“As we watch the sun go down, evening after evening, through the smog across the poisoned waters of our native Earth, we must ask ourselves seriously whether we really wish some future universal historian on another planet to say about us: ‘With all their genius and with all their skill, they ran out of foresight and air and food and water and ideas’”

U Thant, UN Secretary General, addressing 7th Session of the General Assembly, New York, 1970
Drivers

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The scale, spread and rate of change of global drivers are without precedent. Burgeoning populations and growing economies are pushing environmental systems to destabilizing limits. The idea that the perturbation of a complex ecological system can trigger sudden feedbacks is not new: significant scientific research has explored thresholds and tipping points that the planetary system may face if humanity does not control carbon emissions. Understanding feedbacks from the perspective of drivers reveals that many of them interact in unpredictable ways. Generally, the rates of change in these drivers are not monitored or managed, and so it is not possible to predict or even perceive dangerous thresholds as they approach. Critically, the bulk of research has been on understanding the effects of drivers on ecosystems, not on the effects of changed ecosystems on the drivers – the feedback loop.

Patterns of globalization – links between trade, finance, technology and communication – have made it possible for trends in drivers to generate intense pressures in concentrated parts of the world very quickly. There has been a rapid rise in the production of biomass-based fuels for transport – from maize, sugar cane, palm oil and rapeseed. In the early years of the 21st century, biodiesel became more widely available, with production growing at around 60 per cent per year, reaching nearly 13 million tonnes of oil equivalent in 2009. However, recent information raises concerns about the direct environmental and social consequences of large-scale biofuel production. These complex issues include, but are not limited to, land clearance and conversion, the introduction of potentially invasive species, the overuse of water, effects on the global food market, and the purchase or leasing of land by foreign investors to produce food and biofuels, typically in developing and sometimes semi-arid countries.

Drivers typically have high inertia and path dependencies, which can act as barriers to effective action. Three-quarters of the agricultural land in the United States is dedicated to just eight commodity crops: maize, wheat, cotton, soybeans, rice, barley, oats and sorghum. This dominance is reinforced by a set of interlocking structural constraints including high levels of producer subsidies, dietary preferences, and a large industrialized food processing economy. For example, of the top 20 sources of industrial pollution in the United States, eight are slaughterhouses, but even with well-understood environmental and health problems associated with this food system, its highly entrenched nature makes it extremely difficult to modify.

Although reducing the drivers of environmental change directly may appear politically difficult, it is possible to accomplish some environmental co-benefits by targeting more expedient objectives, such as international goals on human well-being. Education is recognized as a basic human right, included in the Universal Declaration of Human Rights. Achieving universal primary education is Goal 2 of the Millennium Development Goals, and it is linked to the improvement of gender equality and women’s empowerment. Together with access to reproductive health, education is a key determinant of fertility levels. Greater investment in education has been correlated with declining fertility, rising incomes and increasing longevity, and also with an educated citizenry able to express concern about environmental matters.

Surveillance and monitoring get results. Even where policy responses are not immediately possible, awareness of the importance of drivers can justify increased efforts at surveillance and monitoring. Many of the most important drivers identified in this chapter are currently not subject to systematic monitoring, their impacts even less so. The evidence, then, is compelling for the need to enhance the understanding and monitoring of drivers and their links with the environment.
INTRODUCTION
The last 100 years was characterized by exceptional growth both in the human population and in the size of the global economy, with the population quadrupling to 7 billion and global economic output, expressed as gross domestic product (GDP), increasing about 20-fold (Maddison 2009). This expansion has been accompanied by fundamental changes in the scale, intensity and character of society’s relationship with the natural world (Steffen et al. 2007; MA 2005; McNeill 2000). In tracking and analysing these transformations, a new understanding of the complexities of the Earth’s biophysical systems has been developed.

It is four decades since Lovelock (1972) introduced the idea that the Earth’s systems were a complex organism. More recently, science has struggled with the realization that many Earth systems are at planetary boundaries that must not be crossed (Rockström et al. 2009). These concepts are useful to communicate both the dependence of human development on the environment and the urgency with which the consequences of collective human activity on the biological, physical and chemical processes of the Earth’s systems need to be addressed. The impacts of human activities include alteration of the global carbon cycle by carbon dioxide (CO2) and methane (CH4) emissions; disruption of the nitrogen, phosphorous and sulphur cycles; interruptions in natural river flows that interfere with the water cycle; destruction of ecosystems that has led to the extinction of countless species; and drastic modification of the planet’s land cover (Rockström et al. 2009).

FRAMEWORK
The fifth Global Environment Outlook (GEO-5) is organized using the DPSIR framework consisting of drivers, pressures, states, impacts and responses along a continuum (Stanners et al. 2007). Drivers refer to the overarching socio-economic forces that exert pressures on the state of the environment. While GEO-4 identified drivers within a thematic context, GEO-5 identifies two major drivers on the continuum – population and economic development – that influence cross-cutting dynamic patterns and generate complex systemic interactions. For example, the pressure of supplying food, feed and fibre to growing urban centres threatens biodiversity, a pressure then exacerbated by climate change.

Pressures can include resource extraction, land-use change and the modification and movement of organisms. For example, as economic growth and the demand for agricultural products rise, so does the conversion of land for agricultural purposes, as well as the use of agrochemicals. Similarly, market demands, trade and globalization patterns can lead to the inadvertent transport of invasive species that may wreak havoc on the natural ecosystems they newly inhabit.

The DPSIR framework asks three questions (Pinter et al. 1999):
• What is happening to the environment and why (pressure and state)?
• What is the consequence of the changed environment (impact)?
• If appropriate, what is being done about it and how effective is it (response)?

Questions regarding the role of drivers behind pressures – and the relationship between the two – can lead to persistent theoretical discussions. GEO-5 assumes that such roles and relationships are fluid, sometimes arbitrary, a stance that should serve the purposes of this assessment.

To facilitate policy-making, this report considers leverage points to be advantageous places to intervene in the complex human interaction with the Earth System (Meadows 1999). In many cases, the most important leverage points for policy may not be the pressures themselves but the drivers. There can be substantial co-benefits, and trade-offs, associated with altering drivers in order to reduce pressure on the environment.

To effectively describe the selected drivers and for a better understanding of the pressures acting on the environment, two questions are asked that focus on why environmental changes are occurring or, more fundamentally, why there is pressure.
• What is the scale or quantity of the driver? This entails both the size of the driver and its growth rate, as well as the extent of its influence and effect on other parameters.
• What is the intensity or quality of the driver? This entails the organization of the driver as well as the various processes it exhibits and influences.

DRIVERS
Population growth and economic development are seen as ubiquitous drivers of environmental change with particular facets exerting pressure: energy, transport, urbanization and globalization. While this list may not be exhaustive, it is useful. Understanding the growth in these drivers and the connections between them will go a long way to address their collective impact and find possible solutions, thereby preserving the environmental benefits on which human societies and economies depend.

Population
Many environmental pressures are proportional to the number of people dependent on natural resources, although technological advances can mitigate individual impacts. When a population of deer, rats or sea urchins grows beyond the carrying capacity of their ecosystem, their populations crash. Sometimes the ecosystem recovers but sometimes it is permanently altered. This has been happening to human populations for millennia as they grow beyond the capacity of their valley, island or landscape to support their society, and they face famine, plague or collapse (Diamond 2005). In the last century, as human numbers grew, people came to exploit most of Earth’s surface, but it is not only the scale or quantity of the population that affects the nature of a pressure on the environment. In addition, how human populations are organized – in cities or villages, in nuclear or extended families, as migrants or those that stay behind – makes a difference to the capacity of the environment to support them in their way of life.

Quantity
The human population reached 7 billion in 2011 and is expected to reach 10 billion by 2100 (UN 2011). Using the regions defined by the UN Statistics Division, the Asia and Oceania region has
the largest population, Africa is the fastest-growing and most youthful region, and Europe and North America have the slowest-growing populations and the highest proportion of elderly. As of 2012, much of the current growth in global population can be attributed to momentum left from past population increases, shifts in generational composition, and communities with high fertility rates in rural areas of less developed countries and elsewhere (Bongaarts and Bulatao 1999). Population momentum explains the apparent contradiction between a growing population size and declining fertility rates. Higher fertility rates in previous decades have resulted in a large generation of youth now entering or in the reproductive age group. This increase in the reproducing population creates conditions for larger numbers of births overall, even though couples are having fewer children.

Fertility is declining in almost all countries, although rates vary broadly. At the global level, the crude birth rate fell from 37 births per thousand in 1950–1955 to 20 per thousand in 2005–2010, while total fertility, or the number of children per woman, declined from 4.9 in 1950–1955 to 2.6 in 2005–2010 (UN 2011). While the fertility decline was more accentuated in developing countries – from 6.0 to 2.7 children per woman between 1950 and 2010 – fertility levels in the countries of the less developed regions are still spread over a broad range. Among developed countries, fertility levels were already relatively low in 1950 at 2.8 children per woman, but continued to fall to 1.6 children per woman in 2010, which is less than the replacement rate of 2.1 children per woman (Box 1.1) (UN 2011). Although the global growth rate peaked more than 40 years ago, some estimates suggest there will be another billion people by 2025 and a further billion before mid-century (UN 2009a).

Fertility and mortality are closely linked. Fewer pregnancies, for example, translate into a reduction in maternal mortality, which in many countries is still a leading cause of death for women of childbearing age. Further, lower infant and child mortality may lead to lower fertility rates as parents become better able to depend on their children surviving (Palloni and Rafalimanana 1999).

The epidemiological transition closely mirrors the fertility aspect of the demographic transition. In regions that are in an early demographic stage – those with high birth and death rates – death clusters around infants, whose deaths are mostly related to nutritional deficiencies, and those dying of communicable diseases such as influenza, malaria, tuberculosis and HIV/AIDS. In regions that have entered a later demographic stage – those with lower birth and death rates – infant mortality is low and deaths coalesce around the elderly and are associated with obesity and aging, with many deaths due to cancer and heart disease (Murray and Lopez 1997).

