Box 3.7. Ecological Footprints

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The concept of *ecological footprints* (Wackernagel and Rees 1996) is useful for estimating, in a semi-quantitative way, the dependence of human populations on the natural world around them. The idea of showing human dependence on nature by quantifying ecosystem areas is not new. In 1967 Borgström introduced the concept of *ghost acreage* to describe a population's need for agricultural products. Since then several similar approaches have been put forward. Odum (1975, 1989) coined the term *shadow area*, using solar energy as the measuring unit and Jansson and Zucchetto (1978), estimating energy flows, showed that the offshore fisheries of the island of Gotland in the Baltic Sea require extensive marine areas.

The ecological footprint approach can be applied in different ways. In some cases the notion of a global steady state is used; in others the world is regarded as dynamic and complex (Folke et al. 1997; Jansson et al. 1999). A dynamic and complex view acknowledges that the ecological footprint approach does not provide information on the resilience of the system, or how close to thresholds the support capacity might be. Furthermore, the dynamic view to ecological footprints does not reduce the work of nature to a single dimension to be used as an operational indicator of ecological carrying capacity, sustainability or as a basis for discussions on equity.

The appropriation of ecosystem goods by a human population, in terms of food and timber, can be quantified by the areas of land and water (sea areas included for marine-derived food) required to produce the amount of these goods consumed by a defined human population. The amount of land or sea needed to absorb wastes is more difficult to estimate. In general, the approach is to first identify potential sink ecosystems within a defined area, followed by an estimation of the amount of land or sea needed to sequester the emission of the substance or compound of interest. Thus, estimating the area needed to sequester the CO_2 emitted annually from human activities often entails estimating forested land, as many forest types are known to provide a significant sink for CO_2 (Dixon et al. 1994). Furthermore, the amount of agricultural land needed to absorb phosphorus (as sewage sludge) excreted by a human population can be estimated, as well as the amount of wetlands needed to retain and denitrify the nitrogen compounds emitted directly by humans. These estimates are conservative. They do not account, for example, for P and N emitted by food processing, household waste, car emissions, etc., nor do they account for the amount of land and inland waters needed to absorb and process the aerosols and dissolved reactive gases emitted by cities and eventually rained out of the atmosphere.

Freshwater is essential for both humans and ecosystems. However, the concomitant use of freshwater by appropriated ecosystems such as forests, wetlands and lakes is almost always neglected. As shown in Fig. 3.58, this water usage is substantial and dwarfs the amount of water that is consumed directly for personal and industrial use, in this case by the average Baltic region dweller. These indirect water footprints show that the trade off between alternative uses of freshwater needs to be explicitly addressed in both renewable freshwater management and assessment, as well as in ecosystem management.

In only a few years the majority of the world's population will live in cities. In response there is a growing interest in investigating the relationship between nature and urbanisation. The ecological footprint approach has an important role to play in this context. Urban areas require a wide range of ecosystem goods and services for their existence – food, water, raw materials for industry and the capacity to absorb and process the wastes that are generated by urban areas. These services tend to be out of sight and mind to most urban dwellers. They are also usually neglected in economic analyses of the benefits and costs of urbanisation. Yet these ecosystem services are a fundamental underpinning of the social and economic development of cities.

Using the ecological footprint approach based on the notion of a dynamic and complex world, Folke et al. (1997) estimated the ecological footprint of the urban areas in the Baltic Sea drainage basin (Fig. 3.59). In the Baltic region the average urban resident requires between 60 000 and 115 000 m^2 of land for appropriation of ecosystem goods and services. When the demands of all 29 major cities in the basin were aggregated, an area corresponding to 75 to 150% of the entire Baltic Sea drainage basin is required, even though the urban areas themselves occupy only 0.1% of the area of the basin. Extrapolation of the methodology to the global scale leads to even more interesting results. For ex-

