Globalands

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Global Land Use Scenarios: Findings from a review of key studies and models

GLOBALANDS Working Paper AP 1.3

prepared by

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List of Acronyms

BMU	German Federal Ministry for Environment, Nature Protection and Nuclear Safety
BMZ	German Federal Ministry for Economic Cooperation and Development
CBD	Convention on Biological Diversity
CCD	United Nations Convention to Combat Desertification
CDM	Clean Development Mechanism (under the Kyoto Protocol of the FCCC)
CO_2	Carbon dioxide
COP	Conference of the Parties
EC	European Commission
EEA	European Environment Agency
EPA	US Environmental Protection Agency
ETS	Emissions trading scheme
FAO	Food and Agriculture Organization of the UN
FSC	Forest Stewardship Council
GDP	Gross domestic product
GEF	Global Environmental Facility
GHG	Greenhouse gas(es)
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IINAS	International Institute for Sustainability Analysis and Strategy
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
LPI	Living Planet Index
LULUCF	Land use, land-use change and forestry
MDG	Millennium Development Goal
MA	Millennium Ecosystem Assessment
MSA	Mean species abundance
OECD	Organisation for Economic Co-operation and Development
PA	Protected area
PBL	Netherlands Environmental Assessment Agency
R&D	Research and development

REDD	Reduced Emissions from Deforestation and Degradation
RoW	Rest of the world
RSPO	Roundtable on Sustainable Palm Oil
SEI	Stockholm Environment Institute
tOE	Tons of oil equivalent
UBA	German Federal Environment Agency
UN	United Nations
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

Zusammenfassung

Das vorliegende Arbeitspapier zu AP 1.3 systematisiert die **Perspektiven** der globalen Landnutzung unter **Variation** relevanter Schlüsselfaktoren auf Basis **vorhandener** Projektionen und entsprechender Szenarien mit den Zeitbezügen 2030 und 2050. Es liefert damit eine **konsistente Übersicht** der verschiedenen globalen Szenarien und Studien zur künftigen Landnutzung und den daraus ableitbaren Handlungsspielraum.

Globale Projekte und Studien, die hierfür herangezogen wurden sind u.a.:

- OECD Environmental Outlook 2050 (OECD 2012),UNEP GEO-5 Global Environment Outlook
- Bericht des High Level Panel on Sustainability (GSP) des UN-Generalsekretärs
- Studien von FAO (2009-2012), Weltbank (2010) sowie des WBGU (2008-2011)

Weiterhin wurden die Ergebnisse globaler Modelle betrachtet:

- IMAGE (Integrated Model to Assess the Global Environment) von PBL,
- PoleStar(integrated sustainability/long-range scenario analysis) von Tellus und
- GLOBIOM von IIASA.

Die Ergebnisse der Durchsicht dieser Szenarien und Modelle ergab eine **dominante Rolle** des künftigen Agrar- und Ernährungssystems. Daher wurden weitere Studien und Modelle zu diesem Bereich analysiert, insbesondere Beddington et al. (2012), Foresight UK (2011), HFFA (2011), IAASTD (2009), NRC (2010) und WEF (2012).

Die Analyse der wesentlichen Treiber ergab neben der Landwirtschaft und dem Bedarf an Nahrungsmitteln sowie deren Zusammensetzung auch die Bevölkerungsentwicklung, die Landnutzungspraktiken sowie – vor allem in regionaler Hinsicht – die Rolle der Bioenergie, die eine potentiell positive Rolle in Bezug auf Landdegradation und ländliche Entwicklung haben kann, jedoch hierfür einer klaren Steuerung in Richtung Nachhaltigkeit der Produktion bedarf.

1 Analysis of Scenarios on Global Land Use: Overview

1.1 Scope of Work

This working paper of the GLOBALANDS project work package 1.3 compiles **existing** projections on global land use and respective scenarios for 2030 and 2050. It is based on an overview of studies and models. The paper takes into account the **variation** of relevant parameters between scenarios to derive a synopsis of key "drivers" of future global land use which will be used in later project phases.

1.2 Scenario Studies and Models Analyzed

From the variety of global models and scenarios which project future land use, a subset was selected based on the following criteria:

- Adequacy: scenarios should be recent to capture post-2005 developments, i.e. published from 2009 onwards
- Documentation and access: scenarios should be described in (some) detail, and models used should be (publically) accessible
- Relevance: the studies/models should be related to (global) policy development, i.e. commissioned or prepared by respective actors and institutions
- Scope: agriculture, forestry, energy/transport, urbanization
- Time horizon: 2030 (minimum) and 2050 (reference)

Using these filter criteria, the broad variety of studies and respective models were qualitatively screened based, and the following candidates were derived:

- UNEP Global Environment Outlook 2012 (GEO-5) and OECD Environmental Outlook 2050 (OECD 2012)
- Studies of FAO (2009-2012) and World Bank (2010), analyses of EEA (2010-2012) and WBGU (2009, 2011)
- Models IMAGE (Integrated Model to Assess the Global Environment; PBL), PoleStar (integrated sustainability/long-range scenario analysis; Tellus) and GLOBIOM (IIASA).

Due to results from the screening which indicate the prominent role of the future food and agriculture system, further studies where considered, especially Beddinton et al. (2012), Foresight UK (2011), HFFA (2011), IAASTD (2009), NRC (2010), and WEF (2012).

