Figure 4.1 The conceptual framework of IAASTD highlights the role of indirect drivers and direct drivers in meeting development & sustainability goals as well as in shaping food systems & agricultural products and services.

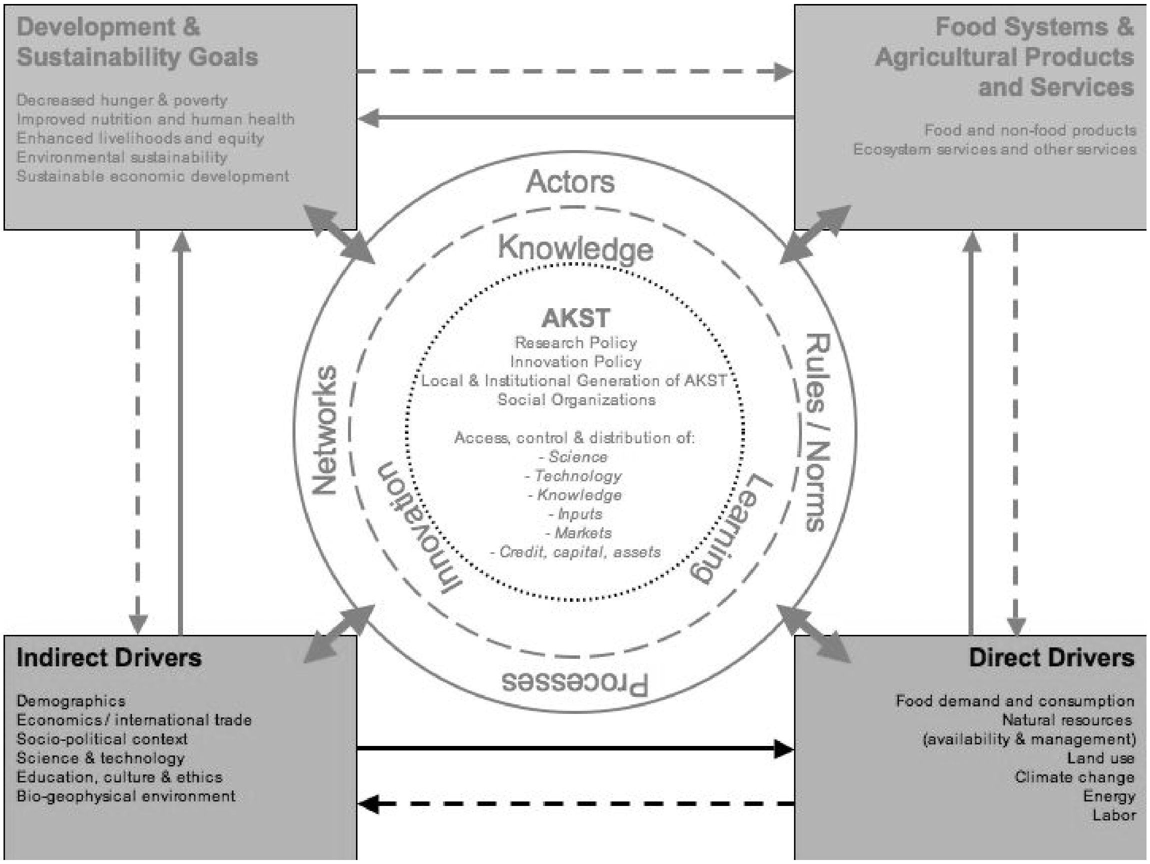


Figure 4.2 Which method is best suited for forward-looking assessments depends on both the complexity and the degree of uncertainty associated to an issue (Source: Zurek and Henrichs, 2006)

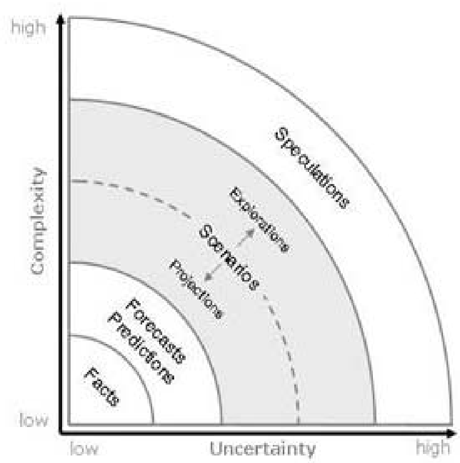


Figure 4.3 Future development of global population according to different scenarios.

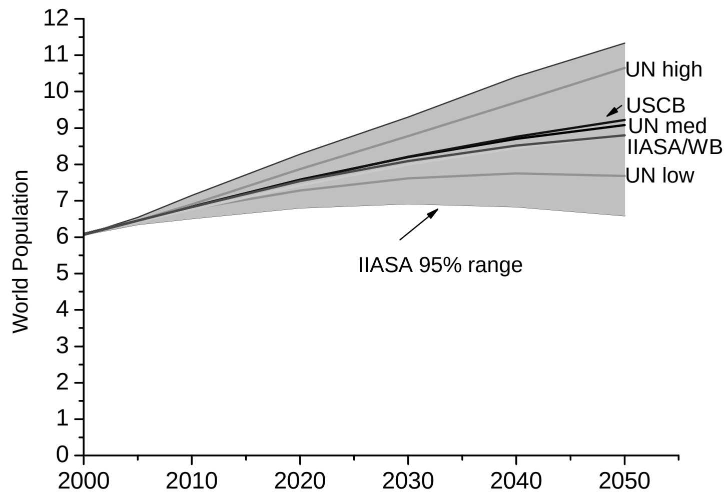


Figure 4.4 Comparison of global GDP growth in the SRES scenarios and more recent projections. SRES = (Nakicenovic et al., 2000) using Scenarios A1, B1, B2, and A2; WB = World Bank (WorldBank, 2004b), DoE = assumptions used by the United States Department of Energy (US.DoE, 2004), IEA assumptions used by IEA (IEA, 2002; IEA, 2004).

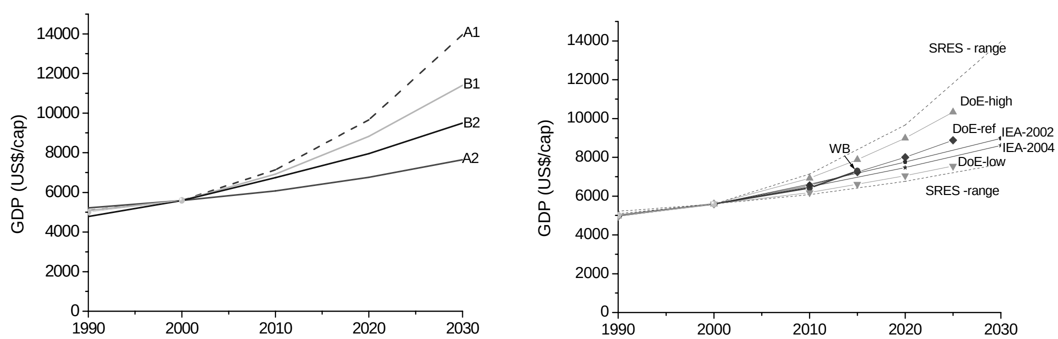
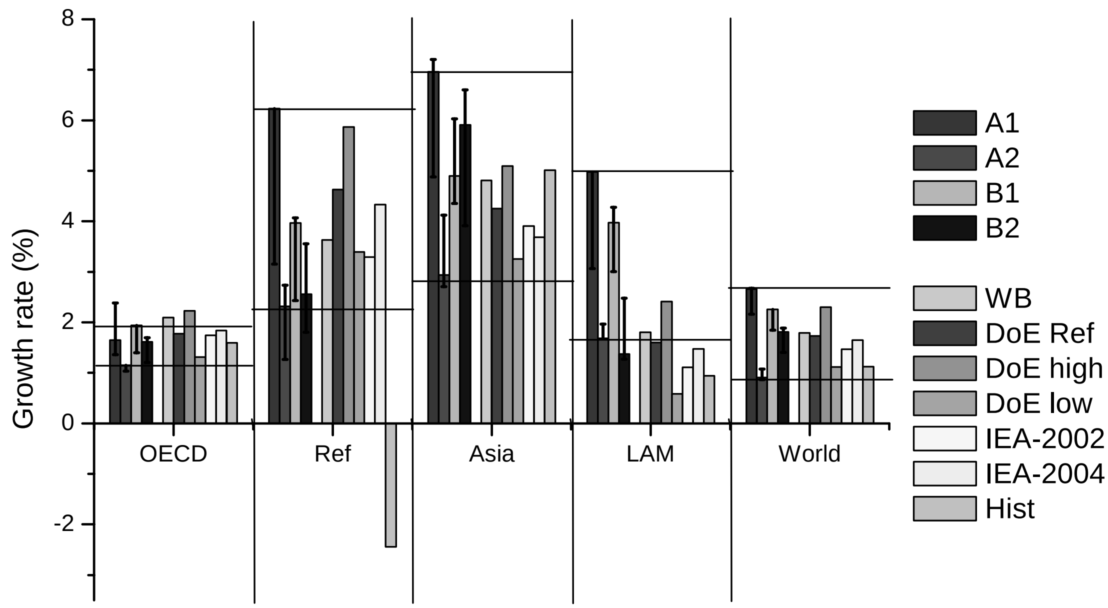


Figure 4.5 Comparison of regional GDP annual average growth rate between 2000-2015 in the SRES scenarios and more recent studies. WB = (World Bank, 2004b), DoE = Reference, high and low scenario of US DoE (2004), IEA = International Energy Agency (IEA, 2002; IEA, 2004). Hist = Historic data from World Bank, 2003.



Note: The horizontal lines in the figure indicate the range of growth rates set out by the SRES marker scenarios. The vertical lines showing uncertainty bars for the SRES scenarios indicate the range of different outcomes of SRES scenarios within the same family (while the bars indicate the growth rates of the Marker scenarios). The historical rate represents the 1990-2000 period.

Figure 4.6 Changes in economic structure for selected countries. Source: MA, 2005ab.

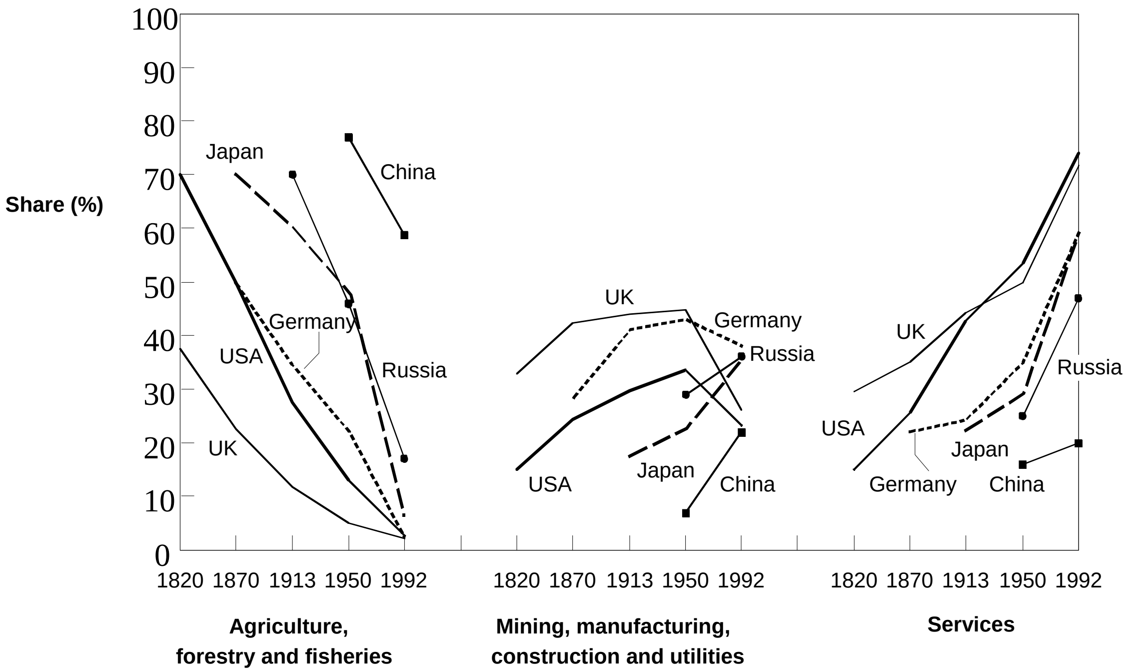


Figure 4.7 Income terms of trade for agriculture. Source: FAO, 2004b. State of Agricultural Commodity Markets 2004.

