Articulating SRES-scenarios for use in integrated modelling of land use, hydrology and nitrogen budgets of the Scheldt catchment

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1. Introduction

Scenarios have become a well-established tool in model applications for a wide range of objectives. Scenarios should be seen as sets of contrasting but internally consistent, plausible descriptions of how the world would look somewhere in the distant or near future. A scenario can be defined as a coherent, internally consistent and plausible description of a possible future state of the world (Parry, 2000). Scenario descriptions are often qualitative and broad-brush 'narratives'. Scenarios are contrasting but broad, over-our-head trajectories of world development and should be distinguished from smaller-scale management options that are within grasp of the manager or policy maker and can be implemented comparatively easily. Scenarios can be used as input for models, but also for rational, deductive thought exercises without interference of formal models (e.g. Turner, 2005). Scenarios are often used to probe into an uncertain future, as exemplified by national economic planning exercises (e.g. for The Netherlands: CPB, 1992, Luttik, 2002; Van de Hamsvoort, 2002; Lajour 2003; or the Foresight exercise in the UK: Office of Science & Technology, 1999), the IPCC assessment of the possible consequent avenues of the interactive effects of climate and world economy change (Berkhout and Hertin, 2000; Lorenzoni et al., 2000; Carter et al., 2001; Arnell et al., 2004), and the Millennium Ecosystem Assessment (2005).

From a modellers perspective, scenarios just form a sensible array of input conditions that make the model produce its output. The formulation of this sensible array is dictated by the demands and needs of the modellers client, the study objectives and extent, the time horizon, and the broader institutional and disciplinary setting of the work. Together, models and scenarios allow answers to 'what-if' questions within a broad but plausible band width by spanning the width of all possible outcomes. Greeuw et al (2001) offer a useful review and analysis of different sets of scenarios that have been developed since the early applications in the industry.

Scenarios may be designed to cover various societal dimensions. An earlier set of the Dutch Economic Planning Office, the three CPB scenarios (CPB, 1992), was specific with respect to the international geopolitical setting, the state of technology and knowledge; socio-cultural values adhered to in society, demographic predictions, and economic development . The newer CPB-scenarios are largely conform those of SRES and focus on demography, labour, trade, capital markets and economic growth and are implemented in an equilibrium model of the world's economy (Lajour, 2003).

The application of scenarios has taken flight around the turn of the millenium, mainly because the IPPC (Carter et al, 2001; IPCC, 2007) and the Millenium Ecosystem Assessment (MEA, 2005), two worldwide and highly recognized exercises where scientists and policymakers have joined forces to make sensible future outlooks, made extensive use of a set of four rather similar scenarios. Particularly the four IPCC- SRES scenarios have been an inspiring and successful attempt to describe strongly contrasting potential directions of world development, and have attracted some convergence among scenario users. These scenarios depict possible future trajectories as spanned by two dimensions of global societal change, the first contrasting globalisation versus regional differentiation, and the second contrasting a focus on economic growth and expansion versus one of sustainable resource use. A summary of these four worldviews depicted by the SRES scenarios as well as those of the Millennium Ecosystem Assessment is given in Table 6.1. Quite notably, different users have felt the need to attach qualifying labels to similar sets of four scenarios, ranging from charismatic animal names (Sea Eagle, Beaver, Dolphin, Lynx; Luttik, 2002) to imaginative sentences ("pull up the drawbridge!" for a scenario similar to A2, and "we got the whole world in our hands" for B1, see Langmead et al., 2009).

This report intends to briefly justify the use of the SRES scenarios as a set of common, well-developed and frequently used scenarios for a specific modelling exercise. This modelling exercise involves the development of a coupled GIS-raster-based hydrological upland catchment model for the Scheldt with a more aggregate dynamic model of land use, throughput in the river and estuary as well as nutrient load of the coastal stretch of the receiving North Sea. The former is developed using PC-Raster, the latter in EXTEND, all within the framework of a European cooperative research project, SPICOSA. The report concludes with a specific articulation and down-scaling of the 4 SRES scenarios in terms of demography, land use economics, governance style and environmental regulation. Implicitly, this report is also a plea for a convergence towards SRES-like scenario sets in larger scale future outlook modelling efforts.

