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Environmental Resource Management and the Nexus Approach

Managing Water, Soil, and Waste in the Context of Global Change

UNITED NATIONS UNIVERSITY
UNU-FLORES
Institute for Integrated Management of Material Fluxes and of Resources

Springer

Chapter 4
A Nexus Approach to Urban and Regional Planning Using the Four-Capital Framework of Ecological Economics

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Abstract Ecological economics views our world as an interconnected complex system of humanity embedded in the rest of nature. It is thus fundamentally a nexus approach. It recognizes four basic types of capital assets necessary, in a balanced way, to produce sustainable well-being of humans and the rest of nature. These include (1) built or manufactured capital, (2) human capital (e.g. human labour and knowledge), (3) social capital (e.g. communities, cultures and institutions, including the financial system) and natural capital (resources and natural ecosystems and their products that do not require human activity to build or maintain). Creating a sustainable and desirable future will require an integrated, systems-level redesign of our cities and our entire socioecological regime and economic paradigm focused explicitly and directly on the goal of sustainable quality of life and well-being with minimal waste rather than the proxy of unlimited material growth. It will require the recognition and measurement of the contributions of natural and social capital to sustainable well-being. It is a design problem on a massive scale. An integrated, nexus approach to urban and regional planning and design must be a central component of this process.

The *ecological economics* framework expands the definitions and connects these critical issues. It focuses not only on population size, density, rate of increase, age distribution and sex ratios but also on access to resources, livelihoods, social dimensions of gender and structures of power. New models have to be explored in which population control is not simply a question of family planning but of economic, ecological, social and political planning, in which the wasteful use of resources is not simply a question of finding new substitutes but of reshaping affluent lifestyles and in which sustainability is seen not only as a global aggregate process but also as one having to do with sustainable livelihoods for all within the safe operating space of the global ecological life-support system.

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H. Hettiarachchi, R. Ardakanian (eds.), *Environmental Resource Management and the Nexus Approach*, DOI 10.1007/978-3-319-28593-1_4

In addition a new vision and goals are needed that go well beyond the narrow and inappropriate use of GDP growth as the primary policy goal. There is broad emerging agreement about the overarching goal that should guide sustainable development. There are many ways of expressing it, but the essence is 'a prosperous, high quality of life that is equitably shared and sustainable'.

There are three elements to this goal that cover the three components of sustainable development—the economy (a high quality of life or well-being), society (equitably shared) and the environment (sustainable—staying within planetary boundaries). There is also the understanding that all three of these elements are highly interdependent and must be satisfied jointly. It is no good to have a high quality of life for an elite few that is not equitably shared or sustainable, or a sustainable but low quality of life where everyone suffers equitably, or a high quality of life for everyone that will collapse in the future. We want all three together in an integrated and balanced way and any one or two without the rest is not sufficient.

It is also important to recognize that the economy is embedded in society, which is embedded in the rest of nature and that these three elements are extremely interdependent. We can no longer treat the economy separately, without considering its dependence on society and the rest of nature.

An integrated, nexus approach to urban, regional, national and global planning must include better, more appropriate measures of sustainable human well-being. These measures need to account for the effects of equity and social and natural capital. The genuine progress indicator (GPI) is one such indicator that shows that in the United States and globally, growth has been 'uneconomic' (not improving genuine progress) since about 1980 if one accounts for the social and environmental costs. However, GPI includes only costs and better accounting for the positive contributions of social and natural capital and ecosystem services is also required. These benefits far exceed conventional GDP.

Scenario planning is one technique that can be used to implement these ideas at community, national, and even global scales, but with the added feature of public opinion surveys around the scenarios. Scenario planning creates an ability to discuss and develop consensus about what social groups want. Predicting the future is impossible. But what we can do is lay out a series of plausible scenarios, which help to better understand future possibilities and the uncertainties surrounding them. Scenario planning differs from forecasting, projections and predictions in that it explores plausible rather than probable future and lays out the choices facing society in whole systems terms. There is no simple answer to how to achieve a nexus approach to urban and regional planning, but a critical first step is to develop a shared vision of the goal for the system. Scenario planning incorporating the four-capital model of ecological economics is one way to do this. There is also the growing possibility to employ online computer games and crowd sourcing to build, evaluate, and communicate scenarios.

Creating a sustainable and desirable future will require an integrated, systems-level redesign of our cities and our entire socioecological regime and economic paradigm focused explicitly and directly on the goal of sustainable quality of life and well-being with minimal waste rather than the proxy of unlimited material growth. It will require the recognition and measurement of the contributions of natural and social capital to sustainable well-being. It is a design problem on a massive scale. An integrated, nexus approach to urban and regional planning and design must be a central component of this process.

1 Introduction

UNU-FLORES defines the nexus approach as:

> The Nexus Approach to environmental resources' management examines the interrelatedness and interdependencies of environmental resources and their transitions and fluxes across spatial scales and between compartments. Instead of just looking at individual components, the functioning, productivity and management of a complex system is taken into consideration.

Ecological economics is fundamentally a nexus approach by this definition. Rather than looking only at the economic subsystem, ecological economics is a whole systems, transdisciplinary approach to science and management of our world (Costanza et al. 2014a). This paper lays out some of the basic characteristics and policy recommendations of ecological economics as a framework for a nexus approach to urban and regional planning and design.

A fundamental law of ecology is that everything is connected. We know that this is the case, but putting it into practice is hindered by the disciplinary structure of academia and the sectorial divisions of planning and management agencies. How do we move beyond these divisions to achieve the needed transdisciplinary, nexus approach to urban and regional planning?

In the past we were living in a relatively 'empty world'—a world where humans and their artefacts were a relatively minor part of the system and human activities had only local or regional impacts. However, the world has changed dramatically. We now live in a 'full world', even according to some, in a new geologic epoch—the Anthropocene (Crutzen 2002). We have moved away from an early successional world empty of people and their artefacts (but full of natural capital) where the emphasis and rewards were on rapid growth and expansion, cutthroat competition and open waste cycles. We have moved towards a maturing world full of people and their artefacts (but decreasing in natural and social capital) where the needs, whether perceived by decision-makers or not, are for qualitative improvement of the linkages between components (development), cooperative alliances and recycled 'closed loop' waste flows.

Can we recognize these fundamental changes and redesign our societies and cities rapidly enough to avoid a catastrophic overshoot? Can we be humble enough to acknowledge the huge uncertainties involved and build resilience to their most dire consequences? Can we effectively develop policies to deal with the tricky issues of wealth and income distribution, population prudence, international trade and energy supply in a world where the simple palliative of 'more growth' is no longer a solution? Can we modify our systems of governance at international, national and local levels to be better adapted to these new and more difficult challenges? Can we design and build urban areas, regions, countries and an integrated global society that can provide a sustainable, equitable and prosperous future for all?

To do this requires a transdisciplinary, nexus approach that recognizes the interconnectedness and interdependence of humans with each other and with the rest of nature. The transdiscipline of *ecological economics* (Costanza et al. 2014a) is based on an interconnected, whole systems view of the world and humans place in it. *Ecological economics* can be a basis for developing a nexus approach to urban and regional planning and design. It incorporates a 'four-capital' model of the assets we have to manage in order to achieve this.

1.1 Four Basic Types of Capital Assets

These assets, which overlap and interact in complex ways to produce all human benefits, are defined as:

- *Natural capital*: The natural environment and its biodiversity, which, in combination with the other three types of capital, provide ecosystem goods and services—the benefits humans derive from ecosystems. These goods and services are essential to basic needs such as survival, climate regulation, habitat for other species, water supply, food, fibre, fuel, recreation, cultural amenities and the raw materials required for all economic production.
- *Social and cultural capital:* The web of interpersonal connections, social networks, cultural heritage, traditional knowledge, trust and the institutional arrangements, rules, norms and values that facilitate human interactions and cooperation between people. These contribute to social cohesion to strong, vibrant and secure communities and to good governance and help fulfil basic human needs such as participation, affection and a sense of belonging.
- *Human capital*: Human beings and their attributes, including physical and mental health, knowledge and other capacities that enable people to be productive members of society. This involves the balanced use of time to meet basic human needs such as fulfilling employment, spirituality, understanding, skills development, creativity and freedom.
- *Built capital*: Buildings, machinery, transportation infrastructure and all other human artefacts and services that fulfil basic human needs such as shelter, subsistence, mobility and communications.

