrum of views to participate in the debate about that future.

Our experiments indicate that certain combinations of assumptions can lead to developments in the world system which are deemed acceptable or even desirable from the point of view of the value system which is supposed to be reflected in those assumptions. These are called utopias. Our quantitative framework suggests that such utopias are feasible in the sense that they do not violate the prevailing insights about the dynamics of the various subsystems and their interlinkages. The experiments also indicate that such utopias are particularly dependent on certain assumptions. If these turn out to be incorrect, dystopian trajectories evolve unless adaptive and, within the corresponding world view, sometimes undesirable policies are implemented. Another insight is that the human-environment system is characterised by changes that take place according to radically different time-scales. Despite the appearance of rapid change, many of the forces behind the transition processes within the human and environment system are, in fact, quite slow. Apart from geological and evolutionary processes, some changes in the environment system which are caused by human activities, occur on a time-scale of five to ten generations, as our model experiments up to the year 2200 clearly show (Figure 17.12). This appears very long from an individual's point-of-view: people's behaviour is generally influenced by much shorter-term considerations. This discrepancy is the cause of a great deal of inertia in the system with regard to policy actions designed to influence global trends.

Global catastrophe does not appear to be imminent. However, the projections presented in this book indicate the risks and uncertainties associated with perpetuating current trends, as presented in many official reports and plans. It seems unlikely that, on current trends, the route to sustainable development as pictured in Agenda 21 will be chosen. Yet, as our explorations confirm, there are ample opportunities to change track without denying the majority of the world population their legitimate aspirations for a better life. Many policy interventions have been identified, which have the potential to accelerate the transitions towards a more healthy life for all and towards a much more resource-efficient economy. They can, and should, focus on reversing negative long-term trends. This requires honest appraisal of the current situation as well as vision and courage, the more so because many of these interventions and measures will require one or even more generations before there are visible effects. Our analyses offer some guidance here: the perspectives of the hierarchist, the egalitarian and the individualist all contain part of the problems and part of the solutions. The best of all worlds might be one in which the stability and responsibility of institutions, the vigour and ingenuity of the entrepreneur, and the prudence and respect of critical citizens work in unison in the search for a more sustainable development path for humankind.

We consider this book as one more step in the integrative research cycle described in Chapter 1. We sincerely hope that it inspires other researchers, especially integrated assessment modellers, to participate in this exciting and necessary venture. We also hope that it helps policy makers and interested lay-people to see the larger picture and to formulate the vision and the strategies which are needed if humankind is not to harm the interests of our children out of pure habit, greed or ignorance.