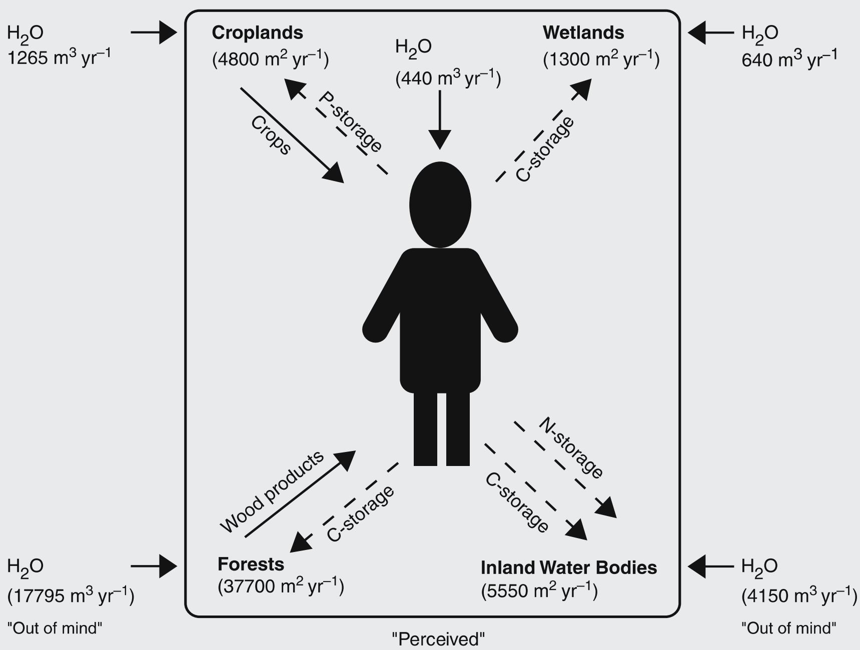

Fig. 3.58.
Goods and services appropriated by a Baltic Sea region dweller: estimated ecosystem areas of forest, croplands, wetlands and inland water bodies annually appropriated by an average person living in the Baltic Sea drainage basin (adapted from Jansson et al. 1999). Services shown include timber and terrestrial food production and the absorption and processing of carbon dioxide (CO_2), phosphorus (P) and nitrogen (N). Also included are the freshwater flows required to generate these services

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ample, the world's 744 largest cities contain 20% of the human population and are responsible for 32% of the global emissions of CO_2 from fossil fuel combustion. The area of forest required to absorb these emissions, even taking into account that a significant fraction would be absorbed by the oceans, is, at a minimum, equal to the entire current global C sink capacity of forests and at a maximum would be three times this area.

The ecological footprint approach does not imply that all of the area required to provide ecosystem goods and services for a city lies in a contiguous area surrounding the city itself. Through world trade, urban areas now appropriate significant amounts of goods and services from far distant places around the Earth. Likewise, through atmospheric and hydrological transport, the effluents from cities move far away from their sources before they are absorbed and reprocessed. The fact that many of these effluents are building up in the global environment is evidence that the overall absorptive capacity of the Earth System is already being exceeded. In many ways urbanisation is a global change phenomenon.

The ecological footprint approach provides a powerful tool for illuminating the dependence of city dwellers on vast ecosystem areas. However, being able to provide only static snapshots, it does not have the capability to answer questions on whether present levels of resource use are sustainable or not (Deutsch et al. 2000).