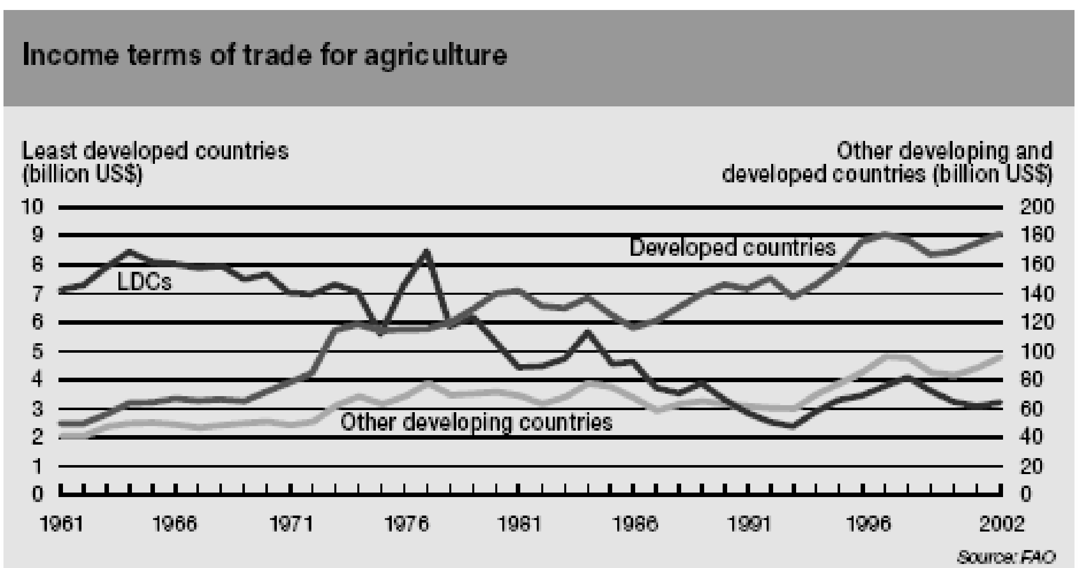


Figure 4.8 Global regimes by type, 1946-2006. Source: http://www.cidcm.umd.edu/inscr/polity/.

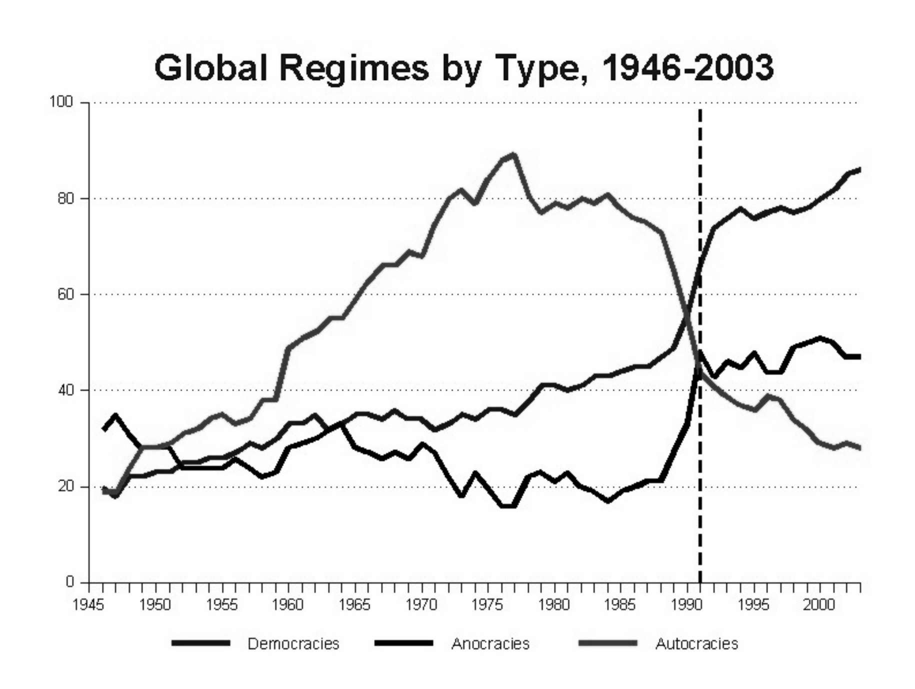


Figure 4.9 Incidence and prevalence of political instability worldwide, 1955-2003. Source: Goldstone et al., 2005.

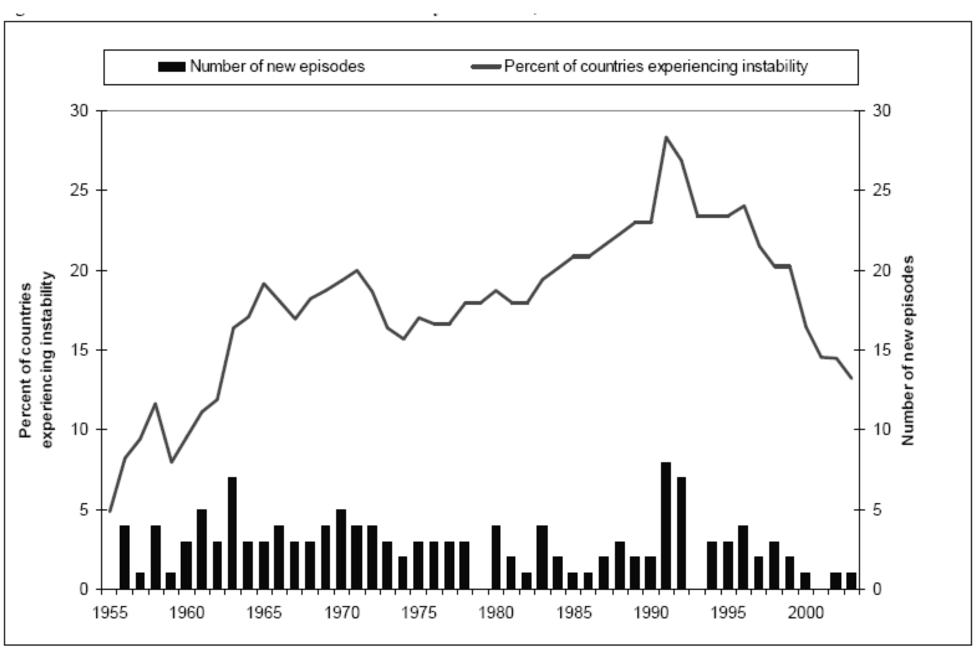


Figure 4.10 Global trends of technological efficiencies in MA scenarios. Technological Efficiency refers, for example, to the conversion efficiency of power plants, or the yield of all crops per hectare. Source: Alcamo et al., 2005.

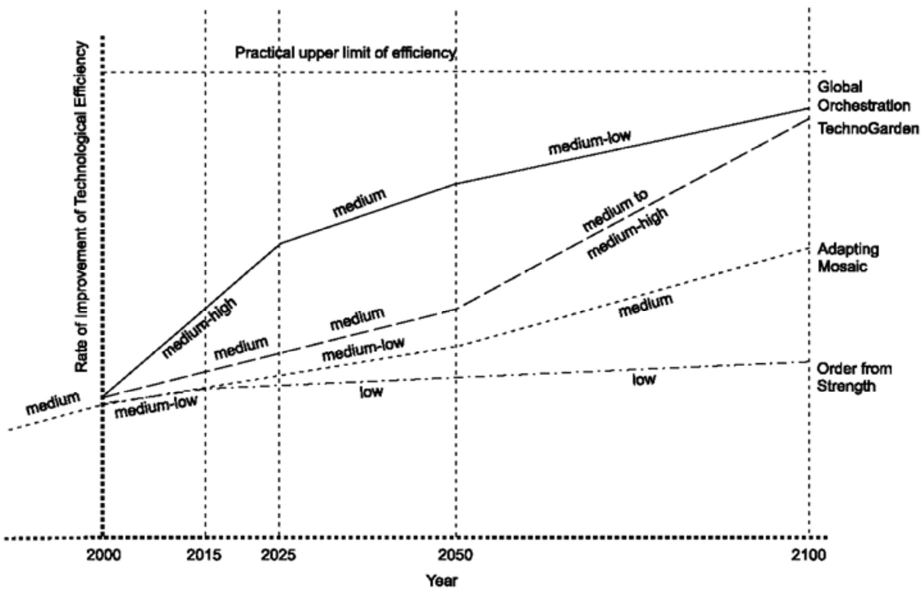
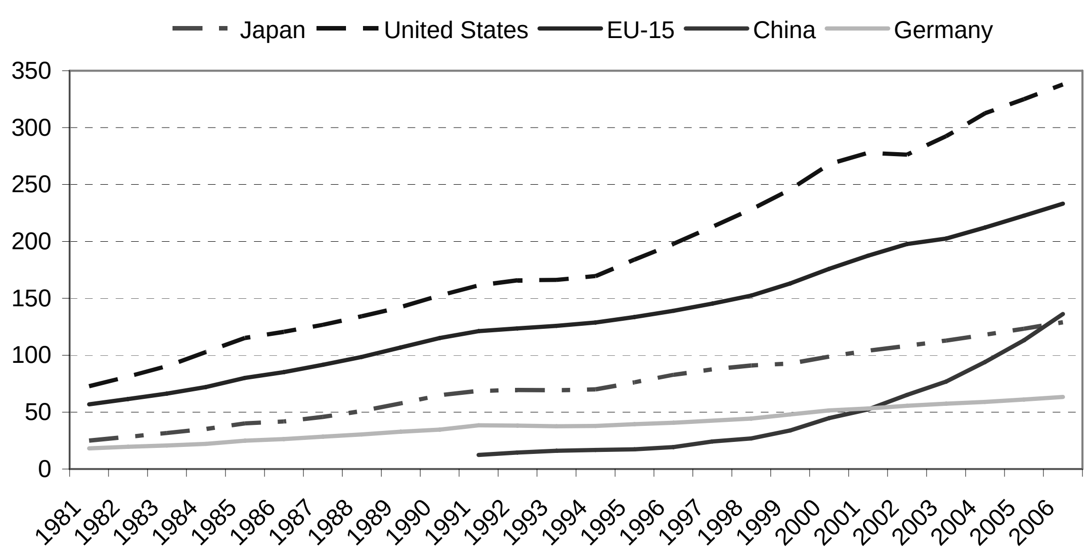


Figure 4.11 Gross domestic expenditure on R&D (billion current ppp$). Source: OECD, Main Science and Technology Indicators, 2006-I.



Note: (1) Figures for 2005 and 2006 are projected on the assumption that growth of R&D expenditure in 2005 and 2006 will be same as average growth over 2000-2004.
Source: OECD, Main Science and Technology Indicators, 2006-I.