2. The SRES scenarios have become popular

SRES scenarios can be encountered in a growing range of applications, both as highly specific inputs for models of variable complexity and typology as well as broad-brush narrative starting points for qualitative sketches. An example of the latter is given by Turner (2005) and Nunneri et al. (2005). Examples of the former can be found in Schotten et al. (2001), Döll and Vassolo (2004), Verburg et al. (2006), Westhoek et al. (2006), McFadden et al. (2007), Eppink et al. (2008) Verburg et al. (2008) and Langmead et al. (2009). All the latter involve some sort of region-specific and issue-specific downscaling of the broader SRES scenarios to provide tailored and articulated band widths of model inputs. These efforts also lead to some of the necessary refinements suggested by Arnell et al. (2004). Notably elaborate modelling tools that incorporate the SRES scenarios are DIVA (a global coastal database and dynamic model for climate change vulnerability assessment; see e.g. McFadden et al., 2007), the Land Use Scanner (a dynamic GIS combining land use pricing and an economic equilibrium model for The Netherlands; see Schotten et al., 2001 or Eppink et al. 2008) and EU-RURALIS (logistic land use modelling for Europe coupled with an economic equilibrium model, see Verburg et al., 2008). The four SRES scenarios do not necessarily lead to divergent outcomes and the overall range is often spanned by two scenarios, although not always the same two, depending on the issue of interest (e.g. Vermaat et al., 2005; Verburg et al., 2006; Eppink et al., 2008; Figure 7.1).

Regionalised climate change projections have been equated, with some caution, to the SRES scenarios (for the Netherlands: Van den Hurk et al., 2006; Table 6.2). Thus it is possible to associate regionalised climate change patterns of temperature and precipitation with socio-economic scenario trajectories. Van den Hurk et al. (2006) highlight that they have not derived their climate change scenarios from those of IPCC-SRES. Thus the difference in circulation strength that discriminates two of these four KNMI (Royal Dutch Meteorological Institute) scenarios cannot be matched to an SRES scenario (Table 6.1). Still, some of the consequences of socio-economic development trajectories that will work through to measurable changes in aspects of climate, such as those for land use, will be traceable and hence can be deduced. We therefore presume that the cautious matching between SRES and KNMI scenarios, as made by Van den Hurk et al. (2006) for the region encompassing the Netherlands, is sufficiently robust to apply.

3. Down-scaled articulation for the Scheldt river basin

The down-scaled articulation of scenarios may detail aspects of the distribution of wealth, the intensity of agriculture, types and distribution of recreation, the planning and regulation of urban sprawl, and adopted life styles by the population at large including health and demographic aspects as well as governance styles. Here our focus is on agricultural land use and other sources of the plant nutrient nitrogen (N) as it moves through the catchment, river and estuary to the sea. We therefore limit ourselves to societal aspects that may affect the intensity of land use and N cycling. We base ourselves on earlier articulations, notably those of Van de Hamsvoort (2002), Luttik (2002), Vonk (2002), Lajour (2003), Westhoek et al. (2006) and Verburg et al. (2006, 2008) for agriculture in the neighbouring Netherlands. All is brought together in Table 6.3. Since the catchment of the Scheldt is shared by different nations and cultures, it is questionable whether some aspects of the articulation are homogeneous across the whole catchment. This is the case for governance styles and spatial planning. Since most of the Scheldt catchment is in Belgium, we have taken this country to lead our deliberations and have assumed homogeneity across the catchment. Clearly, the contrast between A and B scenarios, as depicted in the KNMI meteorological scenarios, is not sufficient to grasp differences in policy towards agriculture, spatial planning and water management. These should be implemented otherwise in modelling efforts, e.g. by bundling management options in a sensible and consistent fashion.