2 Comparative Analysis of Scenarios and Model Results

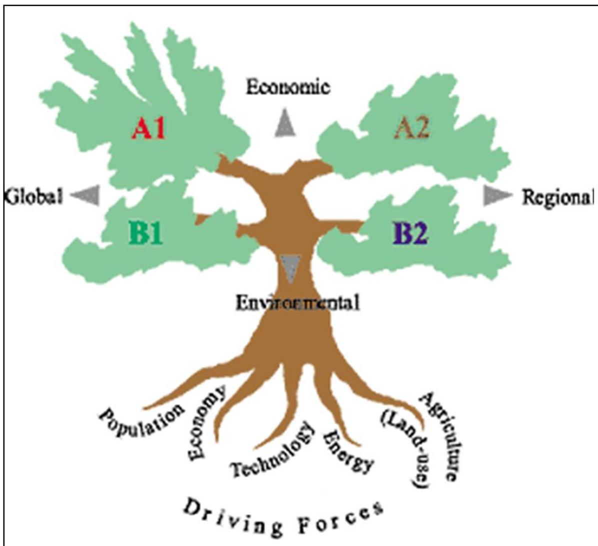
Scenarios and respective models are means to **explore** the unknown, as the future is, by definition, not known today. Since the 1970s, various approaches to **model** the future have been developed, with a rich discussion in the 1990s and 2000s. Since that time, a broad scientific consensus was reached that global modeling requires a certain methodology which relies on the (participatory) development of consistent storylines, followed by transparent modeling (Alcamo 2001).

The scenarios and models analyzed in this paper all follow this consensus.

2.1 Major Storylines

A milestone in global modeling was reached by the IPCC Special Report on Energy Scenarios (SRES) in 2000 which laid down the basic metrics of scenario development by providing four fundamental “storylines” (see following figure).

Figure 1 The IPCC SRES storylines



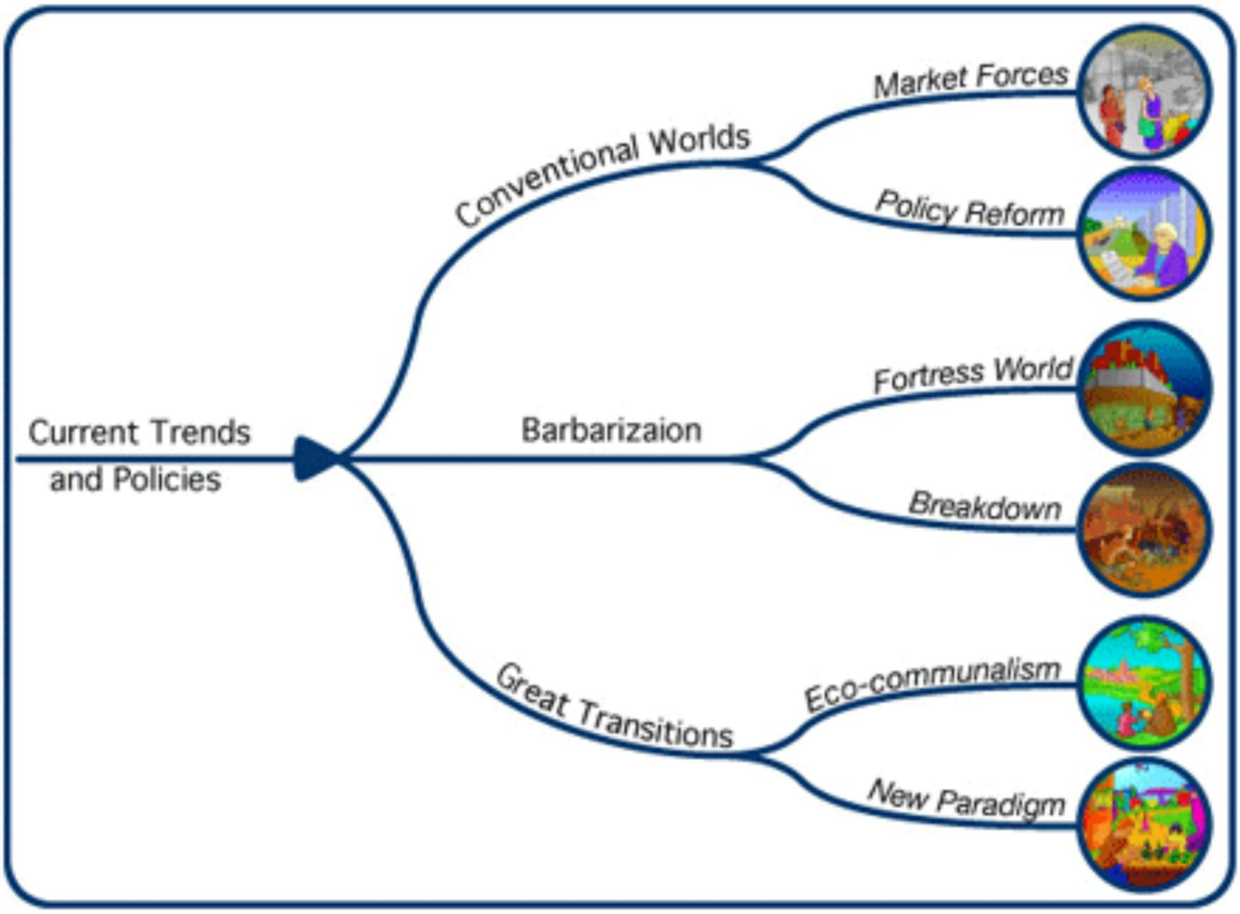
The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income.
The 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 high population growth. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower.
The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes 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.
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 moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines.

Source: IPCC (2000)

The IPCC quadrants A1, A2, B1 and B2 describe the key future storylines which were taken up by many later studies.