Figure 4.12 Application of nitrogen in the form of fertilizer and manure in different regions. Source: Bouwman et al., 2005b

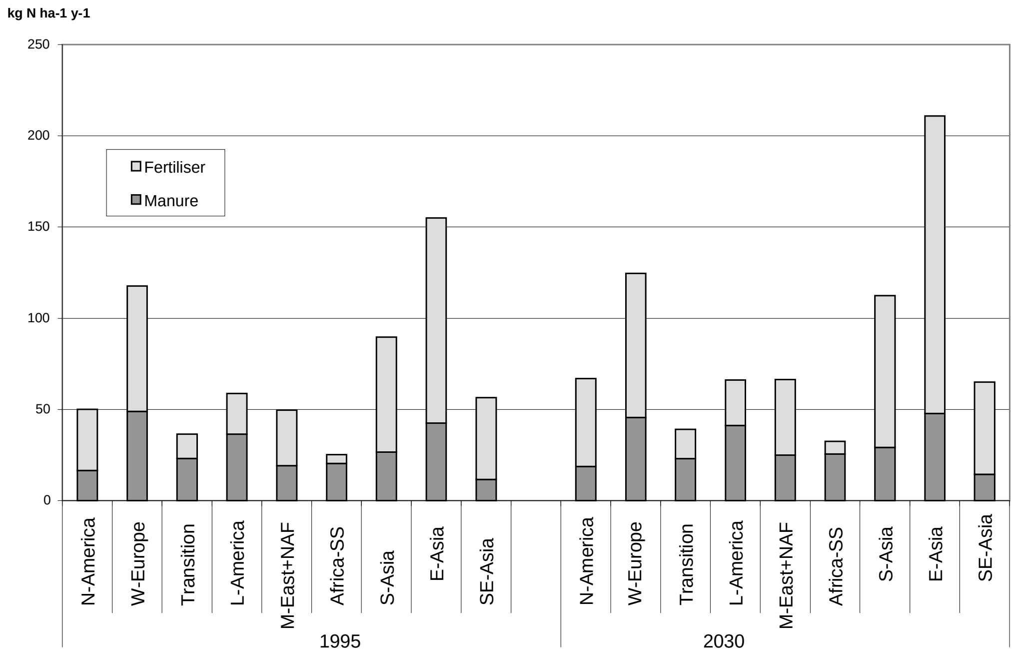


Figure 4.13 Global trends in and 2050 projections of the creation of reactive Nitrogen by anthropogenic activities (MA, 2005ab)

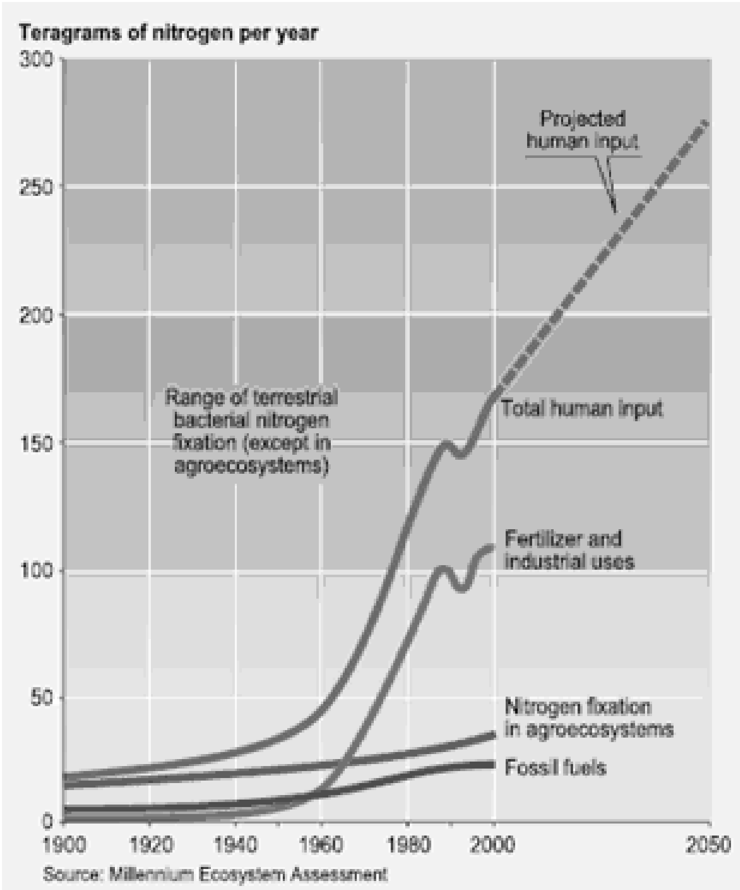
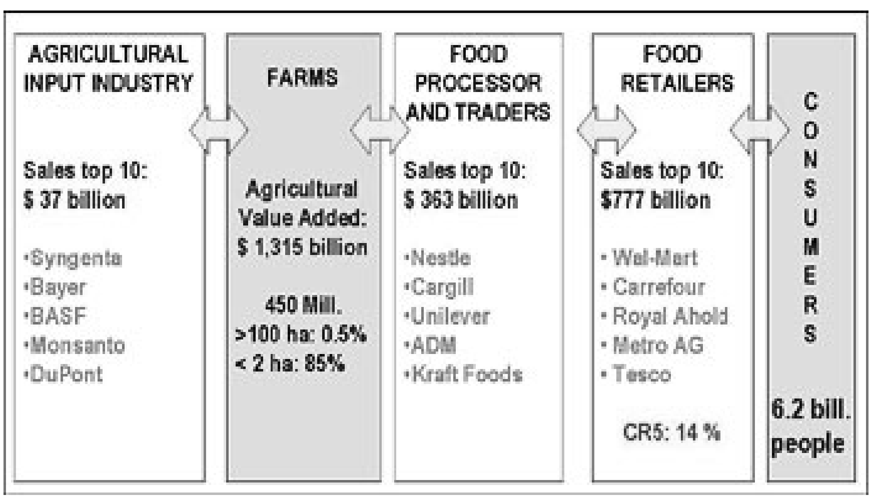
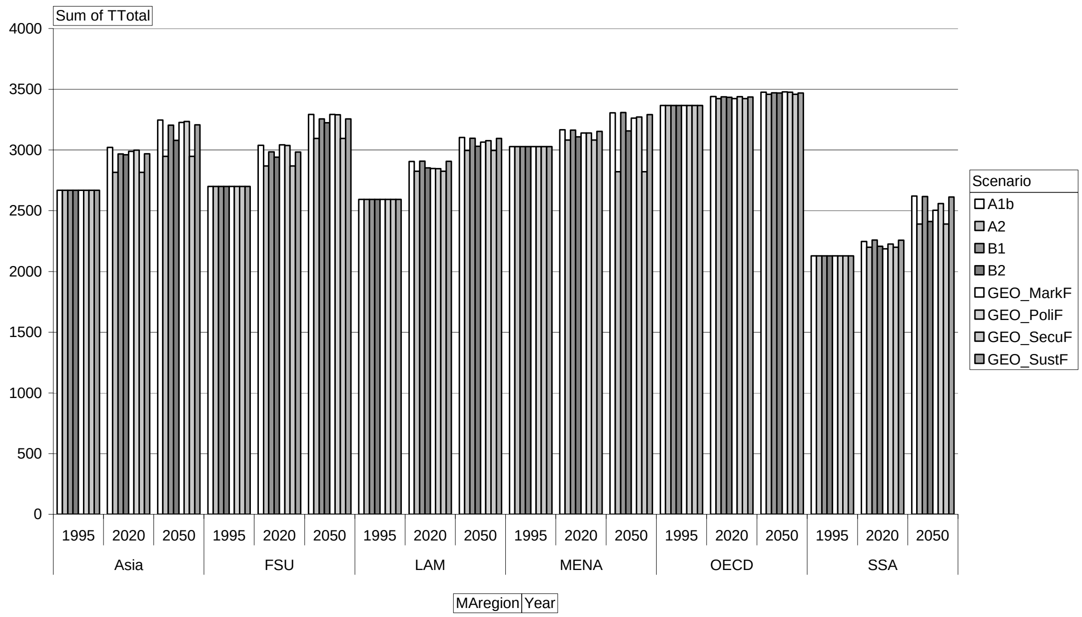


Figure 4.14 Corporate view of the agricultural food business chain. Source: Based on stock market data, http://www.wsj.com and World Bank, 2005b.



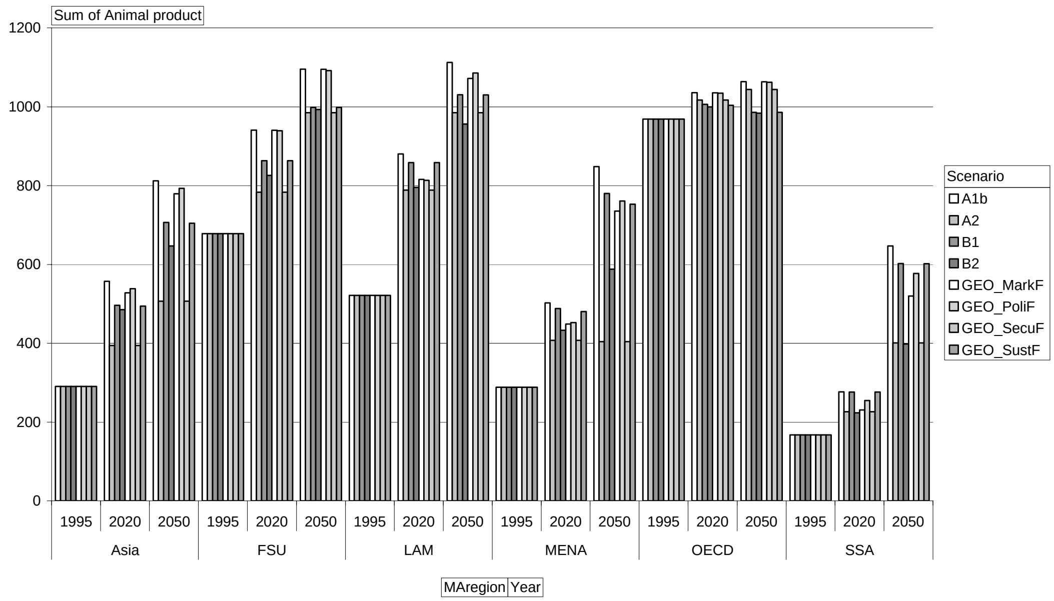
Note: CR5 represents the market share of the top five companies listed in the global retail industry.

Figure 4.15 Kilocalorie availability per capita per day, 1995, and projected 2020 and 2050. Source: Westhoek et al., 2005.



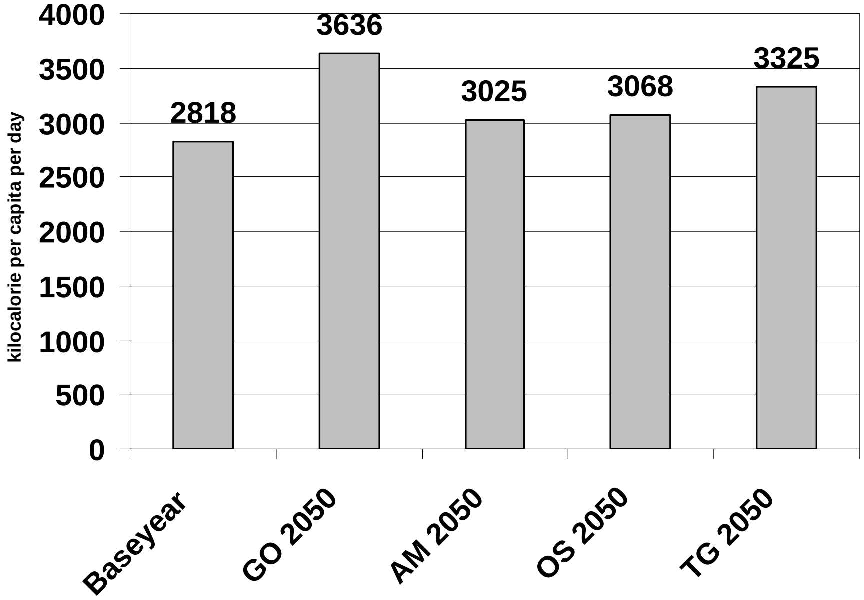
Notes: A1, A2, B1, and B2 are storylines used in IPCC assessments. The results presented here are data underlying but not reported in the third IPCC Assessment Reports. GEO_MarkF, GEO_PoliF, GEO_SecuF, and Geo_SustF relate to four storylines used in UNEP's GEO3 assessment: Markets First, Policy First, Security First, and Sustainability First, respectively. These data are not presented in the final GEO3 report.