Mortality transitions remain distinct between developed and developing countries, despite improvements. Infant mortality has continued to decline and life expectancy to rise everywhere. Global average life expectancy in 1950–1955 was 47 years, while in 2005–2010 it was 65–68 for men and 70 for women (UN 2009a). There are, of course, important regional variations, particularly in terms of infant mortality in the least developed countries, young adult mortality in countries affected by the HIV epidemic, and old-age mortality in developed countries (de Sherbinin et al. 2007; Rindfuss and Adamo 2004). Table 1.1 shows notable disparities in mortality rates. Infant mortality rates vary from 74 deaths per 1 000 live births in Africa to 6 deaths per 1 000 in Europe and North America.

### Table 1.1 Demographic data, 2011*

<table>
<thead>
<tr>
<th></th>
<th>Africa</th>
<th>Asia and Oceania</th>
<th>Europe</th>
<th>Latin America and the Caribbean</th>
<th>North America</th>
<th>World (all countries with data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth rate per 1 000 population</td>
<td>36</td>
<td>18</td>
<td>11</td>
<td>18</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Death rate per 1 000 population</td>
<td>12</td>
<td>7</td>
<td>11</td>
<td>6</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Life expectancy</td>
<td>58</td>
<td>70</td>
<td>76</td>
<td>74</td>
<td>78</td>
<td>70</td>
</tr>
<tr>
<td>Total fertility rate per woman</td>
<td>4.7</td>
<td>2.2</td>
<td>1.6</td>
<td>2.2</td>
<td>1.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Infant mortality rate per 1 000 live births</td>
<td>74</td>
<td>39</td>
<td>6</td>
<td>19</td>
<td>6</td>
<td>44</td>
</tr>
<tr>
<td>Net migration rate per 1 000 population</td>
<td>-1</td>
<td>0.04</td>
<td>2</td>
<td>-1</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>Internal migration rate 1990–2005, %</td>
<td>15.4</td>
<td>13.2</td>
<td>22.3</td>
<td>19.3</td>
<td>17.8</td>
<td>17.5</td>
</tr>
<tr>
<td>Married women aged 15–49 using contraception, all methods, %</td>
<td>29</td>
<td>64</td>
<td>73</td>
<td>74</td>
<td>78</td>
<td>61</td>
</tr>
<tr>
<td>Married women aged 15–49 using contraception, modern methods, %</td>
<td>25</td>
<td>59</td>
<td>60</td>
<td>67</td>
<td>73</td>
<td>55</td>
</tr>
</tbody>
</table>

* Unless otherwise stated.

Source: PRB 2011; UNDP 2009
Box 1.1 Facilitating the demographic transition through education

Population levels and growth rates are not subject to international goals and targets, although population is directly relevant to major policy areas, including the Millennium Development Goals (MDGs). The most cost-effective method of reducing population pressures is through meeting the demand for contraception: many countries formulate policy targets around meeting unmet demand while increasing demand through investing in education for girls. Given that approximately 40 per cent of pregnancies remain unintended, great potential exists to meet latent demand for contraception (Singh et al. 2010).

Education is recognized as a basic human right included in the Universal Declaration of Human Rights (UNDHR 1948). Achieving universal primary education is MDG 2, linked to the improvement of gender equality and women’s empowerment (UN 2000). Together with access to reproductive health (MDG 5b), education is a key determinant of fertility levels. Increasing investment in education has been correlated with declining fertility, rising incomes and greater longevity (Bulled and Sosis 2010), and an educated human population is also able to express greater concern about environmental matters (White and Hunter 2009).

In developing countries, girls’ education is critical not only for reducing fertility, but for the associated lower mortality rates and improvements in health (Lutz and Samir 2011). Between 1970 and 2009, more than half of the deaths prevented among children under the age of five could be attributed to increased women’s education during their reproductive age (Gakidou et al. 2010). In addition, women have been better equipped to resist violence by gaining greater socio-economic standing through education. This empowerment has, for example, helped women avoid HIV/AIDS infection (Bhana et al. 2009; Vyas and Watts 2009).

Great opportunities exist for positive interventions in education. An ethical imperative and a social and economic good, universal education for girls would also empower them to make their own choices concerning starting and expanding their families. Globally, girls represent 60 per cent of the 77 million children not attending primary school (CARE 2011). To achieve the MDG of universal primary school enrolment by 2015 it is estimated that an additional US$10–30 billion per year needs to be invested on top of the approximately US$80 billion currently spent annually on primary education (Bruns et al. 2003; Devarajan et al. 2002).

Migration is another component of the demographic transition and is characterized by shifts from predominantly rural-rural migration in regions at early stages of the transition, to rural-urban and international migration in regions at later stages. The most dynamic of the three population processes, population movements produce local and global environmental consequences. Migration may have any of three direct impacts on the environment:

- rural-rural migration produces direct household impacts on natural resources, often through agricultural expansion;
- rural-urban migration and associated livelihood changes are often accompanied by changing patterns of energy use and increased meat and dairy consumption, which can intensify land pressures in productive rural areas; and
- international migration, with remittances sent home, can have a direct impact through land-use investments or an indirect impact through increased meat, dairy and material consumption.

Africa is increasingly urbanizing, although most of the population remains rural; Asia and Oceania and Latin America and the Caribbean are already largely urbanized and migration streams are increasingly international; and the United States and Europe have high internal migration associated with labour mobility (UNDESA 2011; Zaiceva and Zimmerman 2008).

The sending and receiving areas of rural-urban and international migration remain connected through remittances, with specific characteristics varying considerably across regions. The potential remittance-driven impact on land use change is significant, while remittance-driven consumption may be similar in scale but more diffuse in its environmental impacts (World Bank 2011b).

<table>
<thead>
<tr>
<th>Time</th>
<th>Total population</th>
<th>Birth rate</th>
<th>Death rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>High birth rate and high but fluctuating death rate</td>
<td>Declining death rate and continuing high birth rate</td>
<td>Declining birth and death rates</td>
<td>Low death rate and low but fluctuating birth rate</td>
</tr>
</tbody>
</table>

Source: University of Michigan 2011
Internal migration is increasingly dominated by rural-urban flows, a trend that is expected to continue (Sommers 2010; Rindfuss and Adamo 2004; Cohen and Small 1998). However, in some developing countries, a minority of rural-rural migrants has a disproportionate impact on tropical deforestation (Carr 2009; Lambin et al. 2003). Increasing migration to coastal areas and small islands can affect the environmental integrity of coastal wetlands and associated fisheries (Rindfuss and Adamo 2004).

World population is unevenly distributed, with densities in 2010 varying from 21 000 people per km² in Macao to 0.03 per km² in Greenland. This is due to a number of factors including settlement history, regional variations in demographic dynamics such as fertility, mortality and migration, and the fact that some locations are simply less suitable for human occupation (Adamo and de Sherbinin 2011). Population is particularly concentrated at lower elevations and near coasts. An estimate from 1998 suggested that a zone below an altitude of 100 metres, comprising 15 per cent of all inhabited land, houses about 30 per cent of the human population (Cohen and Small 1998). Low-elevation coastal zones are even more concentrated, representing about 2 per cent of total land area but housing 13 per cent of the population, and growing rapidly (McGranahan et al. 2007).

In 1950 only 29 per cent of the world population lived in urban settings and only New York and Tokyo, with their populations of more than 10 million people, qualified as megacities. The urban proportion reached 50 per cent in 2010 with 20 megacities, with the bulk of the urban population in Asia and Latin America (Figure 1.2). Urban growth rates are high in both Asia and Africa (Satterthwaite et al. 2010), with the highest rates in recent decades in middle-sized cities (Montgomery 2008).

**Quality**

Beyond the size and growth rates of populations, the way people settle and the way they consume can result in effects on different ecosystems.

While all of the world’s net population growth by 2050 is projected to occur in the world’s poorest cities (UN 2009b), virtually all land-cover change will take place in rural environments. The greatest human imprint on the Earth’s surface has been the conversion of forest to agriculture. Currently, 37.4 per cent of the planet’s land surface is used for agricultural production (Foley et al. 2011).

Located on only 0.5 per cent of the global terrestrial surface (Schneider et al. 2009), urban areas’ demand for food is disproportionately large in terms of world land use. At the same time, forest loss is no longer correlated to rural

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### Table 1.2 International migration, 1950–2100

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>More developed regions</td>
<td>6 122</td>
<td>6 076</td>
<td>5 643</td>
<td>7 433</td>
<td>11 895</td>
<td>13 821</td>
<td>17 450</td>
<td>16 558</td>
</tr>
<tr>
<td>Less developed regions</td>
<td>-6 122</td>
<td>-6 076</td>
<td>-5 643</td>
<td>-7 433</td>
<td>-11 895</td>
<td>-13 821</td>
<td>-17 450</td>
<td>-16 558</td>
</tr>
<tr>
<td>Least developed countries</td>
<td>-4 872</td>
<td>-4 301</td>
<td>-5 735</td>
<td>-3 562</td>
<td>2 563</td>
<td>-3 061</td>
<td>-3 351</td>
<td>-5 559</td>
</tr>
<tr>
<td>Least developed countries, excluding China</td>
<td>-1 250</td>
<td>-1 775</td>
<td>92</td>
<td>-3 871</td>
<td>-14 458</td>
<td>-10 760</td>
<td>-14 099</td>
<td>-10 999</td>
</tr>
<tr>
<td>Less developed regions, excluding China</td>
<td>-5 043</td>
<td>-6 210</td>
<td>-5 438</td>
<td>-7 194</td>
<td>-11 068</td>
<td>-13 535</td>
<td>-15 316</td>
<td>-15 107</td>
</tr>
</tbody>
</table>

Note: Figures are in thousands. Positive numbers imply net immigration, negative ones net emigration. Source: UN 2011
population growth; rather at the national scale, it is linked to the international demand for agricultural products and timber harvesting for urban consumption (Defries et al. 2010).