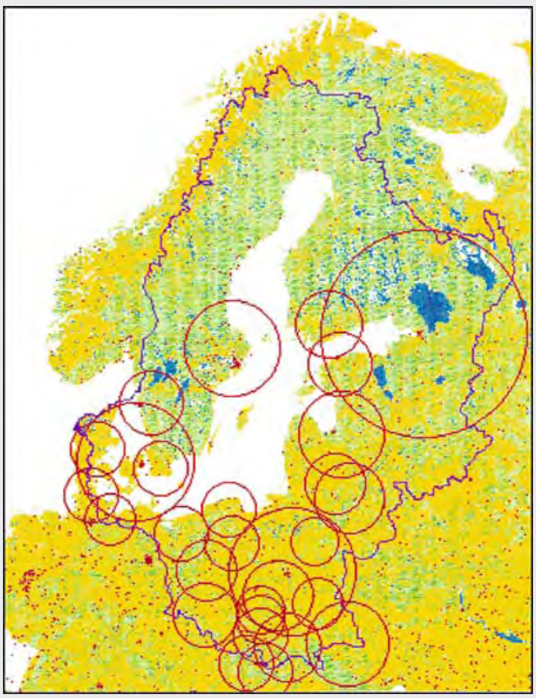

Fig. 3.59. Ecological footprints for Baltic region city dwellers: the location of the 29 largest cities in the Baltic Sea drainage basin and their hidden demand for ecosystem support (Folke et al. 1997). The area of hidden demand is illustrated by the *circles* around each city. The *circles* represent the aggregated average footprints needed to support timber and terrestrial and marine food consumption, carbon sequestration from energy production and phosphorus and nitrogen retention. The figure does not imply that the cities appropriate the actual area within the circles, only that they demand this area. Due to trade appropriation may take place elsewhere on Earth

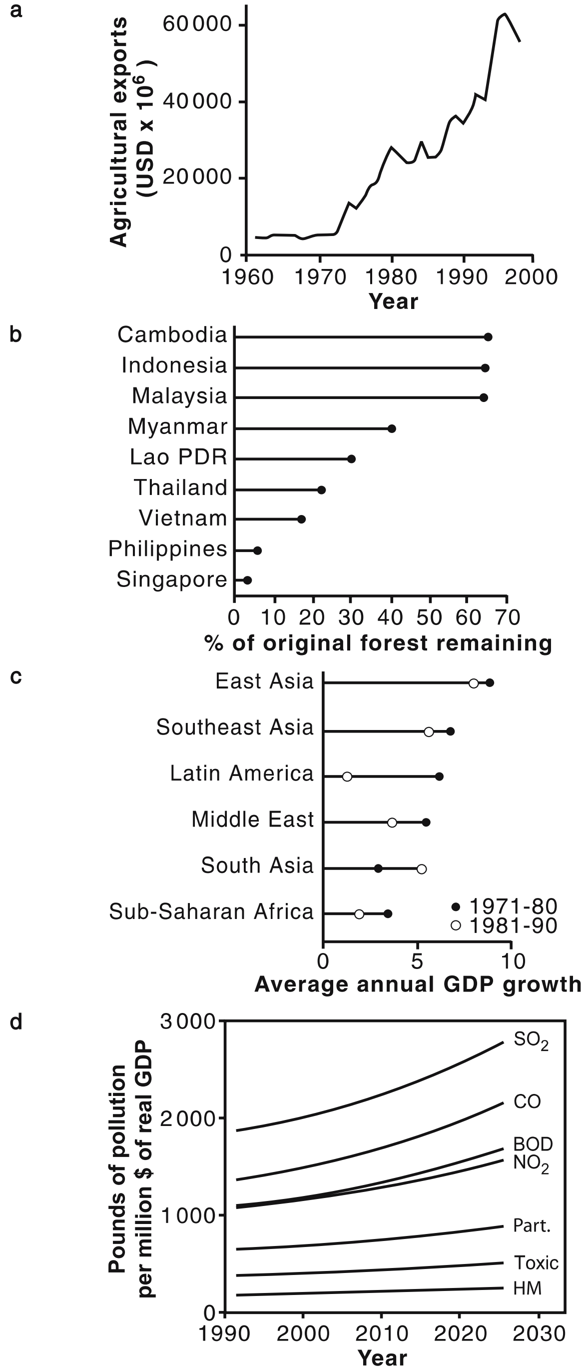

Fig. 3.60. Globalisation and environmental trends in Southeast Asia: **a** value of agricultural exports from ASEAN countries 1960–1998 (FAOSTAT 2002); **b** 1996 forest cover as a percentage of original forest in ASEAN countries (WRI 1999); **c** average annual GDP growth rate of various developing regions of the world (Stallings 1995); and **d** predicted pollution intensity of Thai GDP for 1992–2025 by pollutant (*Part.:* particulate; *HM:* heavy metals)(Angel and Rock 2000)

The environmental consequences of this development include high rates of deforestation (Fig. 3.60b) and accelerating regional air and water pollution problems. In Thailand, for instance, the concentrations of many pol-

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