Figure 4.16 Kilocalorie availability per capita per day from livestock products only, 1995, and projected 2020 and 2050. Source: Westhoek et al., 2005.



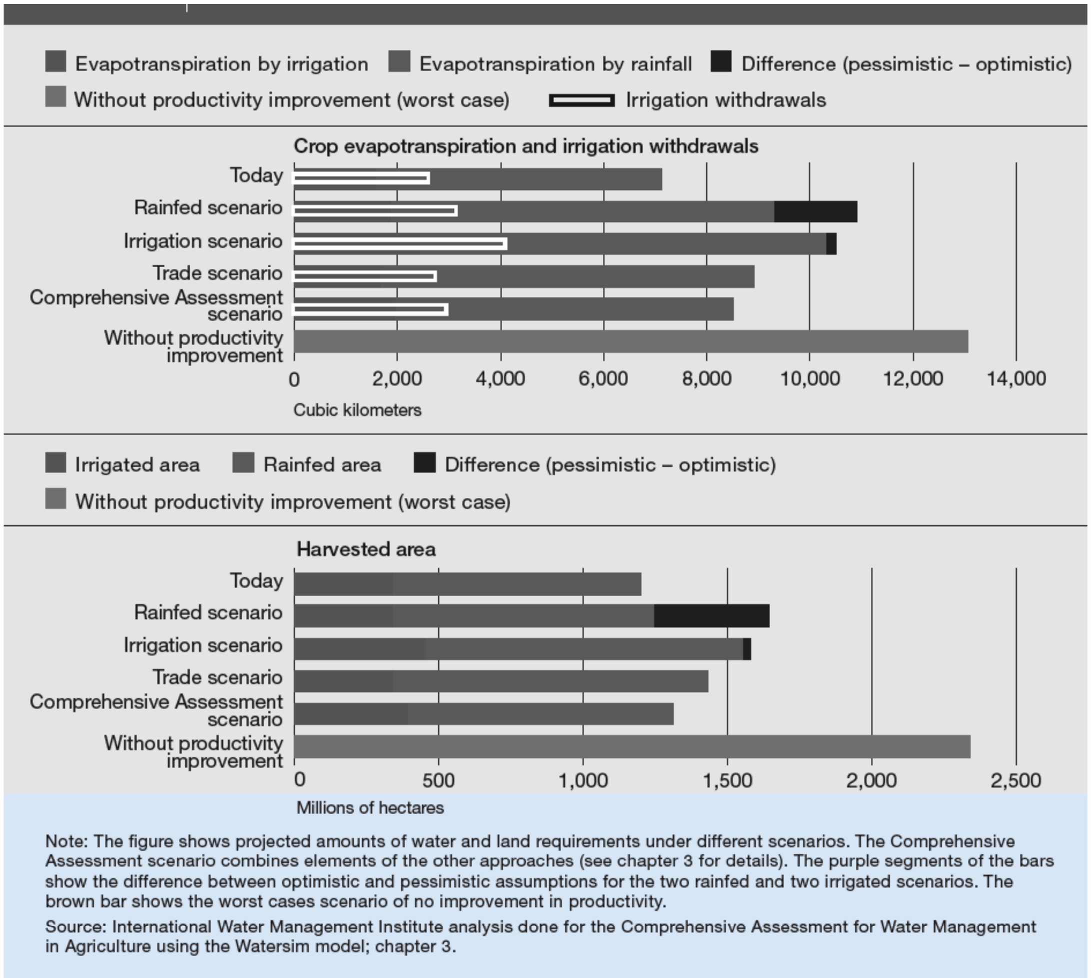
Notes: A1, A2, B1, and B2 are storylines used in IPCC assessments. The results presented here are data underlying but not reported in the third IPCC Assessment Reports.
GEO_MarkF, GEO_PoliF, GEO_SecuF, and Geo_SustF relate to four storylines used in UNEP's GEO3 assessment: Markets First, Policy First, Security First, and Sustainability First, respectively. These data are not presented in the final GEO3 report.

Figure 4.17 Average global kilocalorie availability per capita per day, Millennium Ecosystem Assessment Scenarios. Source: MA, 2005ab.



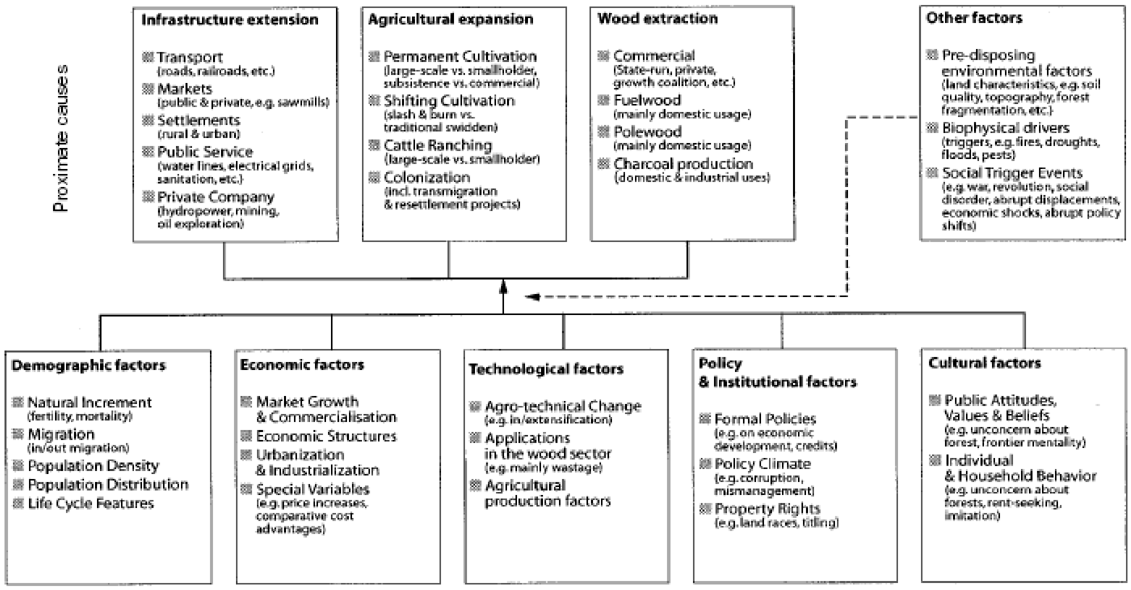
Notes: GO, AM, OS and TG stand for the Global Orchestration, the Adapting Mosaic, Order from Strength, and TechnoGarden Scenarios, respectively.

Figure 4.18 Land and water use today and in the future under different scenarios. Source: CA, 2007



Note: The brown bar represents the worst case scenario in which no productivity improvements in rainfed or irrigated agriculture take place. The 'rainfed scenario' assumes that most of future investments are targeted to upgrading rainfed agriculture. The purple bar denotes the difference between optimistic and pessimistic yield assumptions and gives an indication of the risks involved in this scenario. The 'irrigation scenario' assumes a major drive in improvement of water productivity and expansion of irrigated areas. The 'trade scenario' assumes increased food trade from water abundant to water scarce areas. The 'Comprehensive Scenario' combines elements from all three scenarios depending on regional opportunities.

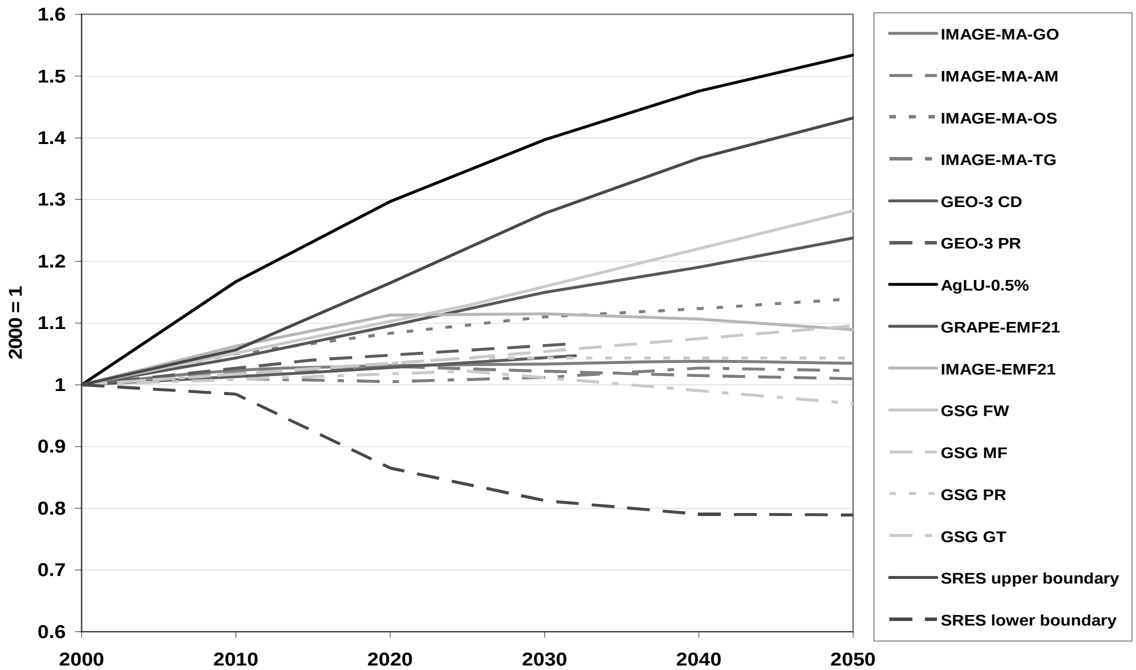
Figure 4.19 Clusters of indirect and direct drivers of land cover change



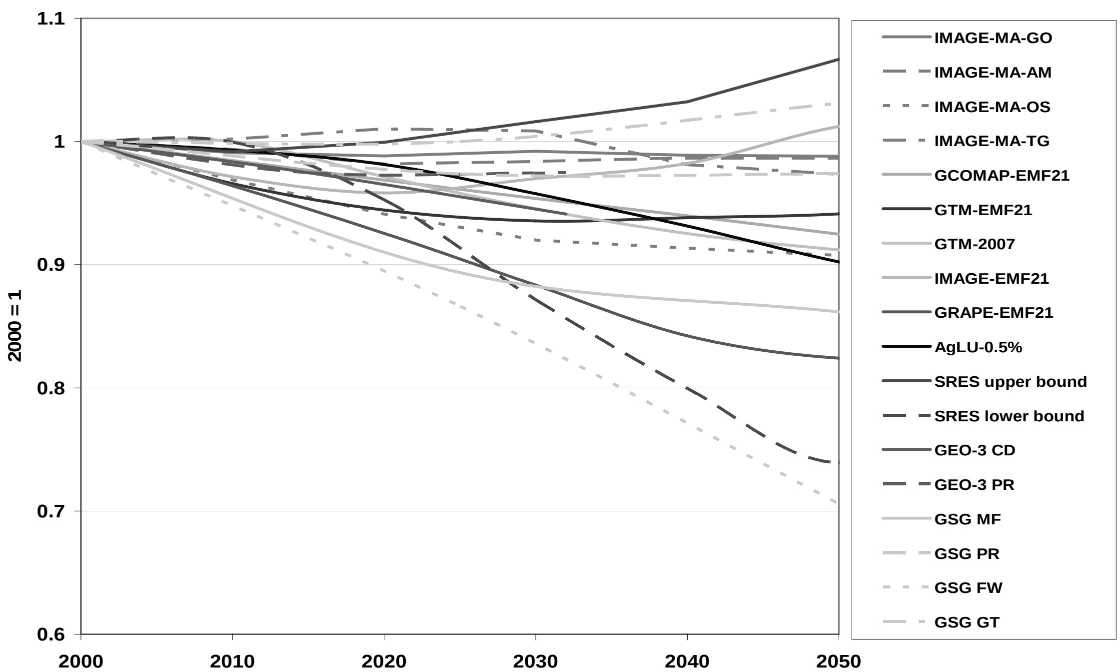
Source: Adapted from Figure 1 in Geist and Lambin (2004).