Tellus Institute together with SEI formed the Global Scenario Group (GSG) which developed several scenarios using its PoleStar model, especially “Bending the Curve”, and “The Great Transition” (Tellus 2009+2010) which were used in UNEP’s GEO report series. The GSG scenario storylines are shown in the following figure.

Figure 2 The Global Scenario Group “Great Transition” storylines



Source: Tellus (2010)

The GSG aggregated these storylines into four major scenarios, as shown in the following table.

Table 1 The GSG Scenarios

Type	Name	Description
Conventional Worlds	Market Forces (MF)	Market-centered growth-oriented globalization
	Policy Reform (PR)	Government-led redirection of growth toward sustainability goals
Alternative Visions	Fortress World (FW)	An authoritarian path in response to mounting crises
	Great Transition (GT)	A fundamental transformation

Source: Tellus (2010)

From 2000 onwards, several other global scenarios were developed using the similar logic to structure "future worlds", as indicated in the following figure.

Figure 3 Global scenario structures and storylines

Study	Horizon	Regions	Focus	Scenario Structure
GSG	2050	11	Environment; poverty reduction; human values	1. *Conventional Worlds:* gradual convergence in incomes and culture toward dominant market model a) *Market Forces:* market-driven globalization, trade liberalization, institutional modernization b) *Policy Reform:* strong policy focus on meeting social and environmental sustainability goals 2. *Barbarization:* social and environmental problems overwhelm market and policy response a) *Breakdown:* unbridled conflict, institutional disintegration, and economic collapse b) *Fortress World:* authoritarian rule with elites in "fortresses," poverty and repression outside 3. *Great Transitions:* fundamental changes in values, lifestyles, and institutions a) *Eco-Communalism:* local focus and a bio-regional perspective b) *New Sustainability Paradigm:* new form of globalization that changes the character of industrial society
GEO-3	2032	6	Environment	*Markets First; Policy First; Security First; Sustainability First* (correspond, respectively, to 1a, 1b, 2b, and 3b above)
SRES	2100	4	Climate change	*A1:* rapid market-driven growth with convergence in incomes and culture *A2:* self-reliance and preservation of local identities, fragmented development *B1:* similar to *A1*, but emphasizes global solutions to sustainability *B2*: local solutions to economic, social, and environmental sustainability
WBCSD	2050	n.a.	Business and sustainability	*FROG!:* market-driven growth, economic globalization *GEOpolity:* top-down approach to sustainability *Jazz:* bottom-up approach to sustainability, ad hoc alliances, innovation
WWV	2025	18	Freshwater crisis	*Business-as-usual:* current water policies continue, high inequity *Technology, Economics, and the Private Sector:* market-based mechanisms, better technology *Values and Lifestyles:* less water-intensive activities, ecological preservation
OECD	2020	10	Environment in OECD countries	*Reference* with policy variants (e.g., subsidy removal, eco-taxes)

Key: GSG Global Scenario Group, GEO-3 Global Environment Outlook, SRES Special Report on Emissions Scenarios, WBCSD World Business Council on Sustainable Development, WWV World Water Vision, OECD Organisation for Economic Co-operation and Development

Source: Carpenter et al. (2005)

Beyond the aggregate narrative logic of the storylines, scenarios are built from many more parameters and variables including, in particular, "driving forces".

Depending on the model used to project world development, some of these parameters can be derived from (other) modeling, e.g. biophysical, engineering or economic, while the majority of variables will be exogenous to the model, i.e. taken from the literature, expert judgments, or trend projections.

A recent good example is given in Foresight UK (2011) which summarizes the approach taken in the UK project on future food and agriculture in which many more parameters were varied to derive scenario storylines, as indicated in the following table.

Table 2 Storyline parameters for the UK Foresight scenarios on food and agriculture

Item	Source	Variation	Modeling domain
population growth	exogenous	high, medium and low growth	demand
income growth	exogenous	high, medium and low growth	demand
governance	exogenous	agricultural support and trade policies, including changes in subsidies and protectionism versus open trade strategies	policies
growth in crop yield	exogenous	various assumptions	production
water	exogenous	competition for water and irrigation efficiency	production
climate change	global circulation models	various climate change scenarios	production
particular climate shocks	exogenous	droughts, simultaneously affecting production in a few countries, with different trade policy responses	production, policies
energy prices	exogenous	significant increase	production
trade	exogenous	major overall increase in protectionism	policies
food	exogenous	increase in the demand for meat: focus on demand shifts in India and China	demand

Source: own compilation based on Foresight UK (2011)

The overall logic of scenario storylines is a consistent system helpful in giving an overall orientation, but to allow for identifying key drivers between scenarios developed by different authors using different models (see next section), a more refined scenario analysis is suggested here which uses a **multi-dimensional** approach according to the metrics shown in the following table.