So, to implement a nexus approach to urban and regional planning, in addition to the built infrastructure of our urban systems and individual people, we must also recognize and design with our social and natural capital assets in an integrated and comprehensive way. In particular, dealing with the major issues of climate change, urbanization and population growth in an integrated way will be key to designing sustainable and desirable urban systems.

2 Dealing with Climate Change, Urbanization and Population Growth in an Integrated Way

Another way of characterizing ecological economics is by the basic problems and questions it addresses: allocation, distribution and scale.

Allocation refers to the relative division of the resource flow among alternative product uses—how much goes to production of cars, shoes, ploughs, teapots and so on. A good allocation is one that is efficient, that is, that allocates resources among product end uses in conformity with individual preferences as weighted by the ability of the individual to pay. The policy instrument that brings about an efficient allocation is relative prices determined by supply and demand in competitive markets.

Distribution refers to the relative division of the resource flow, as embodied in final goods and services, among alternative people, how much goes to you, to me, to others and to future generations. A good distribution is one that is just or fair, or at least one in which the degree of inequality is limited within some acceptable range. The policy instrument for bringing about a more just distribution is transfers, such as taxes and welfare payments.

Scale refers to the physical volume of the throughput, the flow of matter–energy from the environment as low-entropy raw materials and back to the environment as high-entropy wastes.[1] It may be thought of as the product of population times per capita resource use. It is measured in absolute physical units, but its significance is relative to the natural capacities of the ecosystem to regenerate the inputs and absorb the waste outputs on a sustainable basis. Perhaps the best index of scale of throughput is real GDP. Although measured in value units (P × Q, where P is price and Q is quantity), real GDP is an index of change in Q. National income accountants go to great lengths to remove the influence of changes in price, both relative prices and the price level. For some purposes the scale of throughput might better be measured in terms of embodied energy (Costanza 1980; Cleveland et al. 1984). The economy is viewed as an open subsystem of the larger, but finite, closed and nongrowing ecosystem. Its scale is significantly relative to the fixed size of the ecosystem. A good scale is one that is at least sustainable, which does not erode environmental carrying capacity over time. In other words, future environmental carrying capacity should not be discounted as done in present value calculations. A sustainable scale is one that stays within planetary boundaries (Rockström et al. 2009). An optimal scale is at least sustainable (i.e. it lasts), but beyond that it is a scale at which we have not yet sacrificed ecosystem services that are at present worth more at the

[1] Scale in this context is not to be confused with the concept of 'economies of scale', which refers to the way efficiency changes with the scale or size of production within a firm or industry or to geographic scale. Here we are using scale to refer to the overall scale or size of the total macroeconomy and throughput.

margin than the production benefits derived from the growth in the scale of resource use.

Priority of Problems The problems of efficient allocation, fair distribution and sustainable scale are highly interrelated but distinct; they are most effectively solved in a particular priority order, and they are best solved with independent policy instruments (Daly 1992). There are an infinite number of efficient allocations, but only one for each distribution and scale. Allocative efficiency does not guarantee sustainability (Bishop 1993). It is clear that scale should not be determined by prices but by a social decision reflecting ecological limits. Distribution should not be determined by prices but by a social decision reflecting a just distribution of assets. Subject to these social decisions, individualistic trading in the market is then able to allocate the scarce rights efficiently.

Climate change, population growth and urbanization are all interconnected problems of scale, distribution and allocation, but the scale problem now looms very large because it has been ignored by mainstream economics and urban planning for so long. Dealing with climate change, urbanization and population growth in an integrated way means first determining an optimal scale that does not damage the climate system and that is sustainable in terms of human population and its urban component. The idea of 'growth boundaries' that has been used successfully in Oregon to control urban sprawl is one example at the urban scale. Then we must design a fair distribution system and an efficient allocation system within the 'safe operating space' that adequately recognize the value of social and natural capital.

2.1 Population and Carrying Capacity

A primary question is: Are there limits to the carrying capacity of the earth system for human populations? Ecological economics gives an unequivocal *yes*. Where doubt sets in is on the precise number of people that can be supported, standard of living of the population and the way in which food production will reach the limit imposed by the carrying capacity.

Various estimates of global carrying capacity of the earth for people have appeared in the literature ranging from 7.5 billion (Demeny 1988) to 12 billion (Clark 1958), 40 billion (Revelle 1976) and 50 billion (Brown 1954). However, many authors are sceptical about the criteria—amount of food or kilocalories—used as a basis for these estimates. 'For humans, a physical definition of needs may be irrelevant. Human needs and aspirations are culturally determined: they can and do grow to encompass an increasing amount of 'goods,' well beyond what is necessary for mere survival' (Demeny 1988). For a long and careful if somewhat inconclusive discussion of the population issue, see Cohen (1995).

Cultural evolution has a profound effect on human impacts on the environment and on notions of well-being and quality of life. By changing the learned behaviour of humans and incorporating tools and artefacts, it allows individual human resource requirements and their impacts on their resident ecosystems to vary over several orders of magnitude. Thus it does not make sense to talk about the 'carrying capacity' of humans in the same way as the 'carrying capacity' of other species (Blaikie and Brookfield 1987) since, in terms of their carrying capacity, humans are many subspecies. Each subspecies would have to be culturally defined to determine levels of resource use and carrying capacity. For example, the global carrying capacity for *Homo americanus* would be much lower than the carrying capacity for *Homo indus*, because each average American consumes much more than each average Indian does. And the speed of cultural adaptation makes thinking of species (which are inherently slow changing) misleading anyway. *Homo americanus* could potentially change its resource consumption patterns drastically in only a few years, while *Homo sapiens* remains relatively unchanged. We think it best to follow the lead of Daly (1977) in this and speak of the product of population and per capita resource use as the total impact of the human population. It is this total impact that the earth has a capacity to carry, and it is up to society to decide how to divide it between numbers of people and per capita resource use. This complicates population policy enormously, since one cannot simply state a maximum population but rather must state a maximum number of impact units. How many impact units the earth can sustain and how to distribute these impact units over the population is a dicey problem indeed, but one that must be the focus of research in this area.

Many case studies indicate that 'there is no linear relation between growing population and density, and such pressures towards land degradation and desertification' (Caldwell 1984). In fact, one study found that land degradation can occur under rising pressure of population on resources (PPR), under declining PPR and without PPR (Blaikie and Brookfield 1987). Therefore, the scientific agenda must look towards more complex, systemic models where the effects of population pressures can be analysed in their relationships with other factors. The form, structure and metabolism of cities are design variables that can be reoriented towards more comprehensive nexus goals. This would allow us to differentiate population as a 'proximate' cause of environmental degradation from the concatenation of effects of population with other factors as the 'ultimate' cause of such degradation.

Research can begin by exploring methods for more precisely estimating the total impact of population times per capita resource use. For example, the 'Ehrlich identity':

$$\text{Pollution / Area} = \text{People / Area} \times \text{Economic Production / Person} \times \text{Pollution / Economic Production}$$

can be operationalized as

$$CO_2 \text{ Emissions / Km}^2 = \text{Population / Km}^2 \times \text{GDP / Population} \times CO_2 \text{ Emissions / GDP}$$

Thus no single factor dominates the changing patterns of total impact across time. This points to the need for local studies of causal relations among specific combinations of populations, consumption and production, noting that these local studies need to aim for a general theory that will account for the great variety of local experience. Work on the 'ecological footprint' (Wackernagel and Rees 1996) has taken this approach furthest.

Another research priority is to look at the effect adding a new person has on resources, according to consumption levels and the effect that efficiency has on rising levels of consumption. Decreasing energy consumption in developed countries could dramatically decrease CO_2 emissions globally. It is only under a scenario of severe constraints on emissions in the developed countries that population growth in less developed ones plays a major global role in emission growth. If energy efficiency could be improved in the latter as well as the former, then population increase would play a much smaller role.