Figure 4.20 Projected land-use change for (a) agricultural land and (b) forest land from selected scenarios (indexed to year 2000)

(a) Agricultural land



(b) Forest land



Notes: Agricultural land is an aggregate of cropland and grazing/pasture/grassland land types. The following scenarios were redrawn from Alcamo et al. (2006): GSG xx = Global Scenarios Group (Raskin et al., 2002) scenarios from the PoleStar model (MF = Market Forces, PR = Policy Reform, FW = Fortress World, GT = Great Transition); GEO-3 xx = Global Environment Outlook 3 (UNEP, 2004) scenarios using the PoleStar model (MF = Market First, PF = Policy First). The other scenarios were assembled from various sources: SRES = Special Report on Emissions Scenarios (IPCC, 2000); IMAGE-EMF21 = van Vuuren *et al.*, 2006 scenario from EMF-21 Study; IMAGE-MA-xx = Millennium Ecosystem Assessment (2005) scenarios from the IMAGE model for four storylines (GO = Global Orchestration, OS = Order from Strength, AM = Adapting Mosaic, TG = TechnoGarden); AgLU-0.5% = Sands and Leimbach (2003) scenarios with 0.5% annual growth in crop yield; GTM-EMF21 = Sohngen and Sedjo (2006) global forest scenario from EMF-21 Study; GCOMAP-EMF21 = Sathaye *et al.* (2006) global forest scenario from EMF-21 Study; GTM-2007 = Sohngen and Mendelsohn (2007) global forest scenario; GRAPE-EMF21 = Kurosawa (2006) scenario from EMF-21 Study.

Figure 4.21 Comparison of current CO_2 emission scenarios (scenarios since IPCC's Third Assessment Report 2001; mean + std. deviation), IPCC-SRES and WEO2006.

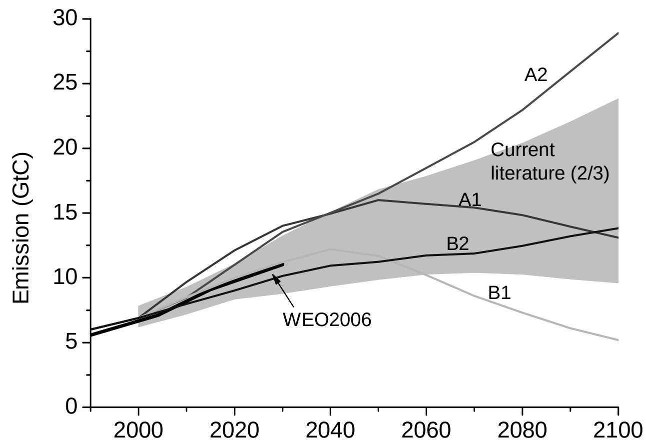


Figure 4.22 Comparison of emission pathways leading to 650, 550 and 450 ppm CO_2-eq. and the IPCC-SRES scenarios (left) and the WEO-2006 scenarios.

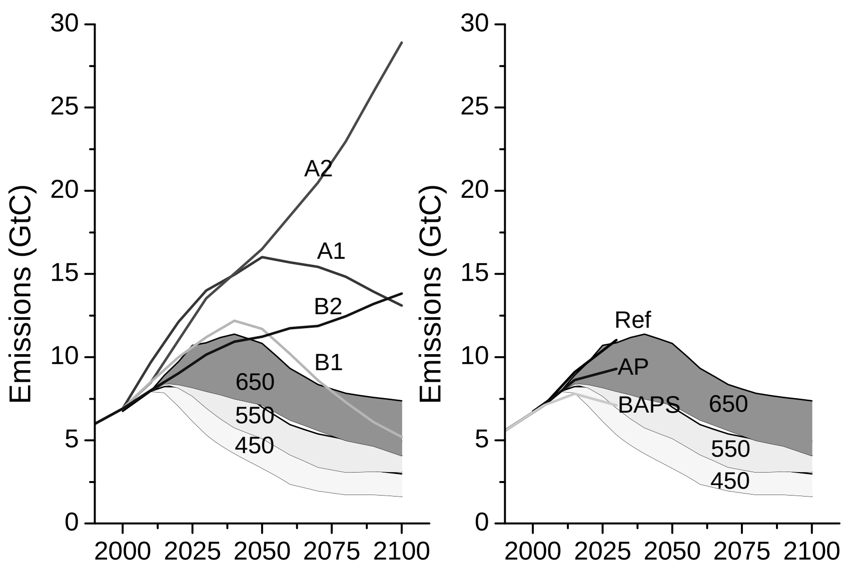


Figure 4.23 Global mean temperature change under the different IPCC scenarios scenarios based on the uncertainty in emissions and the climate sensitivity. Source, IPCC, 2001.

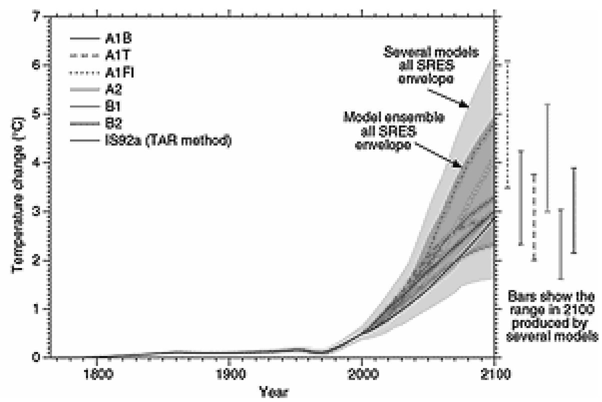


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Figure 4.24. Change in temperature relative to global mean temperature change. Source, IPCC, 2001.

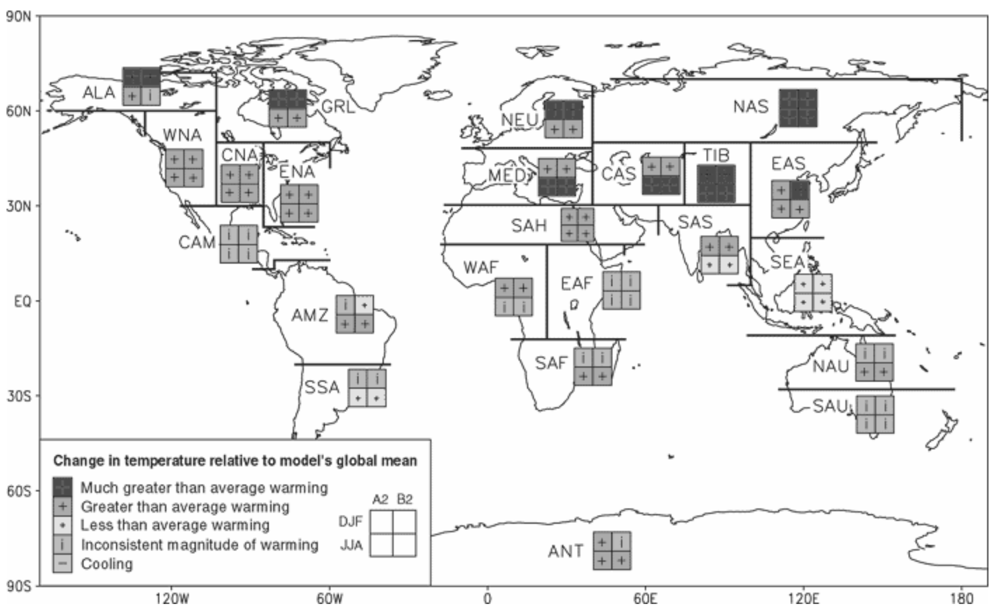

Figure 4.25 Yield sensitivity to climate change for major cereal crops, divided into temperate and tropical regions – from crop simulations with comparable climate scenarios.

Blue= with adaptation
Red= no adaptation

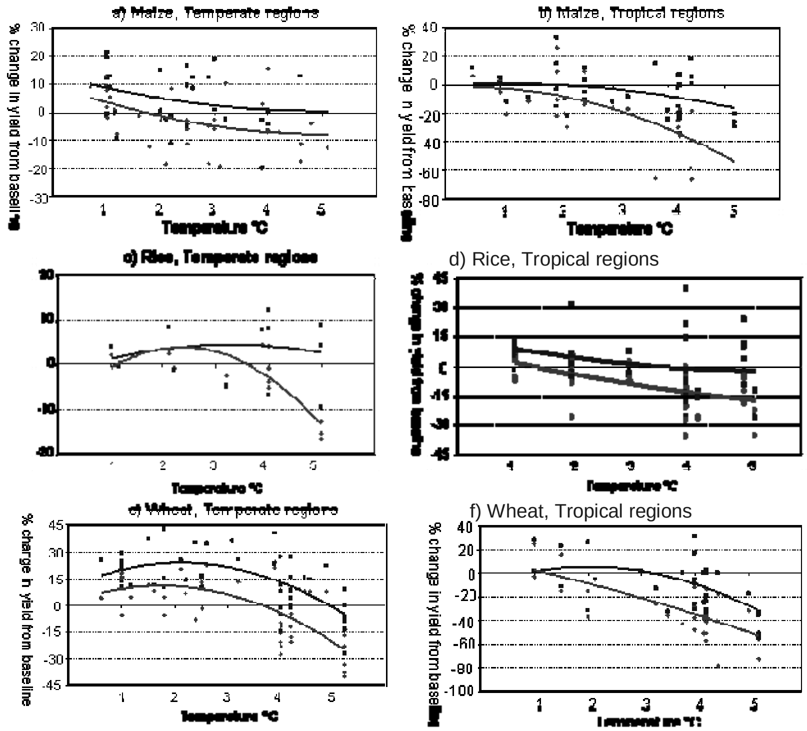

Figure 4.26 Estimated historical and projected N_2O and CH_4 emissions in the agricultural sector of the ten world regions during the period 1990-2020. Source: IPCC, 2007, adapted from US-EPA, 2006a.

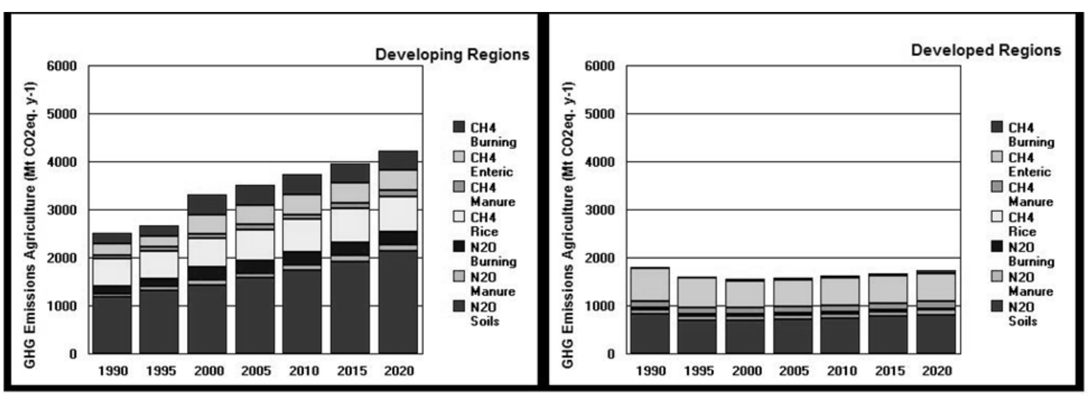

Figure 4.27 Global energy use in the 1880-2000 period.