Table 3 Metrics of the multi-dimensional scenario analysis

Axis	Item
t_i	Time (2010, 2030, 2050 etc.)
x_i	Drivers (key sectoral parameters of sub-models, e.g. population, GDP, agro and forestry products)
y_i	Environmental indicators (e.g. GHG emissions in CO_2 equivalents, land use, non-renewable primary energy use, and non-renewable raw materials)
z_i	Social effects (e.g. employment, access to modern energy, food security)

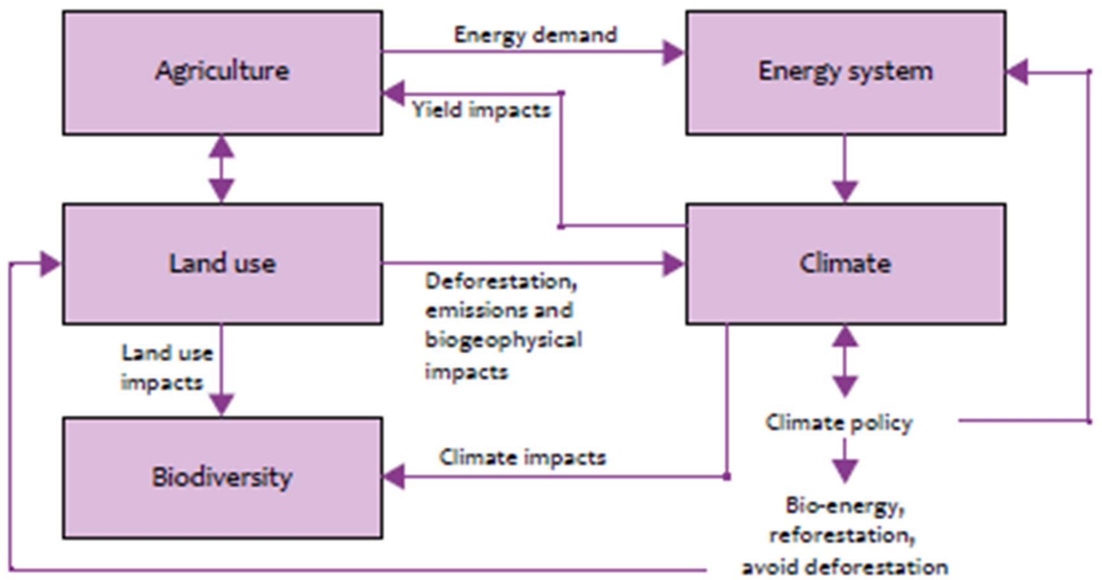
Source: own compilation; the index refers to more sub-dimensions

The basic structure of this matrix was established in Excel, and data compilation is, due to the large number of data items, still ongoing.

2.2 Modeling Approaches

Beyond the scenario descriptions and their choice of parameters, there is a very broad range of models used to project the world development over time. With regard to land use, most models use either a biophysical "core" (with different spatial resolution), or an economic approach based on (empirical or assumed) elasticities, or a hybrid of both. The principal relations between key sectors and model components are shown in the following figure.

Figure 4 Thematic relationships, trade-offs and interlinkages in models



Source: PBL (2009)

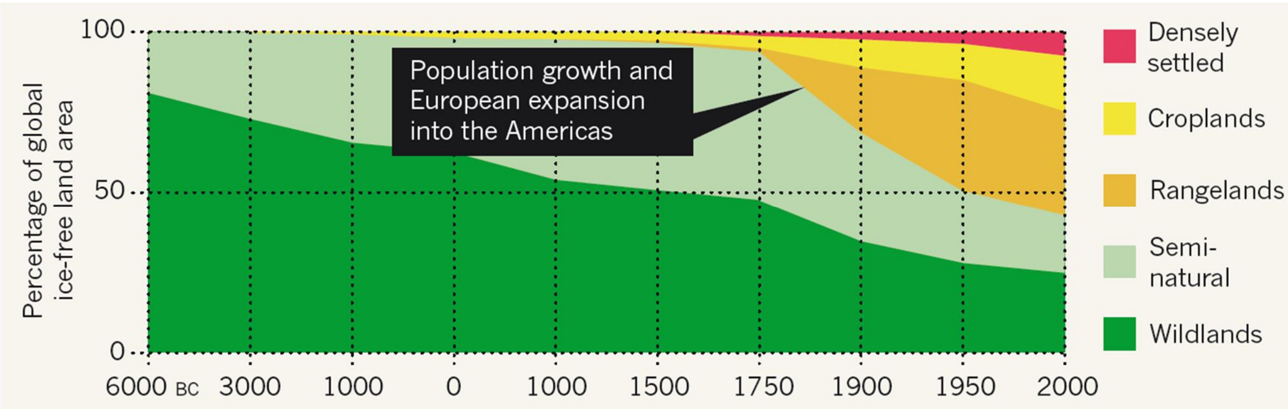
Most models represent the interactions between food/feed, fiber and bioenergy, and the respective feedbacks (prices, climate, water…) through coupling of several sub-models which are "specialized" to transform input variables into model results.

This allows flexibility in data handling and use of different formats (metric, spatial and sectoral aggregation), but creates problems in the validation of model outcomes. This should be kept in mind when discussing the results of global models.

2.3 Global Land Use Results and Related Impacts

To calibrate land use related global models there is a wealth of data available over long time periods. Research has "reconstructed" the global land use dynamic of the past 8,000 years with some level of certainty, as indicated in the following figure.