The world is nearly evenly divided between rural and urban inhabitants. One half includes rural food producers with a direct impact on land in space and time. Their effect on forests is particularly acute and widespread following rural-rural migration and the associated conversion of forests to agricultural land. This very small minority of all migrants is responsible for a significant proportion of tropical deforestation yet remains very little researched (Carr 2009). From a drivers perspective, it is also much more difficult to manage this phenomenon due to the scale and diffuse nature of the activity. The second type is the burgeoning urban population who are concentrated in space but whose impacts on the land are indirect albeit significant.

A rising human population has also been identified as the principal root cause of the water crisis (UNEP 2006). Overall, humans use more than a quarter of terrestrial evapotranspiration for growing crops and more than half of accessible water run-off (Postel et al. 1996). While climate change is making some places wetter (Clark and Aide 2011), much of Africa and the Middle East currently suffer a water scarcity that is worsening with the expanding populations (Sowers et al. 2010). Population growth has also been implicated in water scarcity in rapidly developing countries such as China, where urban growth has exacerbated a decline in the availability of clean water by overwhelming the water supply and sanitation infrastructure (Jiang 2009).

Population is not the only problem: groundwater use is highly inequitable, for example in India where 10 per cent of large farms consume 90 per cent of groundwater (Aguilar 2011; Kumar et al. 1998). Nor is a thirsty populace the only outcome. In the Republic of Tanzania, a diverse series of drivers, including population growth, has led to water conflicts (Mbonile 2005). Water scarcity can also provoke migration, as documented throughout Africa (Mwang’ombe et al. 2011; Grote and Warner 2010; Mbonile 2005).

Addressing population as a driver of global environmental change, households can be considered as units for analysing consumption patterns (Jiang and Hardee 2009; UNFPA 2008; Liu et al. 2003; MacKellar et al. 1995). In the developed world, household size is shrinking as their composition changes from extended families to nuclear ones (Bongaarts 2001). As a consequence, the rise in the number of households has been faster than population growth (Liu et al. 2003). Research suggests that this can cause double the rise in energy consumption that would occur from population growth alone (MacKellar et al. 1995), as there is an increase in the number of appliances and the level of electricity consumed per person (Zhou et al. 2011). Larger households generally use less energy per person than small ones, conforming to the expectations of economies of scale (O’Neill et al. 2001; Ironmonger et al. 1995). The age composition of a household also has an impact on energy consumption, Lenzen et al. (2006), working with data from Australia, Brazil, Denmark, India and Japan, found that the residents’ average age is positively related with per-person energy consumption, while household size and urban location...
are negatively associated. Transport, too, is likely to be more sensitive to the number of households, since an increase in the number of homes occurs primarily in low-density suburban landscapes (Seto et al. 2010), resulting in more passenger vehicles and more commuting, which add to petrol consumption and pollution.

Beyond the household unit, studies also identify impacts associated with absolute population size. A study of Californian counties found that population size significantly contributes to increases in nitrogen oxide and carbon monoxide emissions (Cramer 1998). Similarly, researchers have observed a positive relationship between population size and CO₂ emissions (Cole and Neumayer 2004; Mackellar et al. 1995; Bongaarts 1992), with an inverted U-shaped curve relation for sulphur dioxide (Cole and Neumayer 2004). How households and populations impact ecosystems is highly dependent on the stage of development, the geographic scale and the ecosystem itself, which is discussed further in Chapters 2–6.

Economic development
Consumption and production are both components of economic development and, like population, have a multiplier effect on environmental pressures. While consumption and production are technically separate socio-economic drivers, they are so inextricably linked that it is difficult to discuss them independently: the consumption of raw materials by the primary industries of mining and forestry leads to the manufacture of products that are in turn consumed by individual customers.

Quantity
The production of goods for consumption requires materials – minerals, water, food, fibre – and energy. During the 20th century, global economic output grew more than 20-fold, while materials extraction grew to almost 60 billion tonnes per year (Maddison 2009). This level of materials consumed by the human population is of the same scale as major global material flows in ecosystems, such as the amount of biomass produced annually by green plants (Krausmann et al. 2009; UNEP 2009b).

Consumption and production trends appear to have stabilized in developed countries, while in emerging economies such as Brazil, China, India, and Mexico, per-person resource use and associated environmental impacts have increased since 2000 (SERI 2008), and the less developed countries are just beginning the transition towards higher consumption levels. Should global economic development continue in a business-as-usual mode and population projections persist through 2050, another sharp rise in the level of global resource use is likely (Krausmann et al. 2009; SERI 2008).

Over the period 1970–2010, average global growth rates in GDP per person measured in purchasing power parity (PPP) fluctuated between -2 and 5 per cent annually; the average was about 3.1 per cent (World Bank 2011a). Since 2001, however, China has grown at 10 per cent per year, a seven-year doubling time, and India at 8 per cent per year, a nine-year doubling time, with environmental pressures increasing at much the same pace. As a result, China is now the world’s largest emitter of

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**Figure 1.4 Change in economic output, 1990–2005**

<table>
<thead>
<tr>
<th>Change in output</th>
<th>US$ per 1° grid cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal to significant decline</td>
<td>(-100–11.112)</td>
</tr>
<tr>
<td>Marginal decline to marginal increase</td>
<td>(-11.111–42.482)</td>
</tr>
<tr>
<td>Increase</td>
<td>(42.483–80.861)</td>
</tr>
<tr>
<td>Considerable increase</td>
<td>(80.862–2 397)</td>
</tr>
</tbody>
</table>

Note: The change in economic output aggregated across all cells within a country’s borders equates to the change in GDP.

Source: Nordhaus et al. 2008
Box 1.2 Expressing prosperity beyond GDP

Within the traditional accounting framework for benchmarking economic performance, a considerable amount of nature’s capital and services is externalized (excluded), thereby ignoring key environmental pressures and the forces driving them. Including those pressures requires alternative metrics to GDP and related benchmarks. Such alternatives can be measured in either monetary or physical units.

An alternative monetary approach seeks to maintain the traditional accounting framework and its reliance on market transactions, but augments it by internalizing (including) environmental costs and pressures. A common approach for accomplishing this is to assign market values to nature’s assets and services with the goal of taking full account of both market and non-market costs and benefits (Abraham and Mackie 2005; NRC 2004, 1994; Nordhaus and Kokkelenberg 1999), a procedure that was first attempted by Costanza et al. in 1997.

An alternative physical approach, stemming from the industrial metabolism or industrial ecology tradition, seeks to identify the rates and volumes of material flows through the economy. A system such as material flow accounting (MFA) is presumed to reveal more accurately the pressures on resources and the undesirable impacts on the environment from any part of the life cycle of resources – from extraction through combustion or conversion into a usable commodity and consumer consumption, to recycling, disposal or stewardship.

Two leading indicators are used to chart trends in global, national and urban material flows:

- total material extraction per unit of GDP; and
- metabolic rates – the amount of resource use per person.

During the 20th century, total material extraction increased from 7 billion tonnes to almost 60 billion, while GDP increased by a factor of 24 (Krausmann et al. 2009). Over the same period per-person resource use doubled from 4.6 tonnes to around 9 tonnes, while per-person income increased by a factor of seven (UNEP 2011a; Krausmann 2009). At the same time, resource prices were declining or stagnant. Taken together, these data indicate that resource decoupling or dematerialization, both in the aggregate and on a per-person basis, took place during the 20th century. Since there were no overarching policies specifically devoted to decoupling during the period, it appears that it took place spontaneously, perhaps due to forces within the global economic system. However, there is a clear need for further research to identify the responsible factors.

A more serious challenge – due to limitations in the available data – is determining whether material use is increasing or decreasing on a country-by-country basis. In a production-based system of accounts, environmental pressure is allocated to the country where the pressure occurs, while a consumption-based system allocates the pressure to the country where a product is finally consumed.

Furthermore, trade accounts only measure the weight of traded commodities entering a country, ignoring hidden or indirect flows – materials that are extracted or moved but are not traded directly. Finally, industrialized countries tend to be material importers while developing countries tend to be exporters. Due to these data limitations and patterns, the resource intensity of the advanced countries may be grossly understated because their high resource use is actually happening in exporting countries (Caldeira and Davis 2011).

These data limitations may account for the finding that, with the same standard of living, more densely populated areas and regions consume fewer resources per person than do less densely populated ones (Lenzen et al. 2006; Larivière and Lafrance 1999; Kenworthy and Laube 1996). The difference is even more pronounced when comparing industrialized high-density areas with low-density ones. Since high-density areas are nearly equivalent to urbanization, these areas – not the hinterland – are the hub of international trade where goods and services are received, while the resource intensity and environmental impacts are felt elsewhere as resource extraction typically takes place in areas of low population (Rosa and Dietz 2009).

greenhouse gases per year and, since 2010, its economy is second in size only to the United States (World Bank 2011a).

Much of China’s economic growth has come from its expansion in manufacturing, both for domestic markets and for export. By comparison, the average growth rate is negative for sub-Saharan Africa and less than 1 per cent for the Middle East and North Africa, although Figure 1.4 shows considerable variation across these regions. In addition, since 1995, Russia’s annual growth rate has fluctuated between -7.8 per cent and 10.0 per cent, with an average of 3.3 per cent (World Bank 2011c).

It is difficult to project economic growth: during the 1980s and 1990s the Republic of Korea experienced growth spurts at rates similar to China’s and India’s recent ones, before slowing to more moderate rates (World Bank 2011b). Using the concept of an ecological footprint, which aggregates all environmental pressures into a measure of hypothetical land required to meet current rates of resource use (Wackernagel et al. 2002, 1999), China and India are expected to appropriate 37 per cent of the projected increase in global footprint over the period 2001–2015 unless they are able to improve their production efficiency annually by 2.9 and 2.2 per cent, respectively (Dietz et al. 2007).
Whether these growth rates are realistic when put in the context of the Earth System’s biophysical boundaries remains to be seen (Chapter 7) (Rockström et al. 2009).