4. Conclusion

Clearly, it has been possible to develop an articulate down-scaling of the SRES scenarios to be specific for the Scheldt catchment. Notable differences appear on the trade-off between world market versus local markets, between governance styles, and between historically EC-subsidised high-tech production agriculture versus modern resource prudent and ecologically informed agriculture. These scenario specifications should lead to highly contrasting outcomes once implemented in a modelling tool.

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6. Tables

Table 6.1 A verbal characterisation of four socio-economic SRES scenarios and four MEA scenarios. SRES scenarios from Lorenzoni et al (2000), those for the Millennium Ecosystem Assessment from MEA (2005).

	Narrative
SRES	
A1 – World Markets	The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system.
A2 – Provincial Enterprise	The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.
B1 – Global Sustainability	The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
B2 – local stewardship	The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.
MEA	
Global Orchestration	This scenario depicts a globally connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems but that also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education. Economic growth in this scenario is the highest of the four scenarios, while it is assumed to have the lowest population in 2050.
TechnoGarden	This scenario depicts a globally connected world relying strongly on environmentally sound technology, using highly managed, often engineered, ecosystems to deliver ecosystem services, and taking a proactive approach to the management of ecosystems in an effort to avoid problems. Economic growth is relatively high and accelerates, while population in 2050 is in the midrange of the scenarios.

Order from Strength	This scenario represents a regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, paying little attention to public goods, and taking a reactive approach to ecosystem problems. Economic growth rates are the lowest of the scenarios (particularly low in developing countries) and decrease with time, while population growth is the highest.
Adapting Mosaic	In this scenario, regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems. Economic growth rates are somewhat low initially but increase with time, and population in 2050 is nearly as high as in Order from Strength.

Table 6.2 Correspondence of SRES socio-economic scenarios and KNMI climate scenarios for the Netherlands. Adopted from Van den Hurk et al. (2006).

SRES scenario	Projected temperature rise in 2050 compared to 1990	Corresponding KNMI climate scenario*
A1	1.1-1.8	W, W+
A2	1.2-2.0	W, W+
B1	0.8-1.4	G, G+
B2	1.0-1.8	G, G+

* KNMI scenarios: W=warmer, that is a stronger increase in temperature by 2050 (+2 °C), G = moderately increased temperature (+1 °C), the affix '+' suggests a much stronger air circulation involving warmer, wetter winters and warmer, dryer summers.

Table 6.3 Articulation of SRES scenarios for land use in the Scheldt basin. Adopted from Verburg et al (2008), Vermaat et al (2005) and Westhoek et al (2006).

	A1 (World markets; global economy)	**A2 (Provincial enterprise; continental markets)**	**B1 (Global sustainability; global cooperation)**	**B2 (Local stewardship; regional communities)**
World economic influences on local economy	Rapid global economic growth; export subsidies, import tariffs, farm payments and intervention prices are phased out in the EC towards 2030	Slower global economic growth, regionally variable development; export subsidies kept but reduced, import tariffs, farm payments and intervention prices kept	Stable global economic growth; export subsidies, import tariffs, and intervention prices are phased out; farm payments decline to 50% in 2030	Slow and variable global economic growth, EC does comparartively well; export subsidies are phased out; import tariffs are kept; agri-environmental farm payments and intervention prices increase
Global and regional demography	World population increases to a peak in 2050, to decline afterwards. Total population stable in NW Europe, age distribution skews to longer life expectancies	World population continues to increase. Age distribution in NW Europe as in A1, but limited immigration from the South.	As A1	World population continues to increase, though at first slower than in A2. Otherwise as A2
Policy and governance styles	Rapid introduction of new, clean and efficient technologies; otherwise small burocracies and liberal legislation	Cultural divergence	Structural EC-wide environmental regulation implemented; improved eequity and social cohesion, clean technologies and zero spillage farming; pro-active GHG policy implementation	Cultural divergence; limited modernisation
Agricultural land requirements and intensity	Land requirements will decline drastically due to more efficient production technologies in NW Europe and elsewhere	Current farming practices remain mainstream, thoguh some embrace innivative technologies as well as ecological agriculture; considerable competition from the American continent	Land requirements will decline slightly due to lower stress on export agriculture; high-tech ecological farming is widespread throughout the EC	Similar to A2, larger proportion of ecological farming, notably in combination with regional specificity of products; less competition form America