Figure 5 Transformation of the Biosphere from 6000 BC to 2000 AD



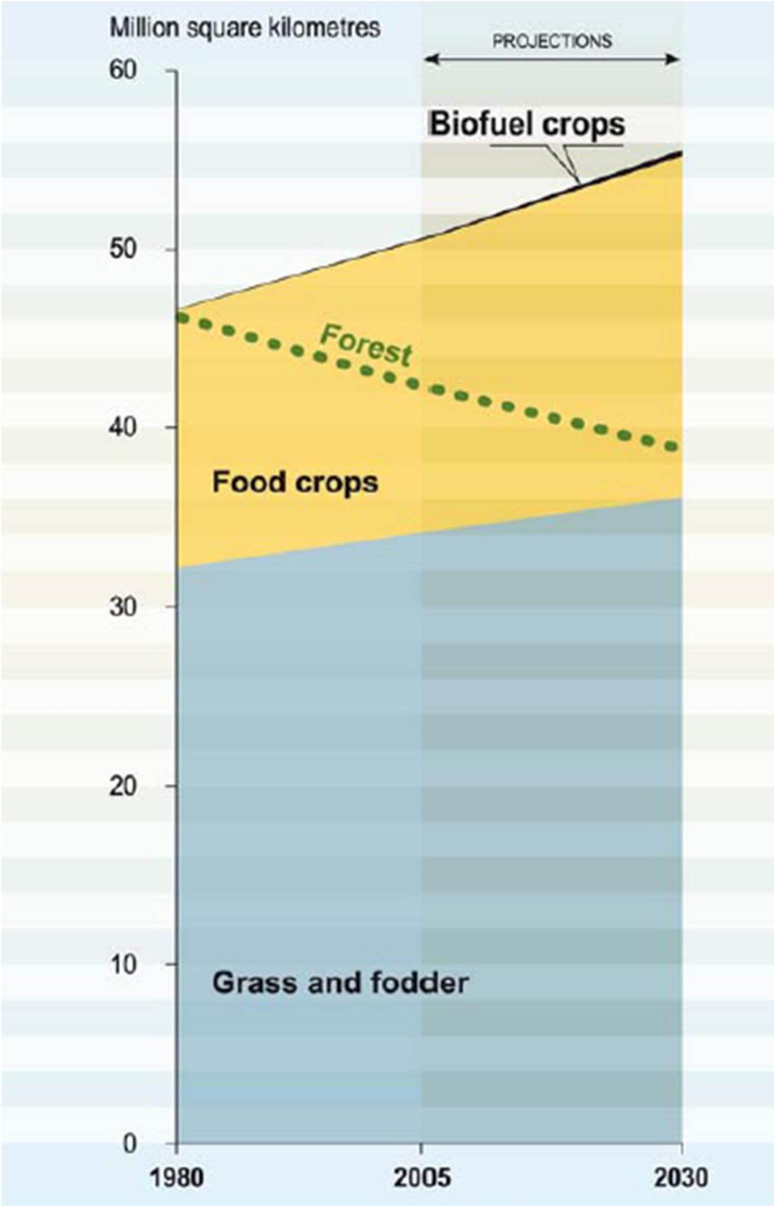
Source: WBGU (2011), based on Jones (2011)

Since the 18th century, human interference with the global land system became significant, transforming wilderness into croplands and pasture, and settlements.

The figure above indicates that today there is human intervention on more than 50 % of global land (ice-free land mass).

This trend will continue in "business-as-usual" scenarios, especially regarding cropland and pasture, and the transformation of forested areas to agricultural production, as indicated in the following figure which represents results from the EEA analysis of major global trends (EEA 2010a).