Research priority should also look at situations where demand (either subsistence or commercial) becomes large relative to the maximum sustainable yield of the resource, or where the regenerative capacity of the resource is relatively low, or where the incentives and restraints facing the exploiters of the resource are such as to induce them to value present gains much more highly than future gains.

Some authors single out a high rate of population growth as a root cause of environmental degradation and overload of the planet's carrying capacity. Consequently, the policy instrument is obviously population control. Ehrlich and his colleagues maintain 'There is no time to be lost in moving toward population shrinkage as rapidly as is humanly possible' (Ehrlich et al. 1989). But, as Ehrlich himself fully recognizes, the policy of focusing solely on population control is known to be insufficient. It has repeatedly been shown that it is not easily achieved in and of itself and that in addition important social and economic transformations must accompany it, such as the reduction of poverty. Even in those cases where population growth has been relatively successfully controlled, as in China, the welfare of the people has not necessarily improved and the environment is not necessarily exposed to lower rates of hazard.

The opposite position is taken by those who see high rates of population growth as stimulating economic development through inducing technological and organizational changes (Boserup 1965) or as a phenomenon that can be solved through technological change (Simon 1990).

Such positions, however, ignore the dangers of environmental depletion implicit in unchecked economic growth: consumption increases and rapidly growing populations can put a very real burden upon the resources of the earth and bring about social and political strife for control of such resources. This position also assumes that technological creativity will have the same outcomes in the future as in the past and in the South as in the North, a questionable assumption. In particular, it assumes that new technology solves old problems without creating new ones that may be even worse. Finally, it heavily discounts the importance of the loss of biodiversity—a loss that is irreversible and whose human consequences are as yet unknown.

According to a World Bank study of 64 countries, when the income of the poor rises by 1 %, general fertility rates drop by 3 % (Lappé and Schurman 1988). In contrast, other authors state that 'population is not a relevant variable' in terms of resource depletion and stress that resource consumption, particularly overconsumption by the affluent, is the key factor (Durning 1992). OECD countries represent only 18 % of the world's population and 24 % of land area, but their economies account for about 59 % of the world gross product, 78 % of road vehicles and over 50 % of global energy use. They generate about 76 % of world trade, 73 % of chemical products exports and 73 % of forest product imports and account for one-third of global GHG emissions (OECD 2011). The main policy instrument in this case, in the short term, is reducing consumption, and this can be most easily achieved in those areas where consumption per capita is highest.

With a world population that is surpassing seven billion, increasing in food and energy prices due to a lack of resources (Brown 2011), slowing of development in already underdeveloped countries due to overpopulation (Birdsall et al. 2003; Bloom and Canning 2004) and a lack of jobs (Cincotta et al. 2003), there has been a refocusing on population stability, often in the form of family-planning policies. Family planning has been proven to be very cost-effective (Singh et al. 2010): for every dollar spent on family planning, the United Nations has found that two to six dollars can be saved in the future on other development goals (UNDESA 2009). Recently the United States and the United Kingdom once again increased their foreign aid funding towards international family planning (UNDESA 2009).

An estimated one-third of global births are the result of unintended pregnancy (Bongaarts 2009). More than 200 million women in developing countries would prefer to delay their next pregnancy or not have any more children at all (Singh et al. 2003). However, several barriers prevent many of these women from making a conscious choice: lack of access to contraceptives, risk of side effects, cultural values or opposition from family members (Carr and Khan 2004; Sedgh et al. 2007).

One of the major impacts of such population growth is the negative impact it is having on the earth's life-supporting ecosystem services (Ehrlich and Ehrlich 1991; Wilson 2003; Speidel et al. 2009). It has been estimated that about half of the productivity of the earth's biosystems has been diverted to human use (Brown 2008; Jackson 2009). As population continues to increase, especially in cities, competition for these increasingly scarce resources will intensify globally. The disconnect between the 'haves' and the 'have nots' will also become more visible.

Thus a new framework should expand the definitions of issues: focus not only on population size, density, rate of increase, age distribution and sex ratios but also on access to resources, livelihoods, social dimensions of gender and structures of power. New models have to be explored in which population control is not simply a question of family planning but of economic, ecological, social and political planning, in which the wasteful use of resources is not simply a question of finding new substitutes but of reshaping affluent lifestyles and in which sustainability is seen not only as a global aggregate process but also as one having to do with sustainable livelihoods for a majority of local peoples.

To address these issues in an integrated way, we have to first better define the overall goal of the enterprise. Next we discuss sustainable human well-being as the ultimate goal and emerging research on what this means and how to achieve it.

3 Sustainable Well-Being as the Goal

Getting a better handle on how to measure the well-being and health of both ecological and economic systems, and the welfare of humans within them, is critical. This section starts with a broader definition of human well-being and how to measure it. It then looks at the conventional macroeconomic measures of welfare (gross domestic product (GDP) and related measures) and their problems as measures of well-being. It then looks at how to move beyond GDP.

3.1 Quality of Life, Happiness, Well-Being and Welfare

There is a substantial body of new research on what contributes to human well-being and quality of life. While there is still much ongoing debate, this new science clearly demonstrates the limits of conventional economic income and consumption in contributing to well-being. For example, psychologist Tim Kasser, in his 2002 book *The High Price of Materialism* (Kasser 2002), points out that people who focus on material consumption as a path to well-being are actually less satisfied with their lives and even suffer higher rates of both physical and mental illness than those who do not focus so much on material consumption. Material consumption beyond real need is a form of psychological 'junk food' that only satisfies for the moment and ultimately leads to depression, Kasser says.

Economist Richard Easterlin has shown that well-being tends to correlate well with health, level of education and marital status and shows sharply diminishing returns to income beyond a fairly low threshold. He concludes (Easterlin 2003) that:

> people make decisions assuming that more income, comfort, and positional goods will make them happier, failing to recognize that hedonic adaptation and social comparison will come into play, raise their aspirations to about the same extent as their actual gains, and leave them feeling no happier than before. As a result, most individuals spend a disproportionate amount of their lives working to make money, and sacrifice family life and health, domains in which aspirations remain fairly constant as actual circumstances change, and where the attainment of one's goals has a more lasting impact on happiness. Hence, a reallocation of time in favour of family life and health would, on average, increase individual happiness.

British economist Richard Layard synthesizes many of these ideas and concludes that current economic policies are not improving well-being and happiness and that 'happiness should become the goal of policy, and the progress of national happiness should be measured and analysed as closely as the growth of GDP [gross domestic product]' (Layard 2005).

Economist Robert Frank, in his book *Luxury Fever* (Frank 1999), also concludes that some nations would be better off—that is, overall national well-being would be higher—if we actually consumed less and spent more time with family and friends, working for our communities, maintaining our physical and mental health and enjoying nature.

On this last point, there is substantial and growing evidence that natural systems contribute heavily to human well-being. In a paper published in the journal *Nature* (Costanza et al. 1997), the annual, nonmarket value of the earth's ecosystem services was estimated to be substantially larger than global GDP. This estimate was admittedly a rough first cut, but the goal of this paper was to stimulate interest and research on the topic of natural capital and ecosystem services.

So, if we want to assess the 'real' economy—all the things that contribute to real, sustainable, human well-being—as opposed to only the 'market' economy, we have to measure and include the nonmarketed contributions to human well-being from nature; from family, friends and other social relationships at many scales; and from health and education. What does such a more comprehensive, integrative definition of well-being and quality of life look like?

3.2 The Index of Sustainable Economic Welfare and the Genuine Progress Indicator

Domestic product, whether gross or net, is not identical with true national income and that subtracting indirect business taxes from net national product (NNP), as is done in the national income accounts to arrive at 'national income', still does not give us a true measure of national income. True income is sustainable, and to calculate this Hicksian income would require a quite different approach.

We have also shown that there is a marked difference between what GDP measures and economic welfare and that the latter has been growing much more slowly than the former as measured by the two proposals that have been made for judging the US economy. A defender of the continuing use of GDP as a guide to policy could argue that, even so, economic welfare *has* advanced along with GDP. If *any* advance in the welfare measure is truly a gain, it is still desirable to increase GDP. The recognition that it takes a great deal of increase in GDP to achieve a small improvement in real economic welfare could be used to argue that ever greater efforts are needed for the increase of GDP.