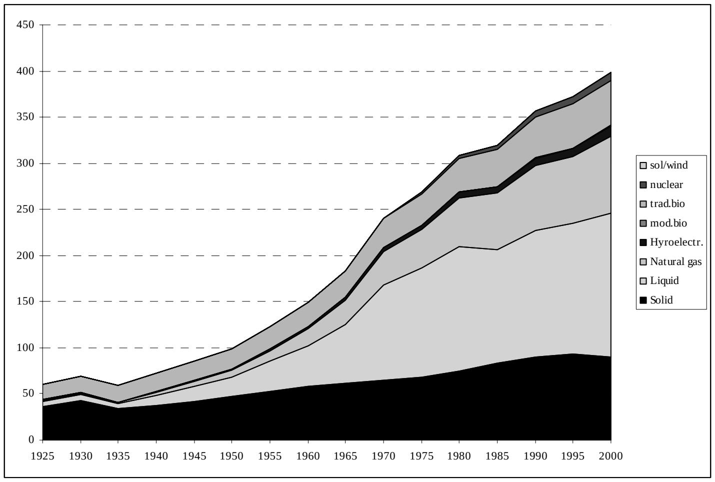

Figure 4.28 Trends in 21st century energy use. Comparison of trends in SRES total primary energy consumption and more recent studies by US.DoE and IEA. DoE = Projections from US. DoE (2004a), IEA-2004 = Projection from the International Energy Agency. Source: IEA, 2004.

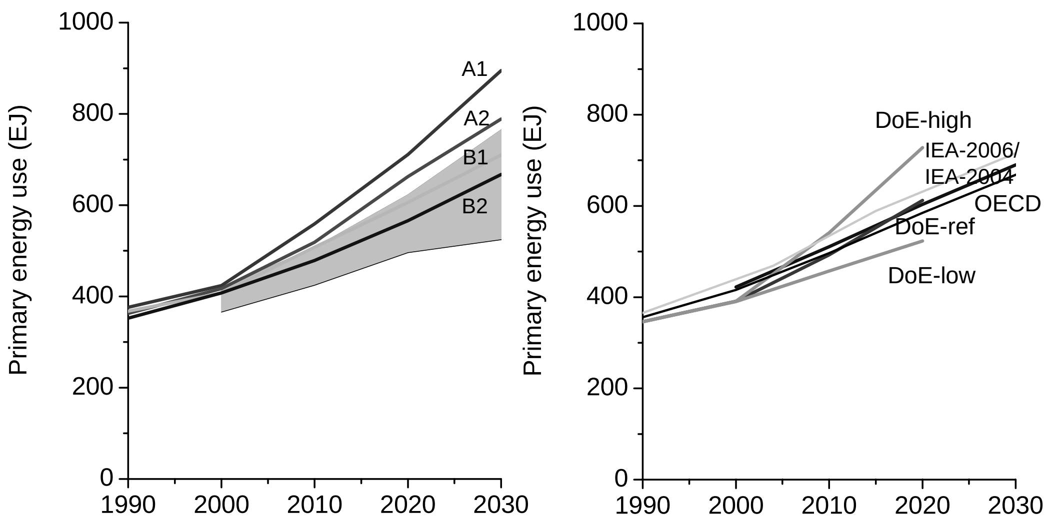

Figure 4.29 Biomass use in the different global energy scenarios. Source: Faaij et al., 2007.

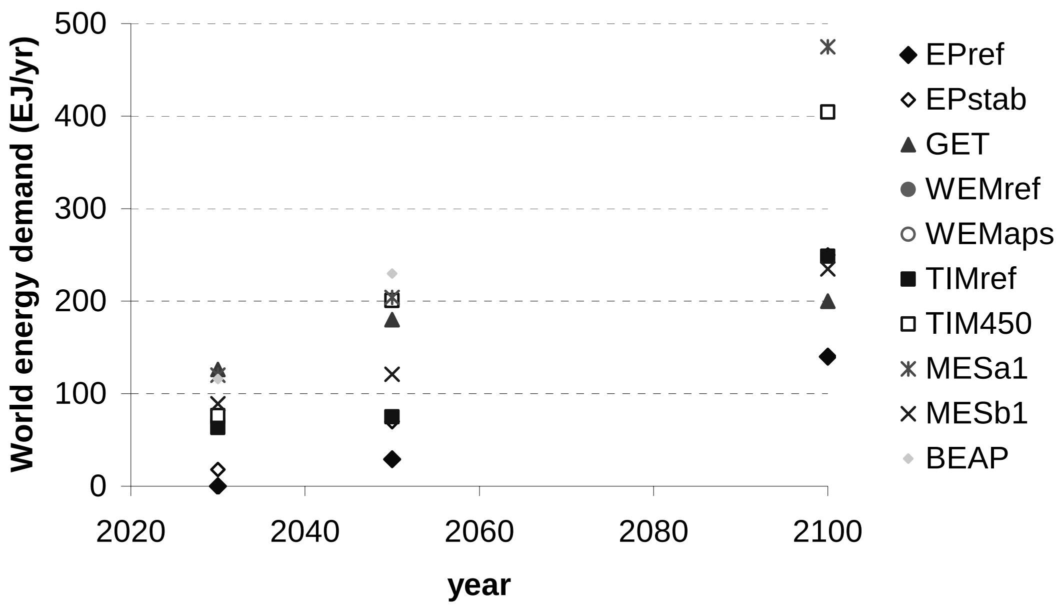

Figure 4.30 Global cereal production in selected scenarios

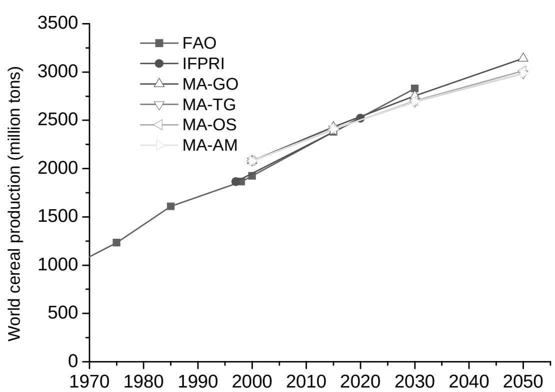

Figure 4.31 Harvested area for cereals and all crops in selected scenarios.

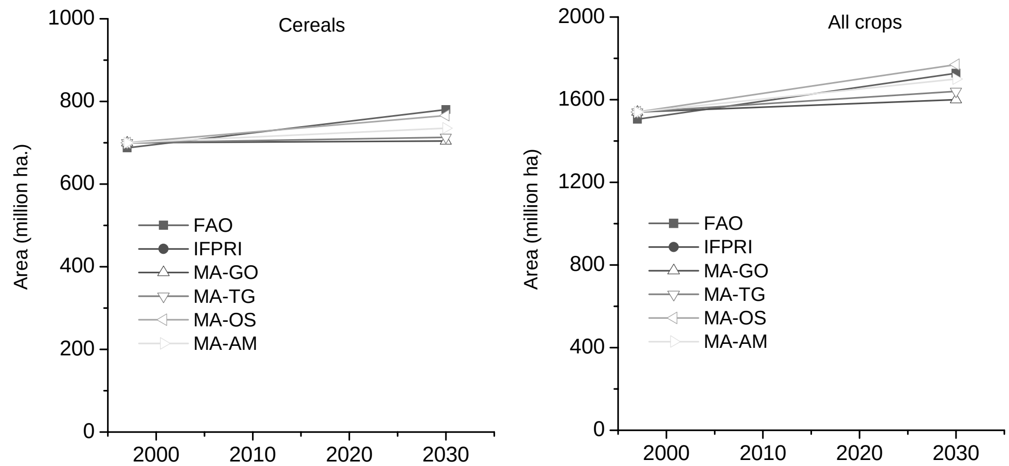

Figure 4.32 Factors underlying production growth in selected scenarios

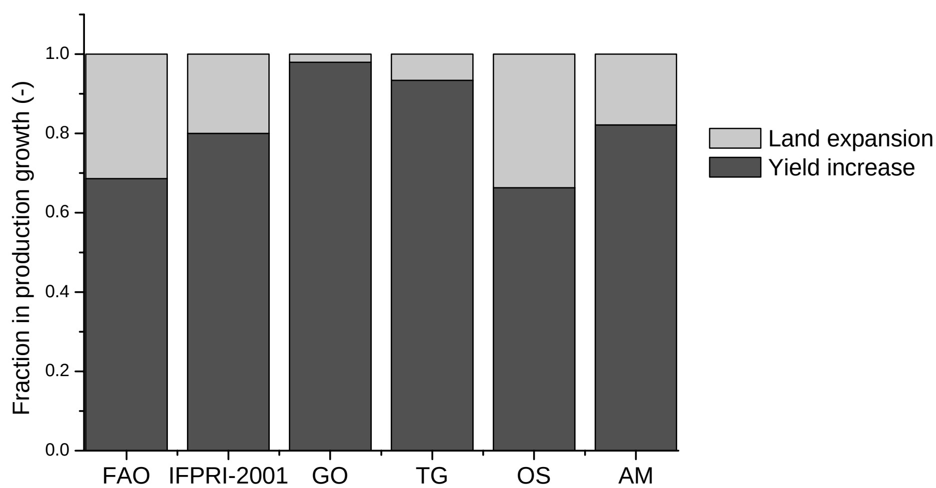

Figure 4.33 World meat production.

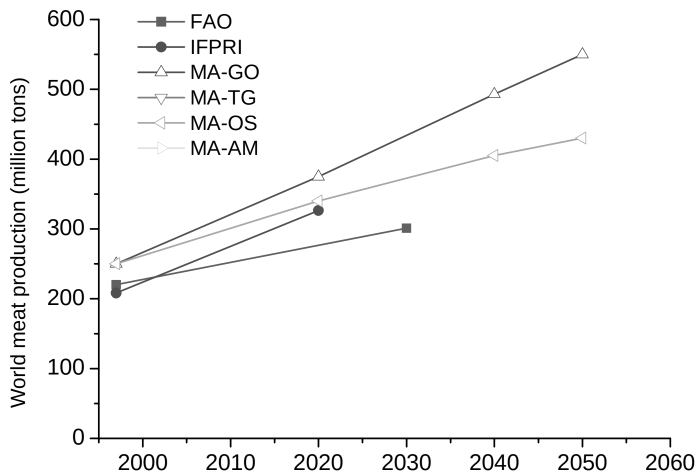

Figure 4.34 Number of large livestock and total grazing area in selected scenarios.

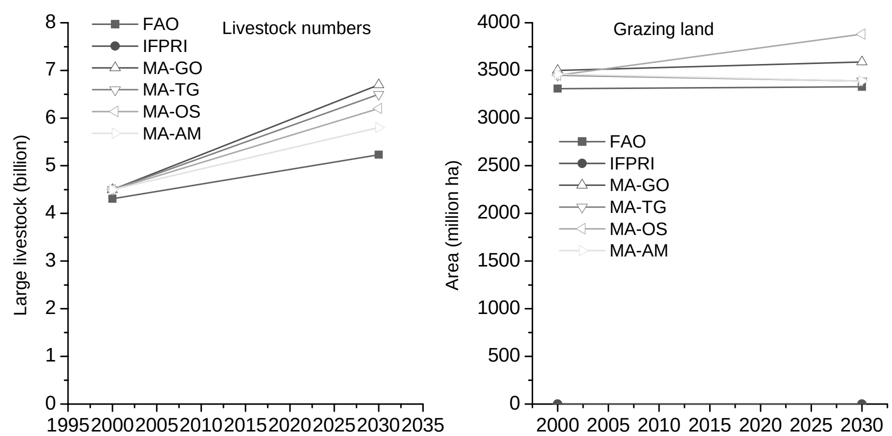

Figure 4.35 World production of forest products.