Figure 6 Projections of changes in global farmland until 2030

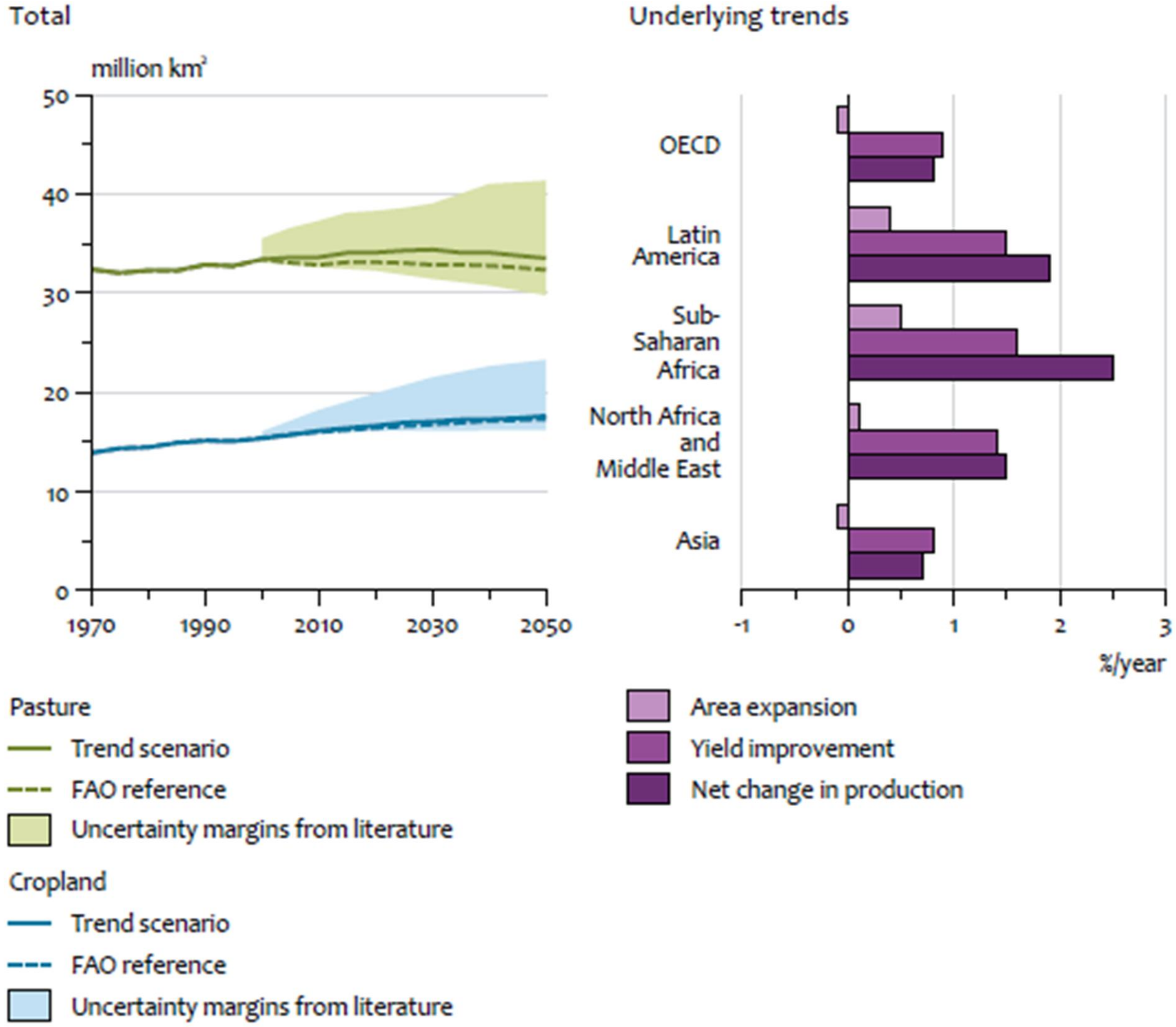


Source: EEA (2010a)

The EEA analysis and other comparable global scenario analyses indicate that the key “drivers” for future land use will be the agricultural production systems, especially the food-feed subsystem.

The results of the PBL analysis of global land use is shown in the following figure which provides a regional breakdown, and gives an indication of the overall uncertainty of the model results.

Figure 7 Global land use for food and feed production in a trend scenario to 2050



Source: PBL (2009)

These fundamental findings are very robust, as the overall linkages between food, feed and respective land use are well understood, and rely on a broad empirical base.

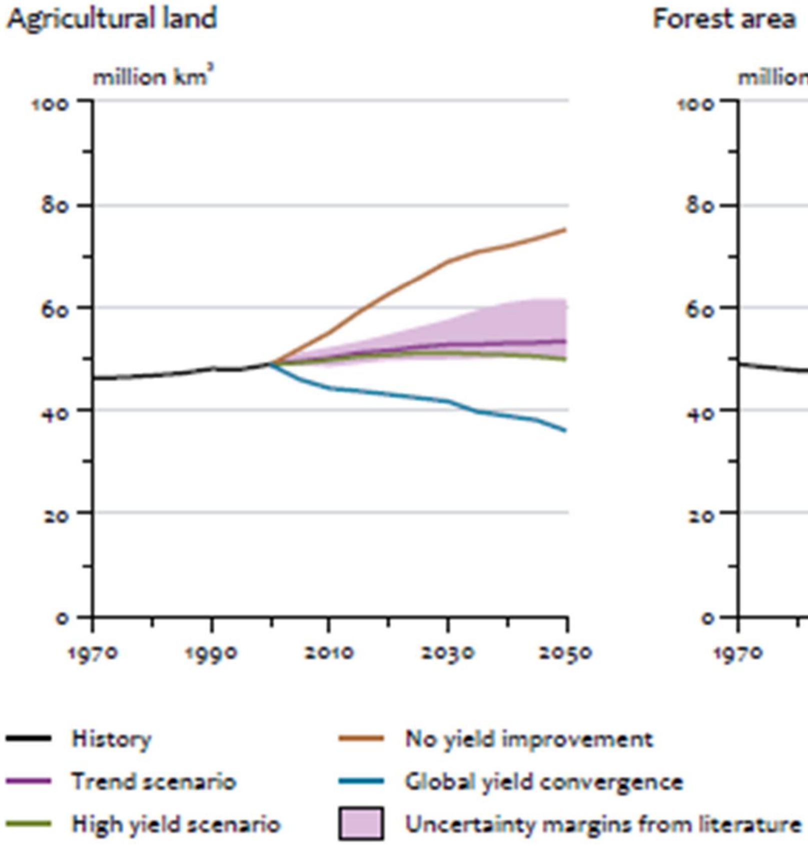
The key uncertainty in the future land use dynamic is the development of demands for agricultural products, and trends in yields of different cultivation systems.

The combination of both gives the answer to the net area expansion (if any), and the internal transformation between cropland and pasture.

All global models and scenarios also indicate the inverse relation between agricultural and forest land:

The century-old trend to convert forested areas into agricultural land will continue at least until 2050, as indicated in the following figure.