To counter such a claim, two points need to be made. First, there are social and ecological indicators that are being adversely affected by growth of GDP. Not all of these are dealt with in any of the welfare measures. This is especially true of many of the pervasive externalities like the depletion of natural capital and ecosystem services (Costanza et al. 2014b).

Second, GDP interprets every expense as positive and does not distinguish welfare-enhancing activity from welfare-reducing activity (Cobb et al. 1995; Talberth et al. 2007). For example, an oil spill increases GDP because of the associated cost of cleanup and remediation, but it obviously detracts from overall well-being (Costanza et al. 2004). GDP also leaves out many components that enhance welfare but do not involve monetary transactions and therefore fall outside the market. For example, the act of picking vegetables from a garden and cooking them for family or friends is not included in GDP. Yet buying a similar meal in the frozen food aisle of the grocery store involves an exchange of money and a subsequent GDP increase. GDP also does not account for the distribution of income among individuals, which has considerable effect on individual and social well-being (Wilkinson and Pickett 2009).

A more comprehensive indicator would consolidate economic, environmental and social elements into a common framework to show net progress in well-being and quality of life (Costanza et al. 2004). A number of researchers have proposed alternatives to GDP that make one or more of these adjustments with varying components and metrics (Smith et al. 2013). Some have also noted the dangers of relying on a single indicator and have proposed a 'dashboard' approach with multiple indicators.

In an effort to address these issues (while remaining mindful of the pitfalls) Daly and Cobb (1989) developed an Index of Sustainable Economic Welfare (ISEW). The ISEW takes the measure of economic welfare (MEW) of Nordhaus and Tobin and the economic aspects of welfare (EAW) of Zolotas (1981) as starting points but incorporates the sustainability issues that EAW ignores and the environmental issues that MEW ignores. Rather than revising and bringing up to date the existing measures, they decided to create a new one that includes some of the elements not dealt with by any of the three indices already discussed, as well as fresh ways of treating topics that were included in them. To summarize these changes, ISEW:

1. Factors in income distribution on the assumption that an additional dollar's worth of income adds more to the welfare of a poor family than a rich one.
2. Considerably alters what Nordhaus and Tobin (1972) did in the calculation of changes in net capital stock. Specifically, it includes only changes in the stock of fixed reproducible capital and excludes natural and human capital in this calculation.
3. Updates Zoltas's (1981) estimates using more recent data for air and water pollution and adds an estimate of noise pollution.
4. Includes estimates of costs of the loss of wetlands and farmlands, depletion of nonrenewable resources, commuting, urbanization, auto accidents, advertising and long-term environmental damage.
5. Omits any imputation of the value of leisure.
6. Includes imputed values for the value of unpaid household labour.

Since then, the ISEW has been renamed the genuine progress indicator (GPI) (Redefining Progress 1995). Like ISEW, GPI starts with personal consumption expenditures (a major component of GDP) but adjusts it using approximately 25

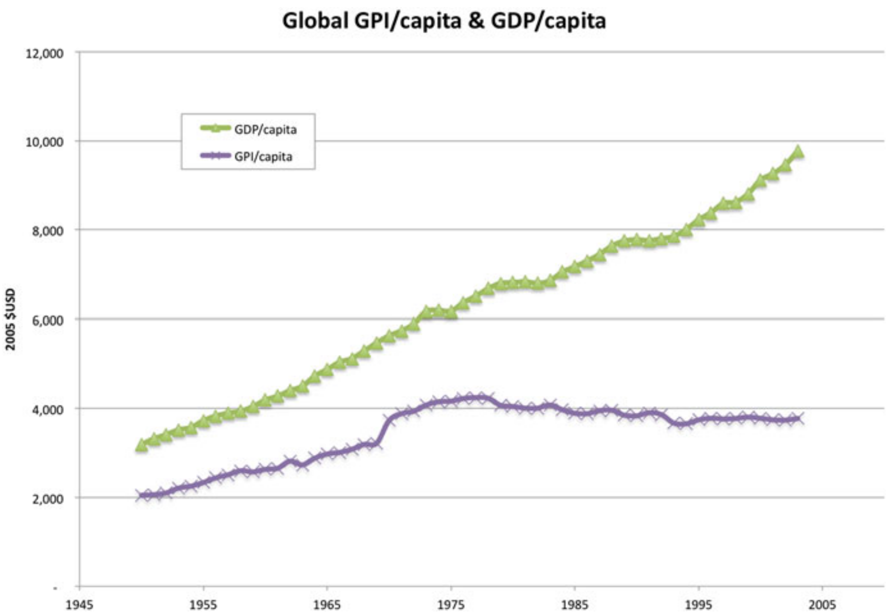

Fig. 4.1 Global GPI/capita and GDP/capita. GPI/capita was estimated by aggregating data for the 17 countries for which GPI or ISEW had been estimated and adjusting for discrepancies caused by incomplete coverage by comparison with global GDP/capita data for all countries. All estimates are in 2005 US$ (Kubiszewski et al. 2013)

different components, including income distribution, environmental costs and negative activities like crime and pollution, among others. GPI also adds positive components left out of GDP, including the benefits of volunteering and household work (Talberth et al. 2007). By separating activities that diminish welfare from those that enhance it, GPI better approximates sustainable economic welfare (Posner and Costanza 2011). GPI is not meant to be an indicator of sustainability. It is a measure of economic welfare that needs to be viewed alongside biophysical and other indicators. In the end, since one only knows if a system is sustainable after the fact, there can be no direct indicators or sustainability, only predictors (Costanza and Patten 1995).

GPI and ISEW have been calculated for various countries around the world. These studies have indicated that in many countries, beyond a certain point, GDP growth no longer correlates with increased economic welfare. A global GPI was also estimated using GPI and ISEW data from 17 countries, containing approximately 53 % of the world's population and 59 % of the global GDP (Kubiszewski et al. 2013). On the global level GPI/capita peaked in 1978 (Fig. 4.1). Interestingly, 1978 is also around the time that the human ecological footprint exceeded the earth's capacity to support humanity. Other global indicators, such as surveys of life satisfaction, also began to level off around this time.

An important function of GPI is to send up a red flag at that point (1978). Since it is made up of many benefit and cost components, it also allows for the identification of which factors increase or decrease economic welfare. Other indicators are better guides of specific aspects. For example, life satisfaction is a better measure of overall self-reported happiness. By observing the change in individual benefit and cost components, GPI reveals which factors cause economic welfare to rise or fall even if it does not always indicate what the driving forces are behind this. It can account for the underlying patterns of resource consumption, for example, but may not pick up the self-reinforcing evolution of markets or political power that drive change.

Recently, two state governments in the United States have adopted GPI as an official indicator, the states of Maryland and Vermont. In addition, the data necessary to estimate GPI is becoming more available in many countries and regions. For example, remote sensing data allow better estimates of changes in natural capital, and surveys of individuals about their time use and life satisfaction are becoming more routine. The bottom line is that the costs of estimating GPI are not particularly high, the data limitations can be overcome and it can be relatively easily estimated in most countries. Alternatively, a simplified version of GPI can also be calculated as an initial step in the process (Bleys 2007).

3.3 Towards a Measure of Total Human Welfare

While the GPI goes a long way towards providing a better measure of economic welfare, it is certainly not a perfect measure of economic welfare and it falls far short of measuring *total* welfare. GPI is still based on measuring how much is being produced and consumed, with the tacit assumption that more consumption leads to more welfare. GPI at least adjusts for the sustainability of this consumption, its negative impacts on natural capital, its distribution across income classes and other reasonable adjustments. This is a huge improvement over GDP and one that tells a very different story about recent changes in aggregate economic welfare.

