

Chapter 5

Integrated Modeling of Global Environmental Change (IMAGE)

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ABSTRACT

Continued population growth, rising per capita income, industrialization and ever-increasing flows of materials, have created growing concern over how to ensure a more sustainable form of global human development. It is widely accepted that human development in currently less developed countries, following a similar path of many industrialized countries in coming decades, will lead to an unsustainable future. In particular, problems associated with climate change, loss of biodiversity, water scarcity, and the accelerated nitrogen cycle will be encountered at global, continental, and regional scales. Solving them will demand a comprehensive understanding of the Earth system. Integrated assessment models such as the Integrated Model to Assess the Global Environment (IMAGE) is a helpful tool for investigating these changes, their causes, and interlinkages in a comprehensive framework. This includes the major feedback mechanisms in the biophysical system. This chapter describes briefly the history of IMAGE, data and sub-models, and how they are linked together. It is adapted from Kram & Stehfest (2006). IMAGE starts from basic driving forces like demographics and economic development, energy consumption and production, and agricultural demand, trade, and production. Important elements in the bio-physical modeling are addressed, such as land cover and land use processes, the global current and historical carbon cycle, the global nitrogen cycle, management of nutrients in agricultural systems, and climate variability including interaction with land use. A short discussion on uncertainty and sensitivity is presented, and finally, an overview of major applications is given.

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1. INTRODUCTION

The current version of the Integrated Model to Assess the Global Environment (IMAGE 2.4), described in this chapter, represents the latest incarnation of a development that goes back as far as the late 1980s. Then a team at the National Institute for Public Health and the Environment (RIVM) in Bilthoven, the Netherlands, embarked on developing a global model to explore relevant aspects of climate change, emerging in those years as an important case for internationally concerted policy deliberations. The first version (1.0), formerly known as the Integrated Model to Assess the Greenhouse Effect (IMAGE), was a global, single-region model describing global trends in driving forces and the ensuing consequences for climatic change and impacts on key sectors, through a coupled set of modules representing the main processes involved (Rotmans, 1990). At the time, IMAGE 1.0 was among the first pioneering examples of Integrated Assessment Models addressing climate change.

Since then, IMAGE has evolved through a series of new versions, each introducing major revisions, enhancements and extensions up to the current version (2.4) briefly described here. This version marks an important milestone on the development path towards a next generation model, referred to as IMAGE 3, aimed at capturing – to a larger extent – the different aspects and domains of sustainability, with emphasis on the ecological domain but also related to the economic and social domains.

Specific features of the IMAGE model include comprehensive coverage of direct and indirect pressures on human and natural systems, closely related to human activities in industry, housing, transport, agriculture and forestry. The socio-economic activities and drivers of change are elaborated at the 24 region level (Figure 1), while the climate, land-cover and land-use change-related processes are represented in a geographically explicit manner on the 0.5 by 0.5 degree grid

scale. It is this latter characteristic, relatively rare in integrated assessment models, that makes IMAGE particularly suited to exploring interactions between human and natural systems.

Key elements of sustainable development include provision of affordable energy while keeping air pollution and climate change under control; management of water systems in support of agriculture, industry and human settlements; increasing agricultural production while protecting soil, groundwater and surface water quality, and slowing down and eventually halting further loss of biodiversity. More generally, these issues can be described as the challenge to strike the balance between the increased use of natural systems for human development and the goods and services provided to humans by natural ecosystems, which are put at risk by human activities (Millennium Ecosystem Assessment, 2005a). An integrated assessment model like IMAGE 2.4 is a helpful tool for investigating these interactions in a comprehensive framework and understanding the major feedback mechanisms within the biophysical systems.

As stated earlier, the current version of IMAGE is the result of many years of development at the National Institute for Public Health and the Environment (RIVM), and –following a recent re-organization – the now separate Netherlands Environmental Assessment Agency (PBL). The development stages can be followed in a series of three books (Rotmans, 1990; Alcamo, 1994; Alcamo *et al.*, 1998). Substantive further development work was undertaken between 1998 and 2001, resulting in the version 2.2 model used to elaborate the IPCC-SRES scenarios (Nakicenovic *et al.*, 2000). The documentation on version 2.2 covering the implementation of the SRES scenarios is included on two CD-ROMs (IMAGE-team, 2001a; IMAGE-team, 2001b).

This chapter summarizes version 2.4 of the IMAGE model and is largely based on Kram & Stehfest (2006). After highlighting some key features of version 2.3 in the framework of a

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