Figure 8 Global agricultural and forest land use scenarios up to 2050



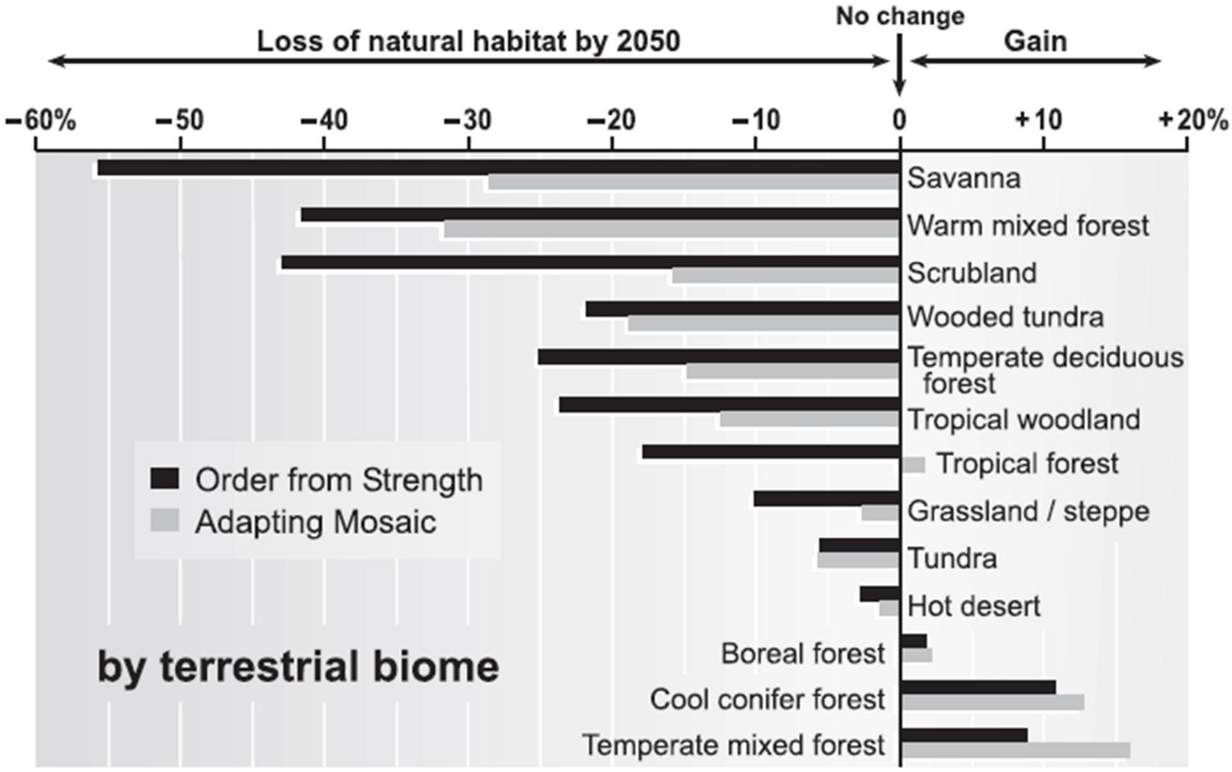
Source: PBL (2009)

The global yield development is a key variable affecting forest land (at given demand levels). In a "high yield" future, forest land could increase slightly, while a world without yield increases would face a stronger deforestation dynamic.

Not only forests will be affected by future land use demands from agriculture, but also savannah and grasslands. With that, changes in habitats and respective biodiversity impacts will be the consequence.

The following figure shows the balance of natural habitats up to 2050 in the MA scenarios which are very close to the PBL baseline.

Figure 9 Natural Habitat Change from 1970 to 2050 in Millennium Ecosystem Assessment



Source: Carpenter et al. (2005)

These results clearly indicate that there could be gains in the overall forest land in boreal and temperate climates, while savannahs and warmer forests will face significant losses.

The PBL scenarios tried to translate this expected shift into a biodiversity response indicator, using the mean species abundance in several biomes as a proxy.

The respective results shown in the following figure are consistent with the MA findings shown above.

Figure 10 Historic and future (baseline) global biodiversity developments

Source: PBL (2009)

2.4 Summary of Global Land Use Scenario and Model Analysis

The results from the key global land use studies give a clear and robust message: up to 2050, the trend (business-as-usual) will imply a **significant shift** in land use from (natural or semi-natural) forested areas and savannahs towards agricultural systems.

The land use changes will be distributed unevenly between industrialized, developing and emerging countries, and also geographically.

Within the agricultural land, a transformation of pasture and grassland towards arable land will occur, though with significant differences between world regions.

The respective impacts in terms of biodiversity, GHG emissions, and water are substantial and will increase over time.

Major uncertainties of these trends and baseline projections are in the future yield development which is subject to climate change feedback and in the overall demand for agricultural and forest products.

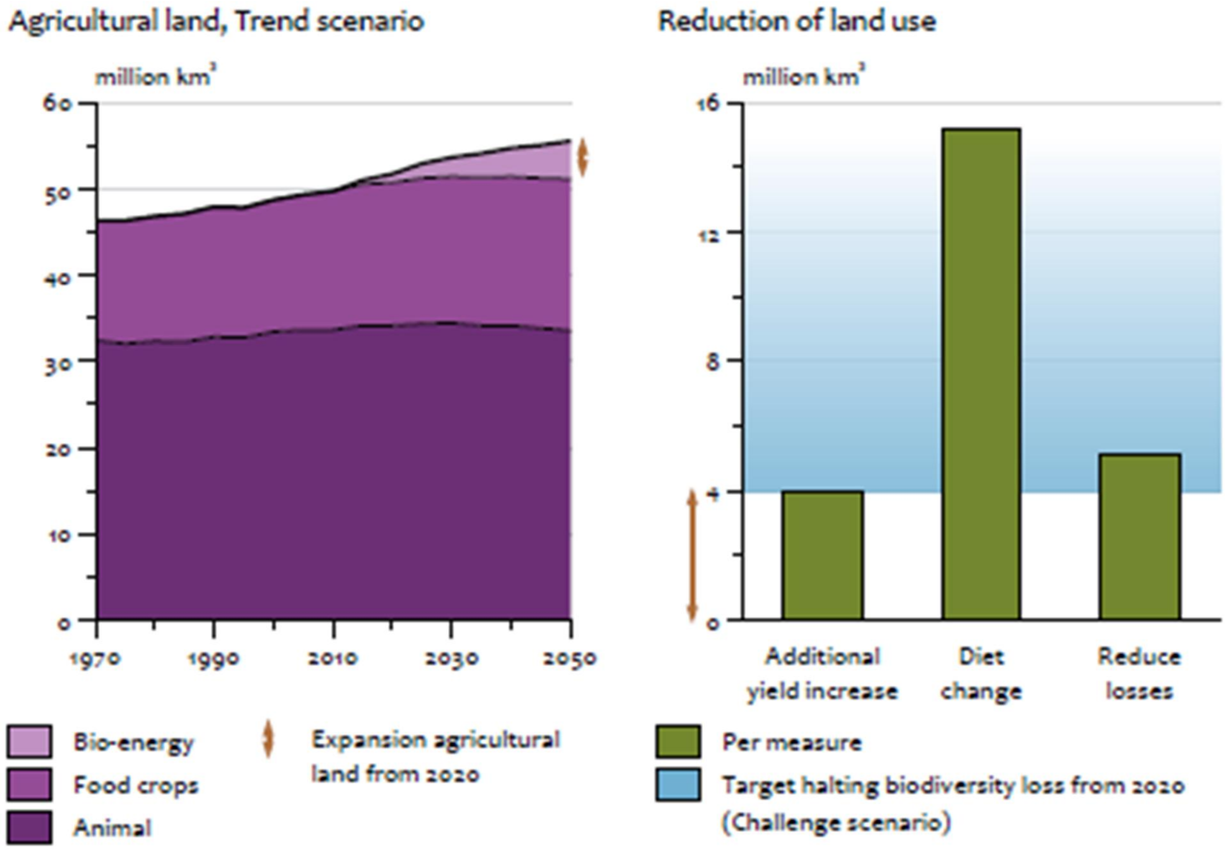
The role of bioenergy (and biofuels) in these scenarios is noteworthy, but a comparatively small share of the overall drivers. Still, studies on land use implications of biofuels indicate that there could be **significant regional** impacts, especially in tropical countries in Sub-Saharan Africa, Latin America, and Southeast Asia.