A completely different approach, however, would be to look directly at the actual well-being that is achieved—to separate the means (consumption) from the ends (well-being) without assuming that one is correlated with the other. Some authors have begun to look at the problem from this perspective. For example, Manfred Max-Neef (1992) has developed a matrix of human needs and has attempted to address well-being from this alternative perspective. While human needs can be classified according to many criteria, Max-Neef organized them into two categories: existential and axiological, which he arranges as a matrix. He lists nine categories of axiological human needs which must be satisfied in order to achieve well-being: (1) subsistence, (2) protection, (3) affection, (4) understanding, (5) participation, (6) leisure, (7) creation, (8) identity and (9) freedom. These are arrayed against the existential needs of (1) having, as in consuming; (2) being, as in being a passive part of without necessarily having; (3) doing, as in actively participating in the work process; and (4) relating, as in interacting in social and organizational structures. The key idea here is that humans do not have primary needs for the products of the economy. The economy is only a means to an end. The end is the satisfaction of primary human needs. Food and shelter are ways of satisfying the need for subsistence. Insurance systems are ways to meet the need for protection. Religion is a way to meet the need for identity. Max-Neef summarizes as:

> Having established a difference between the concepts of needs and satisfiers it is possible to state two postulates: first, fundamental human needs are finite, few and classifiable; second, fundamental human needs (such as those contained in the system proposed) are the same in all cultures and in all historical periods. What changes, both over time and through cultures, is the way or the means by which the needs are satisfied (pp. 199–200).

This is a very different conceptual framework from conventional economics, which assumes that human desires are infinite and that, all else being equal, more is always better. According to this alternative conceptual framework, we should be measuring how well basic human needs are being satisfied if we want to assess well-being, not how much we are consuming, since the two are not necessarily correlated (see the earlier section that discusses subjective well-being measures).

3.4 Substitutability vs. Complementarity of Natural, Human, Social and Built Capital

The upshot of these considerations is that natural capital (natural resources) and human-made capital are complements rather than substitutes. The neoclassical assumption of near-perfect substitutability between natural resources and human-made capital is a serious distortion of reality, the excuse of 'analytical convenience' notwithstanding. To see how serious, imagine human-made capital being a perfect substitute for natural resources. Then it would also be the case that natural resources would be a perfect substitute for human-made capital. Yet if that were so, then we would have had no reason whatsoever to accumulate human-made capital since we were already endowed by nature with a perfect substitute! Historically of course we did accumulate human-made capital long before natural capital was depleted, precisely because we needed human-made capital to make effective use of the natural capital (complementarity!). It is amazing that the substitutability dogma should be held with such tenacity in the face of such an easy *reduction ad absurdum*. Add to that the fact that capital itself requires natural resources for its production—i.e. the substitute itself requires the very input being substituted for—and it is quite clear that human-made capital and natural resources are fundamentally complements, not substitutes. Substitutability of capital for resources is limited to reducing waste of materials in process, for example, collecting sawdust and using a press (capital) to make particleboard. And no amount of substitution of capital for resources can ever reduce the mass of material resource inputs below the mass of the outputs, given the law of conservation of matter–energy.

Substitutability of capital for resources in aggregate production functions reflects largely a change in the total product mix from resource-intensive to different capital-intensive products. It is an artefact of product aggregation, not factor substitution (i.e. along a given product isoquant). It is important to emphasize that it is this latter meaning of substitution that is under attack here—producing a given physical product with less natural resources and more capital. No one denies that it is possible to produce a different product or a different product mix with fewer resources. Indeed new products may be designed to provide the same or better service while using fewer resources and sometimes less labour and less capital as well. This is a technical improvement, not a substitution of capital for resources. Light bulbs that give more lumens per watt represent technical progress and qualitative improvement in the state of the art, not the substitution of a quantity of capital for a quantity of natural resource in the production of a given quantity of a product. In addition, increases in efficiency can sometimes lead to increases in consumption if they free up financial resources that can be spent of other consumption items. Saving money on petrol for your hybrid Prius would allow you to buy more consumption items that may, in fact, consume more resources than the petrol you saved.

It may be that economists are speaking loosely and metaphorically when they claim that capital is a near-perfect substitute for natural resources. Perhaps they are counting as 'capital' all improvements in knowledge, technology, managerial skill and so on—in short anything that would increase the efficiency with which resources are used. If this is the usage, then 'capital' and resources would by definition be substitutes in the same sense that more efficient use of a resource is a substitute for using more of the resource. But to define capital as efficiency would make a mockery of the neoclassical theory of production, where efficiency is a ratio of output to input and capital is a quantity of input.

The productivity of human-made capital is more and more limited by the decreasing supply of complementary natural capital. Of course in the past when the scale of the human presence in the biosphere was low, human-made capital played the limiting role. The switch from human-made to natural capital as the limiting factor is thus a function of the increasing scale of the human presence.

3.5 Growth vs. Development

Improvement in human welfare can come about by pushing more matter–energy through the economy (i.e. increases in scale) or by squeezing more human want satisfaction out of each unit of matter–energy that passes through. These two processes are so different in their effect on the environment that we must stop conflating them. It is better to refer to throughput increase as *growth* and efficiency increase as *development.* Growth is destructive of natural capital and beyond some point will cost us more than it is worth—that is, sacrificed natural capital will be worth more than the extra human-made capital whose production necessitated the sacrifice. At this point growth has become antieconomic, impoverishing rather than enriching.

Development, or qualitative improvement, is not at the expense of natural capital. There are clear economic limits to growth, but not to development. This is not to assert that there are no limits to development, only that they are not so clear as the limits to growth, and consequently there is room for a wide range of opinion on how far we can go in increasing human welfare without increasing resource throughput. How far can development substitute for growth? This is the relevant question, not how far can human-made capital substitute for natural capital, the answer to which, as we have seen, is 'hardly at all'.

Still, great uncertainty and debate exists as to whether economic growth promotes overall well-being. This uncertainty is critical since economic growth policies, also known as neoliberal policies, are being disseminated to all developing countries around the world. The promotion of economic growth is based on the assumption that increases in wealth and material consumption lead to increases in well-being (Samuelson 1947; Easterlin 1995; Oswald 1997; Goklany 2002; Layard 2005; Kusago 2007).

After 20 years of implementing neoliberal policies, many countries have experienced economic growth (Edwards 1992; Amann and Baer 2002) as well as decreases in poverty levels in certain countries (Lodoňo and Skékely 2000) and increases in well-being through improvements in living standards, as measured by GDP, life expectancy and decreases in child mortality (Krueger 1997; Goklany 2002).

However, these neoliberal policies have also brought about high economic, social and environmental costs, often outweighing the improvements in well-being. Chile, often considered as the perfect model of neoliberal growth, has experienced several negative effects due to these policies (Green 1996; Schurman 1996; Altieri and Rojas 1999; Baer and Maloney 2003; Homedes and Ugalde 2005). In recent years, economic growth has either declined or become stagnant in many developing nations (Muradian and Martinez-Alier 2001; Mahon 2003; Held 2005). Subjective well-being has decreased in many developed countries such as the United States, Japan and most countries in Europe, as well as most recently in China (Oswald 1997; Layard 2003; Kahneman and Krueger 2006). The inequality gap within and between countries continues to increase (Lodoňo and Skékely 2000; Muradian and Martinez-Alier 2001; Wade 2004; Navarro 2007). Poverty is still a major problem in many countries around the world, and there is controversy regarding the magnitude of the poverty reduction that has occurred (Lodoňo and Skékely 2000; Wade 2004; Held 2005). Also, increased dependency on degrading (especially primary) natural resources has exacerbated environmental pressures and increased the rate of species extinction (Kessler and Van Dorp 1998; Muradian and Martinez-Alier 2001; Paus et al. 2003; McCarthy and Prudham 2004).