**Quality**

Technology is a key factor in the production of goods and services and an important one in terms of environmental impact. It has been argued that over time, factors of intensity or quality, affected by technological innovation, may more than compensate for the adverse effects of the rise in population, so that economic growth eventually leads to environmental improvements. An example of this is greenhouse gas emission rates in developed countries since 1970, where, it is claimed, emissions increased more slowly than economic activity because of shifts towards technologies that have a lower environmental impact (Bruvoll and Medin 2003; Hamilton and Turton 2002). However, it is not certain whether other sectors were so successful – efforts to reduce deforestation at the national level might have shown domestic improvement, but demand may have driven increased deforestation in other countries (Meyfroidt and Lambin 2009).

The environmental Kuznets curve (Figure 1.5) (Grossman and Krueger 1995) suggested that as countries become more affluent, concern about the environment increases, leading to policies that protect it. At the same time, preferences shift away from the most environmentally damaging goods and services.

This theory has been extensively examined (Carson 2010; Mol 2010; York et al. 2010; Aslanidis and Iranzo 2009; Galeotti et al. 2009; Jalil and Mahmud 2009; Lee et al. 2009; Roberts and Grimes 1997) and while debate continues, there seems to be clear evidence that some companies and industrial sectors have reduced their environmental impact, as the theory predicts. However, there are many obstacles to a shift towards more environmentally benign technologies: in some cases, these are economic challenges as environmentally sound technologies often have higher overall costs. But in many cases, simple cost/benefit calculations are not sufficient to explain the slow pace of growth in new technologies. For example, although researchers have noted the energy efficiency gap for years (Jaffe and Stavins 1994), whereby economically beneficial investments in energy efficiency have not been made, neither consumers nor industry have made significant investments in closing that gap despite the potentially favourable returns in energy costs saved, particularly when life-cycle costing is applied.

On the other hand, technological change that improves resource efficiency can have a perverse environmental effect by decreasing the costs of resource use and thus increasing demand. If the increased demand is greater than the efficiency gains, the overall consumption of a resource can actually increase, with concomitant increases in environmental impact. This phenomenon is known as the Jevons paradox or the rebound effect (Polimeni and Polimeni 2006; York 2006). The choice of technology, which is shaped by economic factors and individual and public decisions, is critical in determining the overall human impact on the environment. Research to explain the obstacles to adopting more environmentally benign, cost-effective technology is just beginning. One key factor, at least for households, is unfamiliarity with life-cycle costing and a lack of understanding of the energy and cost impacts of commonly used technologies (Attari et al. 2010; Carrico et al. 2009), and it appears that the same factors may also affect organizational decision making.

**Values**

It is commonplace to identify values as a key driver of environmental change. At one level, the argument is straightforward: human decisions, especially about consumption, are influenced by values and those decisions have impacts on the environment. However, research on human decision making notes that values are only one element in the cognitive processes, with beliefs and norms also of great importance (Stern 2011). While some decisions reflect a formal weighing of values and beliefs, many are made without much reflection, on the basis of normative expectations, emotions and interpretations of symbols or quick judgements (Kahneman 2003; Jaeger et al. 2001).

There is a voluminous canon of literature exploring the social psychology of environmental decision making, in which several generalizations can be discerned (Carrico et al. 2011; Schultz and Kaiser 2011; Stern 2011; Stern et al. 2010). First, no single factor is sufficient to explain such decisions. Values, beliefs and norms, and trust in others who must also take action or who are providing information, all matter. Second, decisions are often context-specific in the sense that individuals read the context, such as whether to emphasize a gain or a loss, and frame the decision based on that reading. Sometimes individuals act as
consumers, sometimes as members of a community, sometimes as citizens. Third, social networks are of immense importance in providing context as well as shaping values, beliefs, norms, trust and other significant factors (Henry 2009; Jackson and Yariv 2007). Fourth, values, beliefs, norms, trust and other individual characteristics interact with the character of the action to be taken in shaping behaviour – for example, social psychological factors may matter little when a pro-environmental action is exceptionally easy or hard to undertake, but may be critical for actions of intermediate difficulty (Guagnano et al. 1995).

Social psychology has developed many concepts to explain the factors underlying environmental decision making. Among these, values have been explored the most thoroughly and tested empirically across many national contexts (Dietz et al. 2005). In particular, altruism towards other humans, other species and the biosphere has consistently been found to predict pro-environmental attitudes and behaviour. In addition, a willingness to cooperate with others in experimental games, conducted in both laboratory and field settings, varies considerably across individuals and cultures (Henrich et al. 2010, 2005). Recently, the propensity to cooperate has been shown to matter in managing forest commons (Rustagi et al. 2010; Vollan and Ostrom 2010), with a substantial amount of literature showing the importance of trust in commons dilemmas (Fehr 2009). However, research on trust has not yet been linked to the larger literature on values. Consumer surveys have revealed a range of reasons why an individual is unwilling to pay more for an environmentally sensitive product (WBCSD 2010). The top three reasons involve poor understanding of, or apathy towards, the negative environmental impacts of consumption decisions, while the fourth most common was whether the individual viewed an action as common practice among their peers. This last point reveals the importance of societal pressure on values and by extension how decisions that impact the environment are influenced by it.

**Diets**

With economic growth comes a change in dietary intensity, which Popkin (2002) describes as the nutrition transition. This happens in three states: decreased occurrence of famine with rising incomes; the emergence of chronic diet-related diseases due to changes in activity and food consumption patterns; and a stage of behavioural change where diet and activity levels are better managed for prolonged healthier lives.

The growth in food consumption and related requirements for animal feed largely determine the pace at which supplies need to grow to keep up with the domestic and export demand for agricultural goods. Urbanization, demographic change and household wealth in a number of fast-evolving regions – Brazil,
China, India and Indonesia – suggest that changes in food consumption patterns are likely to have profound effects on regional food systems (Satterthwaite et al. 2010). These changes in consumption and consumption preferences introduce increased pressures on food and energy systems from the demand side, which forces compensating adjustments to take place on the supply side through market-mediated, price-driven interactions with producers.

As regional economies continue to grow, so, too, does the consumption and production of meat (Figure 1.6). Livestock production is the largest anthropogenic land use, accounting for 30 per cent of the land surface of the globe and 70 per cent of all agricultural land; 33 per cent of total arable land is used for producing animal feed (Steinfeld et al. 2006). Pelletier and Tyedmers (2010) suggest that, by 2050, the livestock sector alone may occupy the majority of, or significantly overshoot, recent estimates of humanity’s biophysical limits within three environmental areas: climate change, reactive nitrogen mobilization, and appropriation of plant biomass at planetary scales.

As urban areas are generally wealthier than rural ones, there are considerable differences in dietary composition, with urban diets characterized by higher levels of meat, dairy and vegetable oil. These foods are often imported and require more energy-intensive production (de Haen et al. 2003; Popkin 2001). Globalization and urbanization are cited as causing dietary convergence and adaptation. The former refers to the focusing of caloric intake on a smaller number of staple crops, such as wheat, rice and maize, with concomitant health impacts. Dietary adaptation is characterized by a greater reliance on processed foods due to lifestyle changes, greater exposure to advertising and time constraints on food preparation. This concentration of consumption also favours the concentration of the food supply chain among a relatively small number of corporations, with an implicit preference for supermarkets and larger-scale agricultural production (Kennedy et al. 2005).

**Energy-water nexus**

Another important dynamic of consumption is the trade-off between energy and water consumption. This dynamic is important for both energy production and agriculture. Gerbens-Leenes et al. (2009) estimate that 60–80 per cent of water used globally is dedicated to irrigation, rising to nearly 90 per cent in some low-rainfall areas. In addition, energy use for irrigation can be significant. In India, where the government often heavily subsidizes water pumping, 15–20 per cent of electricity is used for this purpose (Shah et al. 2004). Energy use for agriculture is considerable in both developed and developing countries, although in developed countries the energy used for processing and transporting food can be twice that of the entire agricultural production sector (Bazilian et al. 2011).

Water can also be an important resource for energy production and mineral extraction. However, freshwater pollution is a common side effect of mining, including recent hydraulic fracturing activities (Scott et al. 2011). China suffers from water scarcity due to a dwindling supply as well as to industrial pollution; the World Bank (2006) estimates that up to a third of water scarcity in China is due to pollution, the cost of which is equivalent to 1–3 per cent of GDP.

**THE DRIVER-PRESSURE CONTINUUM**

As population and economic development have continued to grow despite depressions and downturns, technological innovations have enhanced the integration of communities and societies into a global civilization. Technological advances in energy and transport continually generate new opportunities for growth in production and consumption, while ingenuity applied to communication and mobility has created new goods and services that previous generations could not have imagined. The growth and integration of human settlements, societies and relationships is evidenced by rapid urbanization and globalization.

**Energy Quantity**

As the world population increases, more people aspire to higher material living standards – creating an ever greater demand for goods and services as well as for the energy required to provide these. From 1992 until 2008, per-person energy consumption increased at a rate of 5 per cent annually. In 2009 total global energy use decreased for the first time in 30 years – by 2.2 per cent – as a result of the financial and economic crisis (Enerdata 2011); half of this occurred in the OECD countries (IEA 2011). Oil, natural gas and nuclear power consumption all decreased while hydroelectric and renewable energy consumption increased. Coal was the only energy source that was not affected. Primary energy consumption in 2010 is estimated to have risen by 4.7 per cent worldwide, easily surpassing the minor reduction in 2009. The rate of growth in the future, however, is expected to decrease due to an assumed levelling of population growth and continued improvements in energy efficiency (IEA 2011).