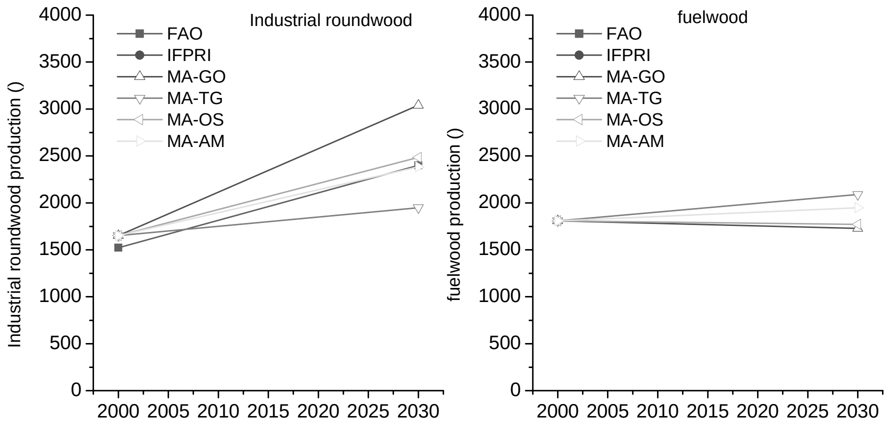

Table 4.1 Overview of relevant global scenario studies

	Main focus	Character of assessment
GSG	Sustainable development	Strong focus on storyline, supported by quantitative accounting system
IPCC-SRES	Greenhouse gas emissions	Modelling supported by simple storylines. Multiple models elaborate the same storyline to map out uncertainties.
IPCC-TAR and AR4	Climate change, causes and impacts	Assessment of available literature and some calculations on the basis of IPCC-SRES
UNEP-GEO3/GEO4	Global environmental change	Storylines and modelling; modelling on the basis of linked models
MA	Changes in ecosystem services;	Storylines and modelling; modelling on the basis of linked models
FAO-AT2020	Changes in agriculture	Single projection, mostly based on expert judgement.
IFPRI	Changes in agriculture	Model-based projections
CA	Water and agriculture	Storylines and modelling; modelling on the basis of linked models

Table 4.2 Key assumptions in different scenario 'archetypes'

	Economic optimism	**Reformed Markets**	**Global SD**	**Regional competition**	**Regional SD**	**Business as Usual**
Economic development	very rapid	rapid	ranging from slow to rapid	slow	ranging from mid to rapid	medium (globalisation)
Population growth	low	low	low	high	medium	medium
Technology development	rapid	rapid	ranging from mid to rapid	slow	ranging from slow to rapid	medium
Main objectives	economic growth	various goals	global sustainability	security	local sustainability	not defined
Environmental protection	reactive	both reactive and proactive	proactive	reactive	proactive	both reactive and proactive
Trade	globalisation	globalisation	globalisation	trade barriers	trade barriers	weak globalisation
Policies and institutions	policies create open markets	policies reduce market failures	strong global governance	strong national governments	local steering; local actors	mixed

Note: This table summarises key assumptions in very general terms. Where differences within a set of archetypes exist, broad ranges are indicated.

Table 4.3 Recent scenario-based assessments mapped against scenario 'archetypes'

	IPCC-SRES	UNEP GEO-3	GSG	MA	IFPRI	FAO
Conventional Markets	A1	Markets First	Conventional worlds		Optimistic scenario	
Reformed Markets		Policies First	*Policy reform*	*Global Orchestration*		
Global SD	*B1* (B1-450)	Sustainability First		TechnoGarde n		
Regional Competion	A2	Security First	Barbarisation	Order from Strength	*Pesimistic scenario*	
Regional SD	*B2*		Great transitions	Adapting Mosaic		
Business as Usual	*B2*				Reference scenario	FAO AT2020

Note: Italics are used to indicate that scenarios are not completely consistent with the group in which it is categorised.

Table 4.4 Population projections in different assessments

	Projections
IPCC-SRES	4 scenarios ranging from 8.7-11.4 billion people in 2050
MA	4 scenarios ranging from 8.1-9.6 billion people in 2050
FAO, 2001	
IFPRI	
GEO4	
OECD outlook	1 scenario; UN-medium (9.1 billion)

Table 4.5 Per capita income growth projections, per year various assessment results. Source: MA, 2005; FAO, 2006b; OECD

Region	Historic *	MA*		FAO**		OECD***	
	1971-2000	1995-2020	2020-2050	2000-2030	2030-2050	2010-2020	2020-2030
Former Soviet Union	0.4	2.24-3.5	2.64-4.91	4.5	4.3	3.7	3.4
Latin America	1.2	1.78-2.8	2.29-4.28	2.3	3.1	2.9	2.8
Middle East/North Africa	0.7	1.51-1.96	1.75-3.42	2.4	3.1	3.6	3.9
OECD	2.1	2-2.45	1.31-1.93	2.2	2.4	2.2	2.0
Asia	5	3.22-5.06	2.43-5.28	5	4.95	4.76	4.1
Sub-saharan Africa	-0.4	1.02-1.69	2.12-3.97	1.6	2.8	4.2	4.4
World	1.4	1.39-2.38	1.04-3	2.1	2.7	2.7	2.5

Table 4.6 MA outlook for agricultural trade, 1997-2050. Source: MA, 2005.

Scenario	

Global Orchestration	-Total trade in grain and livestock products increases. -Net grain trade increases. - The OECD region responds to the increasing cereal demands in Asia and MENA. - Sub-Saharan Africa will be net grain exporter. -Net trade in meat products increases. - Net exports will increase in Latin America, while the OECD region and Asia are projected to increase net imports.
Order from Strength	-Trade is not encouraged, but still total trade in food commodities doubles. - Most trade is done intra-regionally.
TechnoGarden	- Total trade for grains and meat products grows. -Net cereal trade is dominated by Asian and MENA net imports and OECD net exports. - Net meat trade is dominated by net imports in OECD region, supplied through net exports from Latin America, sub-Saharan Africa, and Asia.
Adapting Mosaic	-Total grain and meat trade increases. -Cereal trade increases and accounted for by increased net imports in Asia and the Middle East/North Africa region and increased net exports of the OECD region. -Sub-Saharan Africa is net cereal exporter. - Total net meat trade increases. -Asia is projected to supply livestock products to all other regions except Latin America.

Table 4.7 Investment in food security under the baseline scenario, 1997-2020. Source: IFPRI IMPACT Projections, June 2001.

Region/Country	Irrigation	Rural Roads	Education	Clean Water	National Agricultural Research	Total Investments
	Billions of US Dollars					
Latin America	44.8	36.7	12.1	9.8	37	140.4
West Asia/North Africa	17.9	7.3	21.5	8.5	25.3	80.5
Sub-Saharan Africa	28.1	37.9	15.7	17.3	8	106.9
South Asia	61.3	27.4	14.5	27	18	148.2
India	42.5	23.5	10.5	18.4	15.6	110.5
Southeast Asia	18.6	3.9	6.8	9.4	14.1	52.6
China	3.2	6.8	2.4	14.4	14.6	41.4
Developing countries	174.6	120.3	75.9	86.5	121.7	578.9

Table 4.8 Projections of food budget shares and share of expenditures on grains, selected countries. Source: Cranfield et al., 1998.

	Food budget shares		Share of expenditures on grains	
	1985	2020	1985	2020
Ethiopia	0.52	0.51	0.22	0.21
Senegal	0.41	0.37	0.13	0.11
United States	0.11	0.07	0.02	0.01

Table 4.9 Incorporation of changing food demand patterns in global assessment studies. Sources: UNEP, Global Environmental Outlook, 2002; IPCC, 2001, 2007; MA, 2005; de Fraiture et al., 2007; OECD, 2006; IEA, 2006.

No	Assessment Title	Publication Date	Projections timeframe	Food demand mentioned	Projections follow / adapted from
1	GEO-3 Assessment	2002	2032		FAO (2015/2030 outlook)
2	GEO-4 Assessment	2007	2000-2050	Explicitly	IFPRI IMPACT
3	IPCC 3rd Assessment	2001	Various	Not explicitly	Various, IPCC-SRES
4	IPCC 4th Assessment	2007	Various	Not explicitly	Various, IPCC-SRES
5	Millennium Ecosystem Assessment	2005	2000-2100	Explicitly	IFPRI IMPACT
6	Comprehensive Assessment of Water Management in Agriculture	2007	2000-2050	Explicitly	Watersim, based on IFPRI IMPACT
7	OECD Outlook	2006 Draft	2000-2030	Not explicitly	Partly FAO
8	World Energy Outlook	2006	2030	Not explicitly	-

Table 4.10 Per capita food consumption (kcal/person/day). Source: FAO (2006).

	1969/71	1979/81	1989/91	1999/01	2015	2030	2050
World	2411	2549	2704	2789	2950	3040	3130
Developing countries	2111	2308	2520	2654	2860	2960	3070
sub-Saharan Africa	2100	2078	2106	2194	2420	2600	2830
- excluding Nigeria	2073	2084	2032	2072	2285	2490	2740
Near East / North Africa	2382	2834	3011	2974	3080	3130	3190
Latin America and Caribbean	2465	2698	2689	2836	2990	3120	3200
South Asia	2066	2084	2329	2392	2660	2790	2980
East Asia	2012	2317	2625	2872	3110	3190	3230
Industrial countries	3046	3133	3292	3446	3480	3520	3540
Transition countries	3323	3389	3280	2900	3030	3150	3270

Table 4.11 Changes in the commodity composition of food by major country groups in kg/person/year

World						
Cereals, food	148.7	160.1	171	165.4	165	162
Cereals, all uses	302.8	325	329.3	308.7	331	339
Roots and tubers	83.7	73.4	64.5	69.4	75	75
Sugar (raw sugar equiv.)	22.4	23.4	23.3	23.6	26	27
Pulses, dry	7.6	6.5	6.2	5.9	6	6
Vegetable oils, oilseeds and products (oil eq.)	6.8	8.3	10.3	12	16	17
Meat (carcass weight)	26.1	29.5	33	37.4	47	52
Milk and dairy, excl. butter (fresh milk eq.)	75.3	76.5	76.9	78.3	92	100
Other food (kcal/person/day)	216	224	241	289	325	340
Total food (kcal/person/day)	2411	2549	2704	2789	3040	3130

Table 4.12 Comparison of recent global water use forecasts. *Source: adapted from CA 2007*

Author	projection period	increase in rainfed cereal production	increase in irrigated yield	increase in irrigated harvested area	increase in cereal trade	increase in agricultural water withdrawals
		annual growth rate	annual growth rate	annual growth rate	annual growth rate	annual growth rate
Shiklomanov 2000	1995-2025			0.74%		0.68%
Seckler et al 2000	1995-2025	0.19%	1.13%	0.95%	0.64%	0.56%
Rosegrant et al 2002	1995-2025	1.14%	1.14%	0.36%	2.41%	
Faures et al 2002	1995-2030	1.10%	1.00%	0.95%	2.08%	0.43%
Alcamo et al 2005	2000-2050			0.06% - 0.18%	1.85% - 2.44%	0.40% - 1.22%
Fraiture et al. 2007	2000-2050	0.63% - 1.03%	0.58% - 1.15%	0% - 0.56%	0.98%-2.01%	0.10% - 0.90%

Table 4.13 Proposed measures for mitigating greenhouse gas emissions from agricultural ecosystems, their apparent effects on reducing emissions of individual gases where adopted (mitigative effect), and an estimate of scientific confidence that the proposed practice can reduce overall net emissions at the site of adoption. Source: IPCC, 2007, adapted from Smith and Bertaglia, 2007.