Some people believe that there are truly enormous possibilities for development without growth. Energy efficiency, they argue, can be vastly increased (Lovins and Lovins 1987; Lovins 1997), likewise the efficiency of water use. Other materials are not so clear. Others (Costanza 1980; Cleveland et al. 1984; Gever et al. 1986; Hall et al. 1986) believe that the bond between growth and energy use is not so loose. This issue arises in the Brundtland Commission's Report (World Commission on Environment and Development 1987) where on the one hand there is a recognition that the scale of the human economy is already unsustainable in the sense that it requires the consumption of natural capital and yet on the other hand there is a call for further economic expansion by a factor of 5 to 10 in order to improve the lot of the poor without having to appeal too much to the 'politically impossible' alternatives of serious population control and redistribution of wealth. The big question is: how much of this called for expansion can come from development and how much must come from growth? This question is not addressed by the commission. But statements from the secretary of the World Commission on Environment and Development (WCED), Jim MacNeil (1990), that 'The link between growth and its impact on the environment has also been severed' (p. 13) and 'the maxim for sustainable development is not 'limits to growth'; it is "the growth of limits"' indicate that WCED expects the lion's share of that factor of 5–10 to come from development, not growth. They confusingly use the word 'growth' to refer to both cases, saying that future growth must be qualitatively very different from past growth. When things are qualitatively different, it is best to call them by different names, hence our distinction between growth and development. Our own view is that WCED is too optimistic—that a factor of 5–10 increase cannot come from development alone and that if it comes mainly from growth, it will be devastatingly unsustainable. Therefore, the welfare of the poor, and indeed of the rich as well, depends much more on population control, consumption control and redistribution than on the technical fix of a five- to tenfold increase in total factor productivity.

We acknowledge, however, that there is a vast uncertainty on this critical issue of the scope for economic development from increasing efficiency. We have therefore devised a policy that should be sustainable regardless of who is right in this debate. The basic logic is simple: protect the pessimists against their worst fears and encourage the optimists to pursue their dreams by the same policy, namely, limit throughput.

4 Natural Capital

We have briefly defined the four types of capital assets that are necessary to support human well-being in a sustainable and desirable way. We have pointed out that these four types of capital are, in general, compliments rather than substitutes and that we need to differentiate between *growth* in the scale of the built and human capital components of the system and *development* of the quality of interactions between all four types of capital. Next we go into more detail about natural capital and its importance to both conventional marketed economic production and to the supply of nonmarketed ecosystem services.

One major issue is the relation between natural capital, which yields a flow of natural resources and services that enter the process of production, and the human-made capital that serves as an agent in the process for transforming the resource inflow into a product outflow. Is the flow of natural resources (and the stock of natural capital that yields that flow) substitutable by human-made capital?

Clearly one resource can substitute for another—we can transform aluminium instead of copper into electric wire. We can also substitute labour for capital, or capital for labour, to a significant degree even though the characteristic of complementarity is also important. For example, we can have fewer carpenters and more power saws or fewer power saws and more carpenters and still build the same house. In other words one resource can substitute for another, albeit imperfectly, because both play the same qualitative role in the production: both are raw materials undergoing transformation into a product. Likewise capital and labour are substitutable to a significant degree because both play the role of agent of transformation of resource inputs into product outputs. However, when we come to substitution across the roles of transforming agent and material undergoing transformation (efficient cause and material cause), the possibilities of substitution become very limited and the characteristic of complementarity is dominant. For example, we cannot make the same house with half the lumber no matter how many extra power saws or carpenters we try to substitute. Of course we might substitute brick for lumber, but then we face the analogous limitation—we cannot substitute masons and trowels for bricks.

We may define capital broadly as a stock of something that yields a flow of useful goods or services. Traditionally capital was defined as produced means of production, which we call here human-made capital, as distinct from natural capital which, though not made by humans, is nevertheless functionally a stock that yields a flow of useful goods and services. We can distinguish renewable from nonrenewable natural capital and marketed from nonmarketed natural capital, giving four cross-categories. Natural capital consists of physical stocks that are complementary to human-made capital. We have learned to use the concept of human capital (i.e. skills, education, etc.), which departs even more fundamentally from the standard definition of capital. Human capital cannot be bought and sold, although it can be rented. Although it can be accumulated, it cannot be inherited without effort by bequest as can ordinary human-made capital but must be relearned anew by each generation. Natural capital, however, is more like traditional human-made capital in that it can be bequeathed. Overall the concept of natural capital is less a departure from the traditional definition of capital than is the commonly used notion of human capital.

There is a large subcategory of marketed natural capital that is intermediate between natural and human-made, which we might refer to as 'cultivated natural capital'. This consists of such things as plantation forests, herds of livestock, agricultural crops, fish bred in ponds and so on. Cultivated natural capital supplies the raw material input complementary to human-made capital, but does not provide the wide range of natural ecological services characteristic of natural capital proper (e.g. eucalyptus plantations supply timber to the sawmill and may even reduce erosion, but do not provide a wildlife habitat or conserve biodiversity). Investment in the cultivated natural capital of a plantation forest, however, is useful not only for the lumber, but as a way of easing the pressure of lumber interests on the remaining true natural capital of natural forests.

Marketed natural capital can, subject to the important social corrections for common property and myopic discounting, be left to the market. Nonmarketed natural capital, both renewable and nonrenewable, will be the most troublesome category. Remaining natural forests should in many cases be treated as nonmarketed natural capital and only replanted areas treated as marketed natural capital.

4.1 Natural Capital and Ecosystem Services

Ecological systems play a fundamental role in supporting life on earth at all hierarchical scales. They form the life-support system without which economic activity would not be possible. They are essential in global material cycles like the carbon and water cycles. Ecosystems produce renewable resources and services. For example, a fish in the sea is produced by several other 'ecological sectors' in the food web of the sea. The fish is a part of the ecological system in which it is produced, and the interactions that produce and sustain the fish are inherently complex.

Ecosystem services are the ecological characteristics, functions or processes that directly or indirectly contribute to human well-being—the benefits people derive from functioning ecosystems (Costanza et al. 1997; Millennium Ecosystem Assessment (MEA) 2005). Ecosystem processes and functions may contribute to ecosystem services but they are not synonymous. Ecosystem processes and functions describe biophysical relationships and exist regardless of whether or not humans benefit (Granek et al. 2010). Ecosystem services, on the other hand, only exist if they contribute to human well-being and cannot be defined independently.

The following categorization of ecosystem services has been used by the Millennium Ecosystem Assessment (2005):

(a) *Provisioning services*—ecosystem services that combine with built, human and social capital to produce food, timber, fibre or other 'provisioning' benefits. For example, fish delivered to people as food require fishing boats (built capital), fisherfolk (human capital) and fishing communities (social capital) to produce.
(b) *Regulating services*—services that regulate different aspects of the integrated system. These are services that combine with the other three capitals to produce flood control, storm protection, water regulation, human disease regulation, water purification, air quality maintenance, pollination, pest control and climate control. For example, storm protection by coastal wetlands requires built infrastructure, people and communities to be protected. These services are generally not marketed but have clear value to society.
(c) *Cultural services*—ecosystem services that combine with built, human and social capital to produce recreation, aesthetic, scientific, cultural identity, sense of place or other 'cultural' benefits. For example, to produce a recreational benefit requires a beautiful natural asset (a lake), in combination with built infrastructure (a road, trail, dock, etc.), human capital (people able to appreciate the lake experience) and social capital (family, friends and institutions that

make the lake accessible and safe). Even 'existence' and other 'non-use' values require people (human capital) and their cultures (social and built capital) to appreciate.

(d) *Supporting services*—services that maintain basic ecosystem processes and functions such as soil formation, primary productivity, biogeochemistry and provisioning of habitat. These services affect human well-being *indirectly* by maintaining processes necessary for provisioning, regulating and cultural services. They also refer to the ecosystem services that have not yet or may never be intentionally combined with built, human and social capital to produce human benefits but that support or underlie these benefits and may sometimes be used as proxies for benefits when the benefits cannot be easily measured directly. For example, net primary production (NPP) is an ecosystem function that supports carbon sequestration and removal from the atmosphere, which combines with built, human and social capital to provide the benefit of climate regulation. Some would argue that these 'supporting' services should rightly be defined as ecosystem 'functions', since they may not yet have interacted with the other three forms of capital to create benefits. We agree with this in principle, but recognize that supporting services/functions may sometimes be used as proxies for services in the other categories.

This categorization suggests a very broad definition of services, limited only by the requirement of a contribution to human well-being. Even without any subsequent valuation, explicitly listing the services derived from an ecosystem can help ensure appropriate recognition of the full range of potential impacts of a given policy option. This can help make the analysis of ecological systems more transparent and can help inform decision makers of the relative merits of different options before them (Costanza et al. 2011).