By 2030, more than 55 per cent of the population of Asia will be urban. © Kilbee Park/UN Photo
The shares of energy inputs are likely to change, with the proportion produced from oil decreasing and natural gas increasing. Coal levels are expected to stay relatively constant and nuclear energy use will increase due to investments in Asia. However, with potential policy changes following the Fukushima disaster in 2011, it is difficult to predict the growth trajectory of nuclear power. If nuclear energy plans are not followed through, more coal is likely to be used, with significant implications for climate change mitigation efforts (IEA 2011). Developing regions show a particularly strong increase in per-person energy consumption between 2005 and 2010, although, as of 2010, this seems to be levelling off. The three major economic sectors in terms of energy consumption (IEA 2011) are:

- manufacturing: 33 per cent;
- households: 29 per cent;
- transport: 26 per cent.

Electricity and heat generation account for more than 40 per cent of all CO₂ emissions (IEA 2010). Between 1992 and 2008, the annual rise in CO₂ emissions of more than 3 per cent and the total rise of 66 per cent — a much greater increase than that of the global population — was primarily the result of growth in industrial production, as well as higher living standards in many developing countries.

On a per-person basis, the largest growth in electricity production occurred in the developed countries, increasing from 8.3 megawatt hours (MWh) in 1992 to nearly 10 MWh in 2008, a difference of 1.7 MWh per person (IEA 2010), though in percentage terms this was the smallest rise at 22 per cent. The global average per-person electricity production grew by 33 per cent, from 2.2 MWh in 1992 to 3.0 MWh in 2008, while that of developing countries grew by 68 per cent, from 1 MWh to 1.7 MWh (IEA 2010).

In 2010, 1.44 billion people globally — around 20 per cent of the world population — were still suffering from energy poverty, without access to reliable electricity or the power grid, and entirely dependent on biomass for cooking and lighting (UNEP 2011b).

The energy commodity that dominates trade volume and value is crude oil, with China continuing to rival the United States in terms of consumption (EIA 2010). The Middle East accounts for about half of all global oil trade (IEA 2008). Coal production increased by 3–5 per cent per year during 2005–2009, with China experiencing a 16 per cent increase in production during 2008–2009 and reaching 44 per cent of the world’s total coal production of 3.05 billion tonnes. With rapidly increasing energy demand, however, China became a net importer of coal for the first time in 2007 (Kahrl and Roland-Holst 2008). The United States is the second largest producer of coal at 975 million tonnes per year, followed by India producing 566 million tonnes.

**Quality**

Renewable energy production is gaining much attention: the amount of energy produced from renewable sources, including sun, wind, water and wood, amounted to 13 per cent of the world supply in 2008, and estimates suggest 16 per cent in 2010 (REN21 2011). However, the largest renewable source is biomass at 10 per cent, with nearly two-thirds of that used in cooking and heating in developing countries (IPCC 2011). Thus, when biomass is excluded, other renewable sources provide only about 3 per cent of world energy.

There has been a 30 000 per cent rise in solar energy supply since 1992, a 6 000 per cent increase in wind energy and a 3 500 per cent rise in biofuel production, all from very low bases. This is mainly due to the decreasing cost of these technologies and the 2010 adoption by 199 countries of policies to promote renewable energy (REN21 2011).

There has been a rapid rise in the production of biomass-based fuels for transport — from maize, sugar cane, oil palm and rapeseed. While ethanol has been widely used in Brazil for two decades, its use accelerated globally at the end of the 1990s, increasing by 20 per cent each year to reach 30 million tonnes of oil equivalent in 2009. In the early years of the 21st century, biodiesel became available, with production growing at around 60 per cent per year, reaching nearly 13 million tonnes of oil equivalent in 2009. However, recent information on biofuel production raises concerns about the direct environmental and social impacts of land clearance and conversion, the introduction of potentially invasive species, the overuse of water and the consequences for the global food market. An additional cause for concern is the purchase or leasing of land by wealthier nations to produce food and biofuels — typically in developing and sometimes semi-arid countries. This trend may have serious impacts on fossil and renewable water resources, as well as on local food security (UNEP 2009a).
Investment in greening the energy sector is setting new records, totalling US$211 billion in 2010, up 32 per cent from 2009, and nearly five and a half times the 2004 figure. For the first time, new investment in utility-scale renewable energy projects in developing countries surpassed that of developed economies (UNEP 2011c).

The number of nuclear power plants, seen by some as an opportunity to meet the growing demand for energy, has increased by more than 20 per cent since 1992, rising to 435 by mid-2012. According to the International Atomic Energy Agency (IAEA 2008), in the 30 countries that have nuclear power, the share of electricity generated ranges from 78 per cent in France to 2 per cent in China, which has 14 operational plants, 25 under construction and more planned (WNA 2011a). Since 1992, energy production from nuclear power sources has grown by almost 30 per cent, although the share of nuclear power in the total supply has fallen from 17.5 per cent in 1992 to 13.5 per cent in 2008. Today, around the world, 60 plants are under construction, 155 planned and 339 proposed (WNA 2011b).

Global energy consumption is expected to continue to grow. Though China’s energy intensity decreased by 66 per cent between 1980 and 2002 (IEA 2008; Polimeni and Polimeni 2006), India’s energy use per unit of GDP remained relatively constant over the same period and, due to its growing economy, the country is expected to contribute 8 per cent of the world’s projected growth in emissions by 2030 (World Bank 2008). If the international community continues to have difficulty in addressing climate change in the near future, temperatures could increase by 3.5–6°C by the end of the century (IEA 2011). To stem the rise in global GHG emissions, the Kyoto Protocol encouraged the transfer of cleaner technologies from developed to developing economies. Trade was assumed to be the means of distributing these technologies, but without a significant reduction in existing trade barriers, this route will have limited impact (World Bank 2008).

Serious inequities remain in meeting global demand for access to energy. Today, 1.3 billion people are lacking electricity and 2.7 billion people still rely on the traditional use of biomass for food preparation, with concomitant impacts on deforestation rates, soil erosion and human health (IEA 2011). The reliance on fuelwood also has a demographic aspect, as per-person fuelwood consumption is shown to increase with decreasing household size but to decrease with urbanization, indicating a wealth effect (Knight and Rosa 2011). In order to achieve universal access to primary energy by 2030, an annual investment of US$48 billion is needed (IEA 2011).

**Transport Quantity**

Transport serves people, production and consumption and is an important facilitator of trade. The global economy is currently recovering from a severe recession, with global industrial production and trade climbing back to pre-crisis levels, albeit with marked geographic differences: GDP is growing fastest in China, by 10.3 per cent per year, and India, by 9.7 per cent, in 2010. Data published by Global Insight (2010) suggest that in the next 40 years Brazil, Russia, India and China (the BRIC countries) will start to approach the United States in terms of GDP, surpassing Germany, the United Kingdom, France and Italy, with the distinct possibility that China will have the world’s highest GDP by 2050. This unequal growth has implications for world trade and the flow of goods, posing considerable challenges and opportunities in terms of logistics and supply chains.

Countries and entire regions appear to be specializing in their attempts to become competitive, creating even greater demand for transport. For instance, Europe, the United States, Canada and Japan are dependent on fruit exports from Central and South America, some Western European countries, many Eastern European countries, and portions of Africa. Similar differential production-consumption trends happen with all products, pushing the demand for transport even higher and making freight inelastic to fuel prices. An evolving trend to manage this ever increasing world trade is containerization, which by many in the industry is considered a major revolution in handling goods, using larger ships to achieve economies of scale. It is estimated that from 80 to 90 per cent of world trade is by sea (UNCTAD 2011).

In the United States, the Bureau of Transportation Statistics (BTS 2011) reports that container trade in 2005 and 2006 was double that of the previous decade, increasing to 46.3 million 20-foot-equivalent units (TEUs, 19–43 cubic metres). At the global scale, container trade tripled during the same period. The European Union (EU), the world’s largest trading bloc, carries out 90 per cent of its external trade and 40 per cent of its internal trade by sea, totalling 3.5 billion tonnes (Reynaud 2009; Goulias 2008). However, studies in major ports show that any environmental benefits of seafaring cargo require significant attention at the place of loading and unloading. The Port of Los Angeles in California, a major hub, has, for example, implemented a variety of policies including the introduction of cleaner trucks with refuelling stations for natural gas, performance standards for cargo handlers and harbour craft, modernized and cleaner rail locomotives, and reduced vessel speeds (Port of Los Angeles 2010).

After a slump in 2008 and 2009, air freight began to return to its pre-economic-crisis levels, with annual international growth of 21 per cent in 2010, although 2011 growth is expected to be heavily dependent on consumer spending (IATA 2011). Data from the International Transport Forum (ITF) show some recovery for rail freight but it is still suffering from the economic crisis with unknown implications for the long term; exceptionally, India continues to increase its rail freight. Similarly, recovery of road freight is very slow at the national and international levels for many OECD and ITF countries.

For passenger travel China, India and Brazil recorded 7.1 per cent growth in 2010 relative to 2009. According to the International Air Transport Association, there were 2.4 billion domestic and international passengers in 2010, approximately 6.4 per cent more than ever before, with a similar trend observed in passenger...
kilometres travelled. Rail passenger travel continued to decline, providing space for possible substitution by freight. Data on passenger kilometres travelled in private cars suffers poor harmonization, yet it is clear that the economic crisis reduced overall travel. Moreover, possible saturation of passenger travel by car is observed in developed economies that exhibit non-significant increases in passenger kilometres, hovering at around one digit percentage growth per year.

Quality
While transport enables human interactions that contribute to development, the infrastructure for fast, motorized means of travel also creates displacement and barriers that can divide communities and reduce well-being. Roads and the enormous amount of parking to store the world’s 1 billion cars are the commonest barriers, but airports and seaports for container ships are also significant.

In societies with extremely high levels of mobility, inequities in the social distribution of related environmental pressures and benefits are of increasing concern (Adams 1999). Because most human settlements are located close to supplies of water and agricultural land, transport infrastructure displaces food production while also fragmenting landscapes that are then less able to support wildlife (Huijser et al. 2008). Transport also has secondary environmental impacts through expanded human access to land, as the infrastructure promotes economic activities such as mining, forestry or power generation in new locations. In addition, transport enables more extensive permanent human settlement, particularly suburban and urban growth.