		Mitigative effects[1]			**Net mitigation**[2] **(confidence)**	
Measure	**Examples**	**CO_2**	**CH_4**	**N_2O**	**Agree-ment**	**Evi-dence**
Cropland management	Agronomy	+		+/-	***	**
	Nutrient management	+		+	***	**
	Tillage/residue management	+		+/-	**	**
	Water management (irrigation, drainage)	+/-		+	*	*
	Rice management	+/-	+	+/-	**	**
	Agro-forestry	+		+/-	***	*
	Set-aside, land-use change	+	+	+	***	***
Grazing land management/ pasture improvement	Grazing intensity	+/-	+/-	+/-	*	*
	Increased productivity (e.g., fertilization)	+		+/-	**	*
	Nutrient management	+		+/-	**	**
	Fire management	+	+	+/-	*	*
	Species introduction (including legumes)	+		+/-	*	**
Management of organic soils	Avoid drainage of wetlands	+	-	+/-	**	**
Restoration of degraded lands	Erosion control, organic amendments, nutrient amendments	+		+/-	***	**
Livestock management	Improved feeding practices		+	+	***	***
	Specific agents and dietary additives		+		**	***
	Longer term structural and management changes and animal breeding		+	+	**	*
Manure/biosolid management	Improved storage and handling		+	+/-	***	**
	Anaerobic digestion		+	+/-	***	*
	More efficient use as nutrient source	+		+	***	**
Bioenergy	Energy crops, solid, liquid, biogas, residues	+	+/-	+/-	***	**

Notes:

1 + denotes reduced emissions or enhanced removal (positive mitigative effect);
- denotes increased emissions or suppressed removal (negative mitigative effect);
+/- denotes uncertain or variable response

2 A qualitative estimate of the confidence in describing the proposed practice as a measure for reducing net emissions of greenhouse gases, expressed as CO_2-eq
Agreement refers to the relative degree of consensus in the literature (the more asterisks, the higher the agreement);
Evidence refers to the relative amount of data in support of the proposed effect (the more asterisks, the more evidence).

Table 4.14 Overview of existing assessment and their relationship to agriculture. Source: Zurek and Henrichs, 2006.

	IPCC / IPCC-SRES	UNEP - GEO-3	MA	IFPRI 2020	FAO AT 2015/ 2030	CGIAR CA
Crop production levels and consequences for land	Some	Yes	Yes	Yes	Yes	Yes
Livestock production levels and consequences for land	Some	Yes	Yes	Yes	Yes	Yes
Fisheries (production and stocks)			Some	Some	Yes	Yes
Forestry		Some	Some		Yes	
Distribution		indirect	Indirect	indirect	Yes	indirect
Exchange		International trade	International trade	International trade	International trade	International trade
Affordability		Some	Yes	Yes	Yes	
Allocation		Market	Market	Market	Indirect	
Preferences			Yes	Yes	Yes	
Nutritional Value			Yes	Yes		Yes
Social Value						
Food Safety			Some		Some	
Relationship with environmental variables	Climate	Yes	Yes	Some	Some	Yes
Explicit description of AKST issues			Some	Some	Some	

Box 4.1 Assessing the future: projections and scenarios

Recent international forward-looking assessments have made use of a variety of different approaches to explore key linkages between driving forces and assess resulting future developments. The type of approaches employed range from forecasts, to projections, to exploring plausible scenarios. While these approaches differ substantially, they have in common that they set out to assess possible future dynamics and understand related uncertainties and complexity in a structured manner (Fig. 4.2)

Projection-based studies commonly present one (or even several) probable outlook on future developments, which is often mainly based on quantitative modeling. Commonly, such projections are based on reducing the level of uncertainty within a forward-looking assessment, either by addressing a limited time horizon or by focusing only on a sub-set of components of the socioeconomic and ecological system. Projections are particularly useful when they are compared against different variants to highlight expected outcomes of policy assumptions and well-defined options. Projections have also been referred to as future baselines, reference scenarios, business-as-usual scenarios, or best-guess scenarios, which usually hold many existing trends in driving forces constant.

Conversely, forward-looking assessments based on more exploratory approaches aim to widen the scope of discussion about future developments, or identify emerging issues. These types of assessments build on the analysis of alternative projections or scenarios that highlight a range of plausible future developments, based on quantitative and qualitative information. Such scenarios have been described as plausible descriptions of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces and relationships (MA, 2005a). Multiple projections or scenarios are most useful when strategic goals are discussed and reflected against a range of plausible futures, or when aiming to identify and explore emerging issues.

Determining the forward-looking approach best suited to address a specific issue depends much on the level and type of uncertainty for which one needs to account. Uncertainties have a range of sources, including the level of understanding of the underlying causal relationships (i.e. 'what is known about driving forces and their impacts?'), the level of complexity of underpinning system's dynamics (i.e. 'how do driving forces, impacts and their respective feedbacks determine future developments?'), the level of determinism of future developments (i.e. 'to what degree do past trends and the current situation pre-determine future developments?'), the level of uncertainty introduced by the time horizon (i.e. 'how far into the future?'), or even surprises and unpredictable future developments (either because these factors occur randomly or because existing knowledge is not able to explore them well enough) (for a discussion of different types of uncertainties and their consequences for methods to explore the future, see Van Vuuren, 2007). As a consequence, when assessments are faced only with relatively low levels of uncertainty with regard to future developments, some approaches allow predicting - or at least - projecting plausible future developments with some degree of confidence. Conversely, where the context of high uncertainty makes predictions or projections meaningless, exploratory scenario approaches can help explore possible developments.

Whereas different approaches to developing and analyzing projections and explorative scenarios exist, some common features have emerged in past assessments (see, for example, EEA, 2002). These include:

1. *Current state*, i.e. a description of the initial situation of the respective system, including an understanding of past developments that lead to the current state;
2. *Driving forces*, i.e. an understanding of what the main actors and factors are, and how their choices influence the dynamics of their system environment;
3. *Step-wise changes*, i.e. a description of how driving forces are assumed to develop and interact, and affect the state of a system along different future time steps;
4. *Image(s) of the future*, i.e. a description of what a plausible future may look like as a consequence of assumptions on drivers, choices and their interactions;
5. *Analysis* by looking across the scenarios to understand their implications and implied tradeoffs.

Box 4.2 Five commonalities in the innovation process

1. The process is fundamentally uncertain: outcomes cannot be predicted.
2. Innovation draws on underlying scientific or other knowledge.
3. Some kind of search or experimentation process is usually involved.
4. Many innovations depend on the exploitation of "tacit knowledge" obtained through "learning by doing" or experience.
5. Technological change is a cumulative process and depends on the history of the individual or organization involved."

Box 4.3 Genetically modified soybeans in Latin America

At the global scale, soybean is one of the fastest expanding crops; in the past 30 years planted area more than doubled (FAO, 2002). Of the world's approximately 80 million ha, more than 70% are planted in the USA, Brazil and Argentina (Grau et al., 2005). Argentina's planted area increased from less than a million ha in 1970 to more than 13 million ha in 2003 (Grau et al., 2005). Soybean cultivation is seen to represent a new and powerful force among multiple threats to biodiversity in Brazil (Fearnside, 2001). Deforestation for soybean expansion has, e.g., been identified as a major environmental threat in Argentina, Brazil, Bolivia and Paraguay (Fearnside, 2001; Kaimowitz and Smith, 2001). In part, area expansion has occurred in locations previously used for other agricultural or grazing activities, but additional transformation of native vegetation plays a major role. New varieties of soybean, including glyphosate-resistant transgenic cultivars, are increasing yields and overriding the environmental constraints, making this a very profitable endeavor for some farmers (Kaimowitz and Smith, 2001). Although until recently, Brazil was a key global supplier of non-GM soya, planting of GM soy has been legalized in both Brazil and Bolivia. Soybean expansion in Brazil increased; as did research on soybean agronomy, infrastructure development, and policies aimed at risk-reduction during years of low production or profitability (Fearnside, 2001). In Brazil alone, about 100 million ha are considered to be suitable for soy production. If projected acreage in Argentina, Brazil and Paraguay are realized, an overproduction of 150 million Mg will be reached in 2020 (AIDE, 2005).

Box 4.4 Controversies on bioenergy use and its implications

a) Net energy gains and greenhouse gas emissions

There are many studies on net energy gains, but results differ. These differences can often be traced to different technological assumptions, accounting mechanisms for by-products and assumed inputs (e.g. fertilizers). In some the production of ethanol from maize energy outputs has a small net gain (Farrell et al., 2006), while in others the net result is negative (Cleveland et al., 2006; Kaufmann, 2006; Hagens et al., 2006). Some other crops have a more positive energy balance, including ethanol from sugar cane, oil crops and conversion of cellulosic material (e.g., switchgrass) to second generation biofuels. The greenhouse gas balance, a function of production patterns and agroclimatic conditions, is also important. Maize ethanol in the U.S. is believed to cut GHG emissions only by 10 to 20% compared to regular gasoline (Farrell et al., 2006) but some other crops are reported to obtain better reductions, e,g., ethanol from sugarcane -- up to 90% reduction (CONCAWE, 2002;; Farrell et al., 2006; Hill et al., 2006) and biodiesel up to 50-75% (CONCAWE, 2002; IEA, 2004b; Bozbas, 2005; Hill et al., 2006). More conservative analyses represent a minority, but they point to potential flaws in the mainstream lifecycle analyses, most notably with respect to assumptions about land use and nitrous oxide emissions.

b) Costs of bioenergy

Studies on bioenergy alternatives generally find the low cost range from bioenergy to start at around $12-15 per GJ for liquid biofuels from current sugar cane to around US $15-20 per GJ for production from crops in temperature zones. In most cases, this is considerably more expensive than $6-14 per GJ for petroleum-based fuels crude oil price for oil prices from $30 per bbl to $70 per bbl. It is expected that costs of biofuels (especially the more advanced 2^nd^ generation technology) will be further reduced due to technology progress, but the actual progress rate is highly uncertain. Agricultural subsidies and the economic profitability also affect the value of emission reductions under different climate policy scenarios.

c) Impact on land use

A serious concern in the debate on biofuels is the issue of land scarcity and the potential competition between land for food production, energy and environmental sustainability. The production of 1^st^ generation biofuels from agricultural and energy crops is very land intensive. Land evaluation depends on 1) availability of abandoned agriculture land, 2) suitability of degraded lands for biofuel production and 3) use of natural areas. Obviously, biofuels can also compete with food production for current agricultural land and/or expansion of agricultural land into forest areas. Examples of this can already be seen where expansion of crop plantations for biofuels production have led to deforestation and draining of peatlands, e.g. in Brazil, Indonesia and Malaysia (Curran et al., 2004; FOE, 2005; FBOMS, 2006; Kojima et al., 2007).

d) Impact on food prices

As long as biofuels are produced predominantly from agricultural crops, an expansion of production will raise agricultural prices (for food and feed). This has now become evident in the price of maize (the major feedstock in U.S. ethanol production), which increased 56% in 2006. Analogous price rises are expected for other biofuels feedstock crops in the future (OCED, 2006; Rosegrant et al., 2006). This increase in price can be caused directly, through the increase in demand for the feedstock, or indirectly, through the increase in demand for the factors of production (e.g. land, water etc.). More research is needed to assess these risks and their effects but it is evident that poor net buyers of food would suffer strongly under increasing prices. Some food-importing developing countries would be particularly challenged to maintain food security.

e) Environmental implications

Whereas implications for the environment are relatively low for current small-scale production levels, high levels of biofuels feedstock production will require considerable demand for water and perhaps, nutrients. Some studies have indicated there could be tradeoffs between preventing water scarcity and biofuel production (CA, 2007). Bioenergy production on marginal lands and the use of agricultural residues could negatively affect soil organic matter content (Graham et al., 2007).