	A1 (World markets; global economy)	**A2 (Provincial enterprise; continental markets)**	**B1 (Global sustainability; global cooperation)**	**B2 (Local stewardship; regional communities)**
Spatial planning and urban sprawl	Agriculture is focussed on the best high-productivity soils and disappears from less-favoured areas; otherwise no restrictive regulation and spatial planning; attractive landscapes suburbanise	Agriculture remains in less favoured areas as well. No restirctions on urban sprawl. Villages for the rich emerge in attractive areas whereas urban conglomerates witness a decline in wealth	Agriculture in less favoured areas is extensified and probably joined with the Natura2000 network as extensive grazing ranges. Incentives for compact cities. Provincial towns will grow as a succesful mix of green and social services	Agriculture as A2; Urban sprawl is restricted and involution is practiced; incentives to sustain or revive smaller, rural villages and towns.
Water management	Surface water is functional: transport, irrigation and recreation; flood risks are covered rationally by using economically efficient solutions	As A1: flood risks are dealt with technically or devolved to downstream.	The Water Framework Directive is succesfully and timely implemented across the EC. Flooding and drought are carefully combatted combining economic efficiency and ecological ratio	As A2, but upstream-downstream confilicts are negotiated among neighbours
Type and intensity of recreation	No regulation; mass recreation overseas, holiday destinations reached by air	Overseas recreation less massive than in A1 due to limited wealth across all social strata	Demand for mass recreation is dampened by means of prudent policy, social behaviour and the location of services. Holidays are mainly spent in the safe and familiar EU.	No regulation, still limited long-distance mass recreation
Nature conservation	Existing areas remain protected; land abandoned by agriculture can be allocated to nature conservation; particularly in adjacency of existing reserves	Nature is primarily for recreating people; existing protected areas will service these	Land abandoned by agriculture is added to the Natura 2000 network. Biodiversity decline in the EC is turned to a modest but steady increase. Extinct species recolonise from refugia in or outside the EU.	Nature conservation only thorugh private NGOs. Nature is for people, hence typical landscapes are conserved

7. Figures

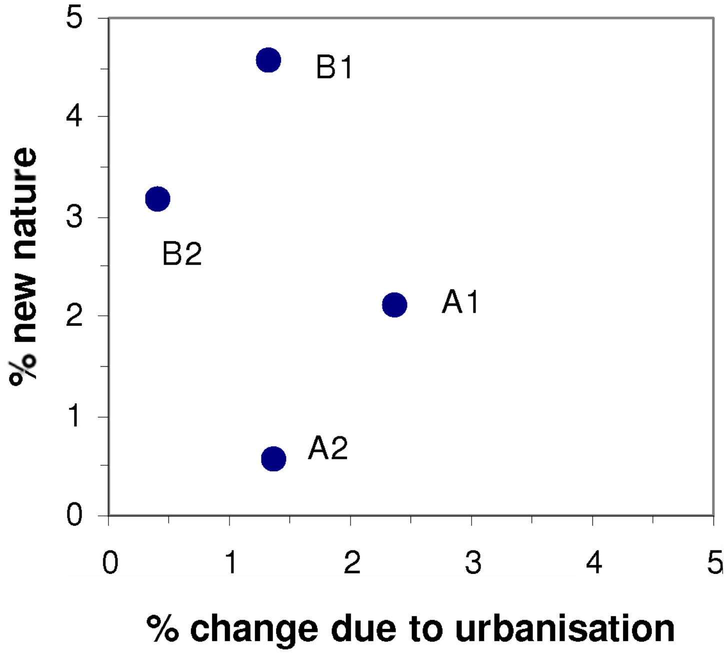

Figure 7.1 Changes in land use in Europe estimated with EURURALIS and the four SRES scenarios: increases in new nature versus zareas occupied by expanding urbanisation (from Verburg et al, 2006).