Most energy for transport comes from fossil fuels, and the rise of the car has produced various specific environmental impacts, from urban health problems through land and water degradation to contributing to climate change. Many people are optimistic about the long-term prospects for shifting to cars powered by fuel cells and electric motors, but a near-term change will be difficult, and the car is noticeably more intensive in its environmental impacts than its competitor technologies, exhibiting the highest levels of energy consumption and greenhouse gas emissions (Chester and Horvath 2009). Private car ownership can also impact patterns of urbanization by permitting dispersed and low-density sprawl, which in many contexts reflects individual household dissatisfaction with urban environments, but collectively degrades environmental quality. Like the transport infrastructure that makes them possible, these new or expanded built areas impinge on natural landscapes and amplify the direct environmental impacts of transport.

There may have been a temporary decrease in transport activity in, for example, the United Kingdom and United States due to the economic recession (Millard-Ball and Schipper 2011; Metz 2010). However, these declines are likely to be outweighed by increases in private vehicle ownership in rapidly developing low- and middle-income nations. At present, the number of motor vehicles in the world is growing much faster than the number of people (World Bank 2012). While it is unlikely that the levels of hypermobility reached in the United States will ever be reached in many other nations, there is still massive potential for growth in the level of travel and shifts towards individual motorized vehicles, especially as incomes increase. In developing nations including China and India, the ownership and use of highly
polluting motorcycles is increasing faster than cars (Pucher et al. 2007). Even when more fuel-efficient vehicles are introduced, rising numbers may outweigh efficiency benefits.

However, with aggressive moves by governments and advocacy groups in the creation of green markets, two related phenomena could emerge. The first is an offset trade market in which companies can buy offsets, as futures and options, to counterbalance their inability to manage and decrease CO₂ production (Lequet and Bellasen 2008). The second is an attempt to develop carbon-neutral supply chains in which the amount of CO₂ produced is offset by a variety of mitigating actions that include partnerships with the local supply chains. From a policy perspective, these could deliver some development benefit by encouraging small local producers to partner with multinational companies, helping reach carbon neutrality. Similarly, new markets are developing around a lifestyle based on promoting health, the environment, social justice, personal justice and sustainable living. Such developments offer new policy opportunities for more sustainable development worldwide that incorporates green transport policies across all sectors.

Urbanization

Quantity

Urbanization exhibits complex interactions with food, discussed earlier, and energy. Urban areas, which house half the world’s population, utilize two-thirds of global energy and produce 70 per cent of global carbon emissions (IEA 2008). The amount of energy an urban area consumes is largely dependent on the built environment – whether residential and commercial buildings or transport infrastructure. Beijing and Shanghai’s rapid economic growth, for example, has been accompanied by a decrease in the proportion of emissions due to industrial activities since 1985. With the increase in personal vehicle ownership, however, emissions from transport have increased significantly, sevenfold for Beijing and eightfold for Shanghai between 1985 and 2006 (Dhakal 2009). This increase may, in part, have been offset by an energy-efficiency labelling programme implemented by the Chinese government, credited with avoiding 1.4 billion tonnes of CO₂ emissions for 2006–2010 (Zhan et al. 2011).

In general, urban populations in developing countries generate higher greenhouse gas emissions per person than surrounding rural populations, while the opposite is true for developed countries (Dhakal 2010). Energy consumption in urban areas, much like food consumption, can be far removed from where environmental impacts occur, with populations remaining oblivious of the greenhouse gas and water pollution impacts of their consumption (Scott et al. 2011).

Due to the links between them, it is difficult to reliably project rates of spatial expansion in urban areas without accurate projections of population growth and GDP. The challenge is magnified by recent research suggesting that the relationship between these three factors can vary significantly across regions. Assessing changing urban spatial spread using satellites shows urban areas to be growing at an average rate of 3–7 per cent per year, with China exhibiting the highest rates. The contribution of population and GDP growth to this expansion has been found to be 28 and 72 per cent respectively for North America and 23 and 30 per cent respectively for India. In the same study, African city growth showed no relationship to GDP, although there is a recognition that in many developing countries there is significant informal economic activity that is not captured by GDP statistics (Seto et al. 2010).

In terms of the spatial distribution of people in growing cities, the defining feature, perhaps most common in East Asia, is peripheral development (Seto et al. 2010). Quantifying this phenomenon using satellite imagery for 2000 shows a range of estimates of the total spatial spread of urban areas of 0.2–2.4 per cent of the terrestrial land surface, due partially to differing definitions of urban land cover (Potere and Schneider 2007). In developed countries such as the United States and Canada, about half the urban population lives in suburbs, while in the developing world squatter settlements or slums host more than one-third of urban populations (UN-Habitat 2003). The spatial distribution of cities demonstrates the complex interactions between urbanization and transport. For instance, when comparing per-person greenhouse gas emissions, Bangkok is dominated by transport emissions, while New York and London have significantly larger contributions from residential and commercial buildings (Croci et al. 2011). The ability to travel within a city is extremely important.
both in terms of the environmental impact and of economic productivity (Bertaud et al. 2011). In developing countries the majority of trips are taken by commuters but, as incomes increase, individuals are likely to make more personal trips. This preference often precipitates the acquisition of personal vehicles, as the locations of shopping or entertainment centres, schools or hospitals are widely spread and less easily connected by a public transport system (Bertaud et al. 2011). Finally, the type of fuel used is an important factor affecting the environmental impact of urban areas. Many trains already run on electricity, but should electric vehicle use increase, more electricity will be needed and – unless energy sources are priced according to their carbon intensity – an increase in electricity production using coal is likely, leading to significant increases in greenhouse gas emissions (Bertaud et al. 2011).

**Quality**

Cities have been seen as an opportunity for developing more sustainable resource management and reducing greenhouse gas emissions. While per-person emissions are generally lower in the cities of developed countries than in surrounding rural areas, the sources are much more diffuse and therefore difficult to manage with one overarching policy tool (Bertaud et al. 2011). Beyond mitigation activities, cities, particularly in developing countries, need to evolve climate adaptation measures (World Bank 2011d). Several cities across South America, Africa and Asia have shown significant leadership in developing innovative adaptation strategies (Heinrichs et al. 2011).

Developing cities are being encouraged to achieve zero waste, the principles of which include a reduction in waste incineration, the recycling of greater volumes of paper and plastics and the mining of precious metals and rare earth elements from existing landfills (Zaman and Lehmann 2011).

The question remains whether the Earth can support several billion additional people with a direct impact on land through subsistence farming, or additional urban billions with indirect impacts through consumer demand for fats and proteins from meats that are mostly produced on large corporate farms. The answer to this question will ultimately reveal how much land will be converted to livestock rearing, feedstock production and agriculture. Not evident in the short term is whether an accelerated or delayed demographic transition is more or less taxing on land systems. But if the living standards of the poorest are raised to more equitably match those of the developed world, then population growth should slow and the related environmental impact should begin to diminish. Demographic and health transitions will continue to be major predictors of environmental change in general and of land-use and land-cover change in particular. Fundamental to facilitating demographic and health transitions will be investments in maternal and child health and education.

**Globalization**

**Quantity**

Trade in food, fuels and minerals has increased dramatically over recent decades and shows few signs of slowing. International trade has grown rapidly since 1990, by 12 per cent per year, doubling in six years (Figure 1.7) (Peters et al. 2011). In addition, annual emissions from exports have grown at 4.3 per cent, often due to production moving from developed
Greater liberalization of trade can exert pressure on the environment in any of three ways:

- increasing economic activity and by extension natural resource extraction, a scale effect;
- changing the type of economic activity to either more or less polluting industries, affecting intensity; and
- changing the technology or intensity of production that can sometimes encourage more environmentally friendly production techniques (Kirkpatrick and Scrieciu 2008).

Regardless of the nature of the local change, wider trade allows the environmental impacts of production to be completely removed, or decoupled, from the site of consumption.

Such decoupling means that household consumption in developed countries can have significant environmental impacts elsewhere, particularly in developing nations. Tracing the impacts of consumption in Norway, Peters and Hertwich (2006) found that a household’s environmental impacts in foreign countries embodied 61 per cent of its indirect emissions of CO$_2$, 87 per cent of sulphur dioxide, and 34 per cent of nitrogen oxides, while imports only represented 22 per cent of household expenses (Wiedmann et al. 2007).

China is an instructive case for understanding trade. In the second half of the 20th century, it rapidly shifted its economy towards a processing base, resulting in a change from being a net exporter of primary resources to a net importer. Much of this processed merchandise is exported directly, with China’s environment absorbing the pollution (Ma et al. 2006). Between 2002 and 2007, for example, 8–12 per cent of China’s CO$_2$ emissions were attributable to exports to the United States (Xu et al. 2009).

Quality

Globalization is confounding the expected effect of the environmental Kuznets curve in countries with emerging economies. With affluence should come improvement in environmental conditions, but the link is proving difficult to confirm. In the case of China, nitrogen oxides and sulphur dioxide emissions have shown a complicated relationship with increasing income, suggesting that the reliance on coal-fired power may be negating improvements in other manufacturing technology (Brajer et al. 2011).

Some invoke a traditional economic dynamic at work – a regulatory race to the bottom, where deregulation is expected to attract economic activity and create a comparative advantage over competitors. This notion suggests that concern for the environment and increasing environmental regulation in the developed countries result in migration of the most polluting industries to less affluent nations, although explicit evidence of this is inconclusive (Kirkpatrick and Scrieciu 2008). A different explanation has also been offered – that the pattern is more akin to the rapidly industrializing countries being stuck at the bottom, since there were no regulations to begin with (Porter 1999). A related argument has also been made over the environmental effects of trade (Jorgenson 2007; Cole 2003).