Examples of these services include the maintenance of the composition of the atmosphere, amelioration and stability of climate, flood controls and drinking water supply, waste assimilation, recycling of nutrients, generation of soils, pollination of crops, provision of food, maintenance of species and a vast genetic library and also maintenance of the scenery of the landscape, recreational sites and aesthetic and amenity values (Ehrlich and Mooney 1983; Folke 1991; de Groot 1992; Ehrlich and Ehrlich 1992; Costanza et al. 1997, 2014b; de Groot et al. 2002). Biodiversity at genetic, species, population and ecosystem levels all contribute in maintaining these functions and services (Worm et al. 2006). Cairns and Pratt (Cairns and Pratt 1995) argue that a highly environmentally literate society would probably accept the assertion that most, if not all ecosystem functions, are in the long term beneficial to society.

Many ecosystem services are public goods. This means they are non-excludable and multiple users can simultaneously benefit from using them. This creates circumstances where individual choices are not the most appropriate approach to valuation. Instead, some form of community or group choice process is needed. Furthermore, ecosystem services (being public goods) are generally not traded in markets. We therefore need to develop other methods to assess their value.

There are a number of methods that can be used to estimate or measure benefits from ecosystems. Valuation can be expressed in multiple ways, including monetary units, physical units or indices. Economists have developed a number of valuation methods that typically use metrics expressed in monetary units (Freeman 2003), while ecologists and others have developed measures or indices expressed in a variety of nonmonetary units such as biophysical trade-offs (Costanza 2004).

The study of ecosystem services has grown exponentially in the past few decades as seen through the publication records (Costanza and Kubiszewski 2012). The most influential of these studies was published in 1997 by Costanza and colleagues, which estimated global monetary value of ecosystems in a *Nature* article entitled 'The value of the world's ecosystem services and natural capital' (Costanza et al. 1997). This paper estimated the value of 17 ecosystem services for 16 biomes to be in the range of US$16–54 trillion per year, with an average of US$33 trillion per year, a figure larger than annual GDP at the time. This area of publication has grown exponentially. In this study, estimates of global ecosystem services were derived from a synthesis of previous studies that utilized a wide variety of techniques like those mentioned above to value-specific ecosystem services in specific biomes. This technique, called 'benefit transfer', uses studies that have been done at other locations or in different contexts, but can be applied with some modification. Such a methodology, although useful as an initial estimate, is just a first cut and much progress has been made since then (USEPA Science Advisory Board 2009).

More recently, with the publication of the Millennium Ecosystem Assessment (MEA), the concept of ecosystem services gained the attention of a broader academic audience and the public (Millennium Ecosystem Assessment (MEA) 2005). The MEA was a 4-year, 1300 scientist study commissioned by the United Nations in 2005. The report analysed the state of the world's ecosystems and provided recommendations for policymakers. It determined that human actions have depleted the world's natural capital to the point that the ability of a majority of the globe's ecosystems to sustain future generations can no longer be taken for granted.

In 2008, a second international study was published on The Economics of Ecosystems and Biodiversity (TEEB), hosted by United Nations Environment Programme (UNEP). TEEB's primary purpose was to draw attention to the global economic benefits of biodiversity, to highlight the growing costs of biodiversity loss and ecosystem degradation and to draw together expertise from the fields of science, economics and policy to enable practical actions moving forward. The TEEB report was picked up extensively by the mass media, bringing ecosystem services to a broad audience.

With such high-profile reports being published, ecosystem services have entered not only the public media (Schwartz 2010) but also into business. Dow Chemical recently established a $10 million collaboration with The Nature Conservancy to tally up the ecosystem costs and benefits of every business decision (Walsh 2011). Such collaboration will provide a significant addition to ecosystem services valuation knowledge and techniques. However, there is significant research that is still required.

Hundreds of projects and groups are currently working towards better understanding, modelling, valuation and management of ecosystem services and natural capital. It would be impossible to list all of them here, but the new Ecosystem Services Partnership (ESP, http://www.es-partnership.org/) is global network that does just that and helps to coordinate the activity and build consensus.

5 An Integrated, Nexus Approach to Urban Design and Planning

How does all this relate to urban design and planning? It means that we have to take a much more integrated, whole systems approach to this problem. Failure to do this has lead to poorly designed, poorly functioning, unsustainable and undesirable urban systems. The neglect of an integrated approach and the current compartmentalization of the different components of planning for urban systems, combined with the disconnect in planning between urban systems and their rural and global hinterlands means that important connections and feedback mechanisms remain invisible.

There are, of course, good examples of cities that have incorporated an integrated approach and these are models that can be built upon. Portland, Oregon, is one well-known example, where the functions of planning and sustainability are integrated in one office, urban growth boundaries have been in effect since the 1970s and social capital, natural capital and ecosystem services are terms that can be heard in every-day conversation.

There is no simple answer to how to achieve a nexus approach to urban and regional planning, but we believe that a critical first step is to develop a shared vision of the goal for the system. Scenario planning incorporating the four-capital model of ecological economics is one way to do this. In addition we can employ the latest in Internet communication and crowd sourcing to build, evaluate and communicate scenarios.

5.1 Scenario Planning and Modelling with the Four-Capital Model

'Scenario' is a term with multiple meanings. Scenario exercises vary in their objectives and hence their characteristics (Biggs et al. 2007), and we acknowledge that each of the many variants has an important place in decision-making processes. In this case, we define scenario analysis or scenario planning as a structured process of exploring and evaluating the future. Scenarios consider how alternative futures, typically structured around the identification of a focal issue (O'Brien 2000), may unfold from combinations of the most influential and uncertain drivers and their interactions with more certain driving forces.

Scenario planning differs from forecasting, projections and predictions, in that it explores plausible rather than probable futures (Peterson et al. 2003). Scenarios are most useful for dealing with uncertainty when there is insufficient information about the probabilities that different events will occur. Scenario planning is based on four assumptions (DTI 2003):

1. The future is unlike the past and is significantly shaped by human choice and action
2. The future cannot be foreseen, but exploring possible futures can inform present decisions
3. There are many possible futures; scenarios therefore map within a 'possibility space'
4. Scenario development involves both rational analysis and creative thinking

Scenarios are best suited to exploring situations of high uncertainty and low controllability (Peterson et al. 2003), for example, climate change and global governance. In these situations, scenarios can help to illuminate the consequences of these uncontrollable forces and to formulate robust responses locally. A frequently cited example is the use of scenarios by Royal Dutch Shell (Wack 1985; Kahane 1992). Shell began developing scenarios in the 1970s and engaged in a process to imagine a future that, at the time, no one thought would happen. When turbulence hit the world oil market in the late 1970s, Shell, though unable to directly intervene in the market, navigated the shocks much better than its competitors who did not use scenarios for strategic planning.

Although aspects of the future worlds depicted by scenarios may come to eventuate in time, these worlds are best treated as caricatures of reality from which we can learn. Often, they illustrate alternative 'stable states' or 'basins of attraction' that can be either desirable or undesirable worlds to live in. The ultimate role of scenarios is to help understand how society can either exit an undesirable world or make it more desirable (Gallopin 2002).

Scenarios have been developed for a range of applications from global to local scales, including corporate strategy (Wack 1985), political negotiations (Kahane 1992; Kahane 2004) and community-based natural resource management (Wollenberg et al. 2000; Evans et al. 2006; Bohensky et al. 2011).

How could scenario planning be applied to integrated urban planning? Representatives of major stakeholder groups can come together to envision plausible futures for these areas. These scenarios would cover the full range of options, from business-as-usual development to more sustainable futures. In all cases the scenarios must be 'plausible'—meaning that they should take scientific evidence into account and combine rational analysis and creative thinking.

Scenario planning has been shown to work, even in very contentious situations, by bringing together stakeholders to think together about options for the whole system (Kahane 2004). It allows participants to step out of their special interest mode and begin to build shared visions. Scenario planning is now embedded in the strategic thinking of some of the world's most influential institutions, including the World Bank and United Nations Environment Programme. Scenario planning was used in the Millennium Ecosystem Assessment to chart possible trajectories for the global community based on the rate and extent of ecological change and the interactions with management policies (Carpenter 2005). Scenario planning need not be static; scenarios can be revisited and reworked as part of a long-term formal process, for example, the application of scenario planning to guide water management in the Netherlands from the 1950s (Haasnoot and Middelkoop 2012).