Either way, the consequence is the same – the creation of centres of pollution in developing countries. This suggests that the environmental Kuznets curve, relevant to a national context, has been disguising the displacement of pollution across national borders, with consumption in the most affluent nations driving environmentally polluting production and consumption to less affluent ones. For example, Cole (2006, 2004, 2003) has shown that trade increases environmental damage in the least developed countries while decreasing many forms of pollution in developed ones. Perhaps the environmental Kuznets curve does not work when all borders have been crossed by pollution.

Energy consumption and greenhouse gas emissions seem to follow this displacement pattern. A low-income country with less stringent regulations will find that an increase in trade openness increases energy consumption as its comparative advantage in dirty production deepens, while a high-income country will see energy consumption fall in response to trade liberalization (Cole 2006).

So, will future goods produced for consumption inevitably also produce more pollution, despite regulations in developed countries? Carbon-intensive industries are leaving areas of stricter carbon regulation and moving to those that do not have such regulations (World Bank 2008). At the beginning of the 21st century, developed countries remained the largest greenhouse gas emitters in per-person terms. However, in the next few decades, the growth of emissions will come primarily from developing countries. So, despite 20 years of negotiations...
Box 1.3 Greenhouse gas emissions and international trade

Recently developed analytic methodologies allow the representation of carbon emissions embodied in goods and services that are internationally produced, consumed and traded (Peters and Hertwich 2006). Plotting these data over time illustrates changes in trade balances and the transfer of emissions (Caldeira and Davis 2011). The most recent emission and trade data reveal the effects of the global financial crisis that started in 2008 (Peters et al. 2012).

Figure 1.8 tracks economic activity and CO₂ emissions in developed and developing countries for 1990–2010. The tinted areas represent relative trade balances, with consumption lower than production in developing countries, but higher than production in developed countries. In developing countries, the total emissions embodied in the production and consumption of goods and services rose steeply, especially after 2002, with the trade balance increasing slowly as production and consumption diverged. In contrast, the emissions embodied in production and consumption in developed countries were more horizontal until about 2002, after which they rose steeply, peaking in 2008. Their negative trade balance increased over the decades. As represented by embodied carbon emissions, developed countries seem to be back to business as usual by 2010, while emissions in developing countries have passed them with hardly a pause. On a per-person basis a large disparity persists between CO₂ emissions from developed and developing countries, as shown on the right.

Although the global financial crisis could have presented an opportunity to establish the decoupling of economic development from carbon emissions, the return of high emissions growth in 2010 may mark the passing of the opportunity. The effects of environmentally sound and low-carbon economic stimulus packages are not yet evident, but the persistent implementation of low-carbon economic plans oriented towards resource-efficiency could show positive effects in future tracking of embodied emissions (Peters et al. 2012).

**DISCUSSION**

Drivers are interacting in unpredictable ways, resulting in some surprising consequences. This section, which links the drivers with a number of pressures on the environment, is intended to illustrate the complexity and provide some methods with which policy makers might be able to work to ameliorate the effects.

**Critical thresholds**

Critical thresholds are being approached or even crossed. Ecosystems and the biosphere are systems that may change in a
Figure 1.9 The great acceleration after the Second World War

Source: Adapted from Costanza et al. /2007/
direct and linear way as a result of human stresses, or that may have more complicated dynamics (Levin 1998). Although some can absorb a substantial amount of stress before they exhibit any response, change can take place abruptly and irrevocably when a threshold is exceeded, leaving little opportunity for human adaptation (Carpenter et al. 2011; Folke et al. 2004).

To understand the dynamics of a complex system, analysts seek out leverage points. The study of leverage points in complex systems suggests that indirect interventions can have great power and direct interventions can be used to enhance co-benefits, that both probable and possible outcomes should be addressed, and that difficult challenges can be broken down to manageable portions. The system must be monitored for both intended and unintended change (Meadows 1999).

The idea that the perturbation of a complex ecological system can trigger sudden feedbacks is not new: significant scientific research has explored thresholds and tipping points that the planetary system may face if humanity does not control carbon emissions. From the perspective of drivers, understanding feedbacks reveals that many of them interact in unpredictable ways. Generally, the rates of change in these drivers are not monitored or controlled, and so it is not possible to predict or even perceive the thresholds as they approach. Critically, the bulk of research has been on understanding the effects of drivers on ecosystems, not on the effects of changed ecosystems on the drivers – the feedback loop.

From Figure 1.9, it is evident that the rate of these changes and the anthropogenic drivers acting on them are accelerating. In fact, Costanza et al. (2007) argues that this “great acceleration” began after the Second World War, with the scale of population growth and economic consumption and production increasing at rates that are orders of magnitude greater than in previous eras. It is this scale and speed that makes redirecting humanity’s trajectory toward more sustainable development within the limits of planetary boundaries an extremely daunting challenge but one that we cannot afford to delay.

**Overexploitation of natural resources**

Considering that 14–16 per cent of animal protein consumed globally comes from the sea, overfishing of marine resources offers a useful example of overexploitation of natural resources. At the global level, overfishing has been widespread but far from universal, and in those parts of the world with the capacity to manage fisheries, there is evidence that overfishing can be stopped and that previously overfished stocks can recover (Worm et al. 2009). There remain, however, a number of cases where overfishing continues despite the efforts of the international community, emphasizing the need for capacity building for both policy formulation and effective management.

The greatest expansion in fishing fleets and harvesting occurred after the Second World War, as governments provided significant subsidies to encourage more investment in harvesting technologies, which massively increased yields. In many cases the increased yield proved to be unsustainable, and fishery declines were widespread by the 1970s (Pauly 2009). Extension of jurisdiction with the United Nations Convention on the Law of the Sea (UNCLOS) resulted in improved management practices in many coastal areas, but a second round of expansion of fishing capacity resulted in a second round of declines (FAO 2010). Overcapacity remains a serious problem in global fisheries despite an international agreement to address it, the 1999 International Plan of Action for the Management of Fishing Capacity (FAO 2010).

Part of the problem in sustainably managing fisheries is the difficulty of monitoring the state of fish populations, especially in areas outside the jurisdiction of national or international authorities where biological information and even basic catch data may be unavailable or unreliable. Moreover in many fisheries, data are not recorded on species taken as by-catch – unwanted fish caught inadvertently, often returned to the sea dead or dying – so their status and the impacts of fishing are unknown and unmanaged (Myers and Worm 2005). More generally, poor monitoring means that there is little knowledge about the dynamics of many fish populations, making it difficult to discern whether the observed populations are showing signs of natural variability or imminent collapse (Carpenter et al. 2011). Chapters 4 and 5 discuss the environmental impacts of these collapses in more detail.

**Driver combinations and feedbacks on human health**

Looking specifically at food production, human and ecosystem exposure to chemicals increased dramatically with the industrialization of agriculture (Wallinga 2009). There has been limited research on the human and environmental health impacts of long-term exposure to these chemicals, but it is known that the risks are much higher in developing countries where 99 per cent of current global deaths from pesticide exposure occur, both from occupational exposure and from casual exposure resulting from lax or absent health and safety controls (De Silva et al. 2006).

Nitrate pollution from both crop cultivation and livestock production is among the most destructive impacts of food production, with the scale of meat production having serious ramifications for local pollution levels. In the United States, for example, of the top 20 sources of industrial pollution, eight are slaughterhouses (Hamerschlag 2011; EPA 2009). In addition, the country’s Concentrated Animal Feeding Operations (CAFOs) produced 500 million tonnes of manure in 2007: three times the United States’ 2007 total amount of human waste (Hamerschlag 2011; EPA 2009). A further problem from centralized meat production facilities involves how bacteria convert excess nitrate in such waste into nitrous oxide, a potent greenhouse gas, or it can leach into waterways and groundwater (Wallinga 2009).

**Generating intense pressures**

Drivers of environmental change are growing, evolving and combining at such an accelerating pace, at such a large scale and with such widespread reach that they are exerting unprecedented pressure on the environment. Most forms of consumption and production use the environment as a source of raw materials
Part 1: State and Trends

The rising pace and scale of drivers of environmental change are related to the process of globalization, which has enhanced the rapidity and reach with which people, ideas, and technologies move. The explosive demand for mobile telephones and the resources with which they are made has concentrated impacts in producing countries. Since 1994, more than 10 billion mobile telephones have been produced, and as of mid-2010, there were an estimated 5 billion users worldwide (ITU 2010). This growth has led to an accelerating demand for tantalum, extracted from coltan ore, a key component of consumer electronics. Most coltan is mined in Australia, but approximately 8–9 per cent of the global coltan supply comes from the eastern Democratic Republic of the Congo (DRC) (Global Witness 2010). The environmental impacts are likely to be significant for a number of reasons: among other things, illegal mining operations are carried out with few environmental safeguards, often within the borders of national parks; land clearance and pollution from the mines contribute to erosion and the degradation of streams and water tables; and mining operations typically lead to an increase in poaching and the local bushmeat trade, threatening wildlife (Hayes 2002). In addition, since most mining operations in the eastern DRC are outside government control, lucrative revenues from the extraction and trade in coltan and other minerals have often been used to finance violence and other human rights violations.

Pearl River basin, China

In 2008, a quarter of the world’s electronic equipment was manufactured in China and more specifically in the Pearl River basin of southern China (Yunjie et al. 2010). China’s GDP growth was 9 per cent in 2009, while the Guangdong region of the basin exhibited growth levels 2–3 percentage points above national averages (World Bank 2011e). In the past decade, the region constituted one-fifth of China’s area, contained a third of its population and produced 40 per cent of national GDP (Barak 2009). The environmental impact of this economic growth has been poorly monitored, with estimates of tens of thousands of tonnes of heavy metals, nitrates and fuel being dumped untreated into the ocean each year (AsiaNews 2005). Without better coordination of water treatment, farmers have suffered severe crop losses from using the heavily polluted water for irrigation. The information technology industry has been blamed for much of the heavy metal dumped in the region, with the Pearl River basin named the most polluted river system in the country in 2004 and 2005 (Xu 2010).

Agbogbloshie, Ghana

A huge dumping site for electronic waste is located in the suburbs of Ghana’s capital city, Accra. The Agbogbloshie slum, populated by domestic migrants from the northern reaches of Ghana, has witnessed an explosion of discarded computers, screens, hard drives and mobile telephones over the last ten years. What was once a productive wetland has become a hazardous chemical zone, home to approximately 40,000 people (Safo 2011). The local economy depends on recycling this waste, with the majority of the workforce young boys aged 11–18 earning roughly US$8 per day. The sources of much of this waste appear to be Parties to the Basel Convention, although a significant proportion also seems to come from the United States, which along with only Afghanistan and Haiti has not signed this treaty.

To date there has been little study of the effects of this trade, but toxins have been discovered in soil and food samples due to chemicals accumulating in the food chain (Dogbevi 2011; Monbiot 2011), and the local toll could be considerable. Exposure to chemical fumes can inhibit development of the reproductive and nervous systems, particularly in children with high lead levels, while mercury, cadmium and lead may all retard the cognitive and immunological development of the young workforce. The story of Abogbloshie gives an initial snapshot of the very real, localized environmental and health impacts of rapidly emerging global phenomena such as the shift to information technology – replete with its disposable approach to obsolete equipment. It is a cautionary tale of how technological innovation can have both an extraordinary effect on the global economy and society itself while, nearly invisibly, wreaking havoc on the more vulnerable, especially where the necessary institutional oversight is absent. It is this disconnection between the global and local that the current economic paradigm has created, and researchers must work backwards through the supply chain if the present situation is to be understood.

and as a sink for wastes. The impacts can be highly concentrated in some parts of the world – such as nuclear waste storage facilities and residual accumulation of toxic compounds at e-waste recycling sites (Box 1.4) – or systemically spread over the entire globe – such as PCBs delivered along the food chain from equator to poles – and they can quickly create new and potentially dangerous situations. In many instances their impacts can be so deep, rapid and unpredictable that they risk exceeding environmental thresholds and societal capacity to monitor them or respond adequately.

The combination and scale of some drivers can create dynamic patterns that, in turn, generate complex systemic interactions. One example is the rise in greenhouse gas emissions, the scale of which has defied global efforts to stimulate the necessary action to stem emissions. In addition to rising global temperatures and
sea levels, scientists predict that the pace and scale of climate change could eventually exceed certain ecological limits or thresholds, leading to surprising and dangerous consequences such as the alteration of the world ocean’s chemical composition with increasing proportions of acidifying carbon, the global loss of coral reef ecosystems, or the collapse of the West Antarctic ice sheet (Fabry et al. 2008; Lenton et al. 2008).

One driver can trigger a series of drivers and pressures that act in a domino fashion. For example, concerns about climate change impacts, including crop vulnerability and food insecurity, gave rise to policies that included mandates to increase biofuel production, such as legislation introduced in 2003 in the EU and in 2008 in the United States. The resulting demand generated a cascading set of pressures including crop diversion to biofuels. This diversion of cropland then contributed to higher food prices in 2008 and 2010, increasing worries about food insecurity.

Inertia and path dependencies
As global ecological and institutional systems are extremely complex and slow to change, decisions made today have long-term and far-reaching impacts. Without addressing the drivers behind the current trajectory, it will be difficult to move to an environmentally sustainable suite of choices and outcomes. At the same time the need for urgency must be recognized. Finally, due to the inertia in the system and an unwillingness to address these drivers in the past, future generations are committed to a range of impacts that could have been avoided. The most daunting of these problems is climate change, where a coalescing of several drivers has made reducing carbon emissions a very complicated task. For instance, current fossil-fuel-dependent energy and transport infrastructures are estimated to have committed the planet to emitting 496 billion tonnes of CO₂ from now until 2060 (Davis et al. 2010). These calculations do not include currently uncommitted transport network extensions, additional fossil-fuel-based power plants or the complex economy of refuelling stations or factories dependent on combustion energy, all of which are entirely reliant on the current model of energy generation and transport. The issue is not solely about the existing physical infrastructure that would be costly to replace, but the millions of jobs, processing facilities and entire sub-industries that have developed as a result of the status quo.

The case for investments in transport infrastructure has been made before. However, the institutionalization of global food production offers similar barriers to change. United States farm policy provides an illustrative example of this phenomenon, although it is by no means the only country where it occurs. Currently, 74 per cent of agricultural land in the United States is dedicated to eight commodity crops: maize, wheat, cotton, soybeans, rice, barley, oats and sorghum, supported by 70–80 per cent of government agricultural subsidies (Jackson et al. 2009), while the farming industry has consolidated to become an industrialized food production system. Unfortunately, the emphasis on producing these eight crop commodities has resulted in a food system where healthier food options, such as vegetables and fruits, increased in price by more than 100 per cent between 1985 and 2000, while the price of unhealthy fats and oils derived from these basic foodstuffs rose by only 35 per cent (Jackson et al. 2009). With many of the country’s consumers making daily consumption decisions based on cost, decades of investment in this vertically integrated and politically powerful industry make fundamental changes in the health outcomes of the food system extremely challenging.

However, not all health effects are diet related, but can be linked to such atmospheric pollution as nitrate formation and chemical pollution resulting from enhanced pesticide use, amongst other sources. For instance, in the United States, a high proportion of maize and soybean crops are genetically modified to resist the effects of the herbicide glyphosate, applied in vast quantities to eradicate weeds. Within the supply chain, maize and soy make up 83–91 per cent of livestock feed grains. Ongoing research raises the question of the endocrine-disrupting potential of glyphosate (Daniel and Margareta 2009; Gasnier et al. 2009).

The residence time of glyphosate in the environment is difficult to model, as it is dependent on a number of biophysical factors (Vereecken 2005) and monitoring capability is only recently catching up with its widespread use. However, in communities located near agricultural fields, evidence of glyphosate and its most common degradate aminomethylphosphonic acid (AMPA) can be found in the atmosphere, rain and local water bodies (Chang et al. 2011).

Organic, pesticide-free maize stalks, in Santa Cruz, California.
© David Gomez/iStock
Part 1: State and Trends

Box 1.5 Conclusions of driver-centred thinking

A display at the UN Conference on Environment and Development, in June 1992, registered increases in world population, and decreases in the amount of productive land. © Michos Tzovoras/UN Photo

Focus on causes, rather than effects. It has not conventionally been popular to think about drivers – the causes – as a focus for environmental policy. Rather, policy responses typically concentrate on reducing pressures – the effects. There are, however, two compelling reasons to take a fresh look at drivers as an appropriate focus for policy. Firstly, unprecedented rates of change are being experienced and even where coping with one set of pressures is successful, others are around the corner. Secondly the global community has embraced a set of international environmental goals that are designed to tackle the drivers of environmental change more directly than previous efforts. The major legal agreements of the 1992 United Nations Conference on Environment and Development – on climate change, biodiversity and land degradation – recognize that long-term progress requires an ability to manage the evolution of underlying drivers. A relevant set of insights is available, providing policy makers with a menu of leverage points from which to choose driver-focused options for managing environmental problems.

The relationship between human well-being and environmental sustainability is synergistic. MDG 1 to end poverty and hunger, MDG 2 to achieve universal education, and MDGs 3–5 on gender equality and child and maternal health are all synergistic with MDG 7 on environmental sustainability. For example, approximately three-quarters of all human land use is for meat and dairy production. Red meat is several times more demanding of land and water than poultry or vegetarian foods, and is also linked to cancer and heart disease. Policies encouraging lower consumption of red meat would contribute to the MDGs related to human health and environmental sustainability. Similarly, universal education and enhanced gender equality are mutually synergistic. Improvement in both of these areas increases demand for maternal and child health services, reducing unwanted births which in turn reduces population impacts on the environment.

Indirect interventions can go a long way. Sometimes policy interventions targeted directly at drivers are not practical. Policies that set specific targets for population growth, for example, are seldom politically viable and have been called into question on moral and humanitarian grounds. However, there are often policy options that can reduce a driver indirectly in ways that are more acceptable. Fertility rates, for example, have been shown to be very responsive to levels of women’s education and to access to family planning programmes, consistent with two key MDGs as well as imperatives of ethical human justice.

Direct interventions can be targeted at many different entry points. Even where indirect interventions are not practical, the fully disaggregated representation of key drivers opens up opportunities for effective intervention. For example, economic growth is generally considered a positive outcome across the world, so policies aimed at reducing growth, whether directly or indirectly, are not well received. However, that does not mean that driver-oriented policies are impossible. In China, for example, recognition of the problems associated with growth has led to ambitious targets aimed at energy efficiency.

Unintended consequences matter. Policies intended to bring about improvement in one environmental domain may result in unintended consequences in another. Negative consequences may take the form of cross-systemic links, the effects on food security of biofuel promotion, for example, or of path dependence such as policies that favour one type of infrastructure and make a switch to more favourable infrastructures more difficult. Policy makers seeking to manage drivers need to find ways of designing policies to minimize such negative consequences.

Even intractable drivers can be reframed. A core tenet of conflict resolution is to break down seemingly intractable elements into separate parts, which can then be subject to effective bargaining. Recent discussions around alternative measures of well-being have elements in common with this. Whereas GDP per person is treated as a proxy for well-being and as a universal policy objective, recent explorations have promoted alternative formulations where GDP is analytically separated from well-being. This opens up investigations into a broader range of proxies for well-being that could be pursued.

Surveillance and monitoring get results. Even where policy responses are not immediately possible, awareness of the importance of drivers justifies increased surveillance and monitoring. Many of the most important drivers are currently not subject to systematic monitoring, their impacts even less so. The evidence, then, is compelling for the need to enhance the collection and monitoring of anthropogenic drivers and their links with the environment.
World Bank (2011a). Data Indicators: GDP growth (annual %). World Bank, Washington, DC