Once a range of scenarios is created, a consensus often emerges among participants as to which options are most desirable and risk averse, given underlying uncertainties about the future. For example, in South Africa a scenario planning process involving all political parties developed four scenarios for the country's transition out of apartheid (Kahane 2004). The 'flight of the flamingos' scenario that envisioned both black and white South Africans rising up together emerged as the clear consensus and lead to the truth and reconciliation and other strategies that allowed a relatively peaceful and cooperative transition in a situation that might have otherwise become quite violent and repressive. The development of an evidence-based understanding of how the world works, combined with a shared vision of how we want it to work, are powerful tools to tackle even the most complex and recalcitrant of problems.

To take the process of empowerment to its logical conclusion, we recommend that scenarios be put to the public in the form of opinion surveys (Costanza 2000; Costanza et al. 2015). As far as we are aware, such sampling of public opinion about scenarios has been very limited. An instructive example is provided, however, by the designers of an online scenario game for exploring futures in New Zealand (Landcare Research Scenarios Working Group 2007). Several hundred game participants provided telling feedback on the scenario space they considered New Zealand to be in now, where they would like the country to be in 50 years and where they thought New Zealand was actually heading. While the overwhelming majority of respondents sought a future characterized by greater environmental sustainability and social cohesion, they considered that the country was heading in the opposite direction.

5.2 *The Potential for Computer Games and Crowd Sourcing*

Games have been popular throughout human history to educate and entertain. Even the simplest of games can be thought of as simulations of some aspect of life. Some of these simulations can be quite complex and useful. Examples include war games and flight simulators. Games that can be used for research to understand some aspect of human behaviour have also become quite popular and useful. For example, von Neumann and Morgenstern (Von Neumann and Morgenstern 1953) formulated much of economic behaviour around 'games of strategy'. More recently, the Prisoner's Dilemma game has been used extensively to understand the evolution of cooperative behaviour. A search of the ISI Web of Knowledge for the topic 'Prisoner's Dilemma' turned up over 1,700 papers. The most frequently cited of these was the 1981 article by Axelrod and Hamilton (1981). In 2002, Vernon Smith was awarded the Nobel Prize in economics for his pioneering role in the development of experimental economics, which, in essence, uses simple games to test behavioural responses to different value propositions.

Rapidly advancing technology has provided the increasing ability to bring realistic detail to recreational computer games. Imagine such a game that also offers academically rigorous, peer-reviewed representations of earth's attributes including human interactions. Millions of players could test and provide solutions to problems that challenge policy analysts, corporate executives, climate scientists, philanthropists, economists, government leaders, sociologists and scenario planners.

The promise of games that integrate research, education and entertainment is huge, but has rarely been achieved. One of the few examples is the 'World Game' first developed in 1961 by R. Buckminster Fuller, originally as a global simulation alternative to war games. The World Game allows a group of players to cooperatively develop a set of global scenarios. The goal is to 'make the world work for 100% of humanity in the shortest possible time through spontaneous cooperation without ecological damage or disadvantage to anyone', thus increasing the quality of life for all people. The World Game has been played by thousands of people, with and without the aid of computers over the years. It is now offered by *osearth.com* as a global simulation game for 40–600 players in educational workshops. Another recent example is an extension to a very popular board game 'Settlers of Catan' called 'Catan: Oil Springs' (Griswold 2013) that incorporates oil resource depletion into the game.

We now have the capability to link relatively sophisticated computer simulations with engaging game interfaces over the Internet, allowing us to observe and record player behaviour. Harvesting such information—or crowd sourcing—from games may help answer both basic and complex research questions, while at the same time entertaining and educating game players. In this paper we outline a novel approach for integrating research, educational and entertainment outcomes within a gaming environment, focusing on and facilitating exploration of the valuation of ecosystem services—that is, on those processes and functions of ecosystems that benefit human society. To date, while some popular games broadly explore aspects of the nexus approach advocated here, or could be modified to do so (e.g. SimCity, Civilization, Myst), there is a huge opportunity to better integrate such interfaces with research and public participation in the urban and regional design process. This could allow a huge increase in public engagement in the design and planning process that could incorporate the ecological economics framework we have discussed.

6 Conclusions and Recommendations

Ecological economics and the four-capital model provide a framework for an integrated, nexus approach to urban and regional planning. It is based on a reformulation of the central goal as a high and sustainable quality of life that is equitably shared. Our current socioecological regime and its set of interconnected worldviews, institutions and technologies all support the vision of unlimited growth of material production and consumption as a proxy for quality of life. However, abundant evidence shows that, beyond a certain threshold, further material growth only marginally contributes to improvement in quality of life. Not only does further material growth not meet humanity's central goal, there is mounting evidence that it creates significant roadblocks to sustainability through increasing resource constraints (i.e. peak oil, water limitations), sink constraints (i.e. climate disruption, biodiversity loss, pollution) and the inequitable distribution of wealth. Overcoming these roadblocks and creating a sustainable and desirable future will require an integrated, systems-level redesign of our cities and our entire socioecological regime and economic paradigm focused explicitly and directly on the goal of sustainable quality of life and well-being with minimal waste rather than the proxy of unlimited material growth. It will require the recognition and measurement of the contributions of natural and social capital to sustainable well-being. It is a design problem on a massive scale. This transition, like all cultural transitions, will occur through an evolutionary process, but one that we, to a certain extent, can control and direct through the process of shared envisioning and the creation of both physical and computer models. Visions and models of integrated sets of worldviews, institutions and technologies are needed to stimulate and seed this evolutionary redesign.

To make the transition to a just and sustainable world will require:

1. A fundamental change of worldview to one that recognizes that we live on a finite planet and that sustainable well-being requires far more than material consumption
2. Replacing the present goal of limitless growth with goals of material sufficiency, equitable distribution and sustainable human well-being
3. A complete redesign of the world economy that preserves natural systems essential to life and well-being and balances natural, social, human and built assets

The dimensions of the new system include, but are not limited to, the following:

Sustainable scale: respecting ecological limits:

- Establishment of systems for effective and equitable governance and management of the natural commons, including the atmosphere, oceans and biodiversity

- Creation of cap-and-auction systems for basic resources, including quotas on depletion, pollution and greenhouse gas emissions, based on basic planetary boundaries and resource limits
- Consuming essential nonrenewables, such as fossil fuels, no faster than we develop renewable substitutes
- Investments in sustainable infrastructure, such as renewable energy, energy efficiency, public transit, watershed protection measures, green public spaces and clean technology
- Dismantling incentives towards materialistic consumption, including banning advertising to children and regulating the commercial media
- Linked policies to address population and consumption

Fair distribution: protecting capabilities for flourishing:

- Sharing the work to create more fulfilling employment and more balanced leisure–income trade-offs
- Reducing systemic inequalities, both internationally and within nations, by improving the living standards of the poor, limiting excess and unearned income and consumption and preventing private capture of common wealth
- Establishment of a system for effective and equitable governance and management of the social commons, including cultural inheritance, financial systems and information systems like the Internet and airwaves

Efficient allocation: building a sustainable macroeconomy:

- Use of full-cost accounting measures to internalize externalities, value non-market assets and services, reform national accounting systems and ensure that prices reflect actual social and environmental costs of production
- Fiscal reforms that reward sustainable and well-being-enhancing actions and penalize unsustainable behaviours that diminish collective well-being, including ecological tax reforms with compensating mechanisms that prevent additional burdens on low-income groups
- Systems of cooperative investment in stewardship (CIS) and payment for ecosystem services (PES)
- Increased financial and fiscal prudence, including greater public control of the money supply and its benefits and other financial instruments and practices that contribute to the public good
- Ensuring availability of all information required to move to a sustainable economy that enhances well-being through public investment in research and development and reform of the ownership structure of copyrights and patents

An integrated nexus approach to urban and regional planning and design based on an ecological economics framework can be a central component of this transition to a sustainable and desirable future.

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