2.5 Great Transformation Scenarios and Land Use Related Impacts

Given the important role of future agriculture in global land use, many studies have tried to identify alternative development pathways and scenarios. The underlying idea is to avoid the negative impacts of the trend scenarios through implementing mitigation policies and measures, or a more ambitious “Great Transformation”.

The following figure shows the global agricultural land projection for the trend scenario of PBL, and the respective reduction options through changes in the food system.

Figure 11 Agricultural land use in trend scenario to 2050 and reduction options



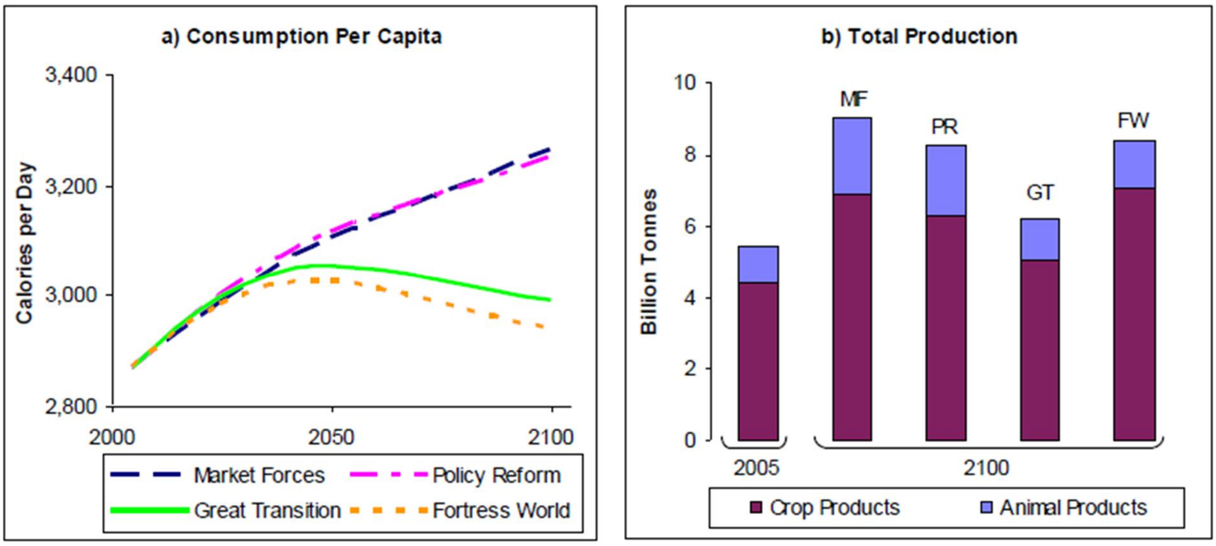
Source: PBL (2009)

This result underlines that (assumed) additional yield increased – beyond the ones already assumed in the trend scenario – could play some role in reducing land use for agriculture[1], but changes on the **demand side** would allow far more reductions.

[1] This would imply trade-offs with regard to agrobiodiversity, fertilizer use and respective GHG emissions and water pollution, though. PBL has published respective work later.

This has been explored in more detail by PBL in a late study (PBL 2010), and by the GSG team in the Great Transformation scenarios, as shown in the figure below.

Figure 12 Results of the GSG "Great Transformation" scenarios



Source: Tellus (2010)

Changes in food consumption per capita – and in the composition of the diet with regard to cereals, dairy products and meat – can lead to a significant reduction in agricultural land use, and respective reductions in deforestation, and other land conversion.

Tellus (2010) and PBL (2010) also researched other implications of such changes and found that positive trade-offs regarding biodiversity, employment, human health and GHG emissions would occur.

PBL (2010) and the EU FP7 project EUPOPP further researched the distributional effects of sustainable European food policies, i.e. the impacts on land, emissions and farmers outside of Europe and found positive results for those as well.

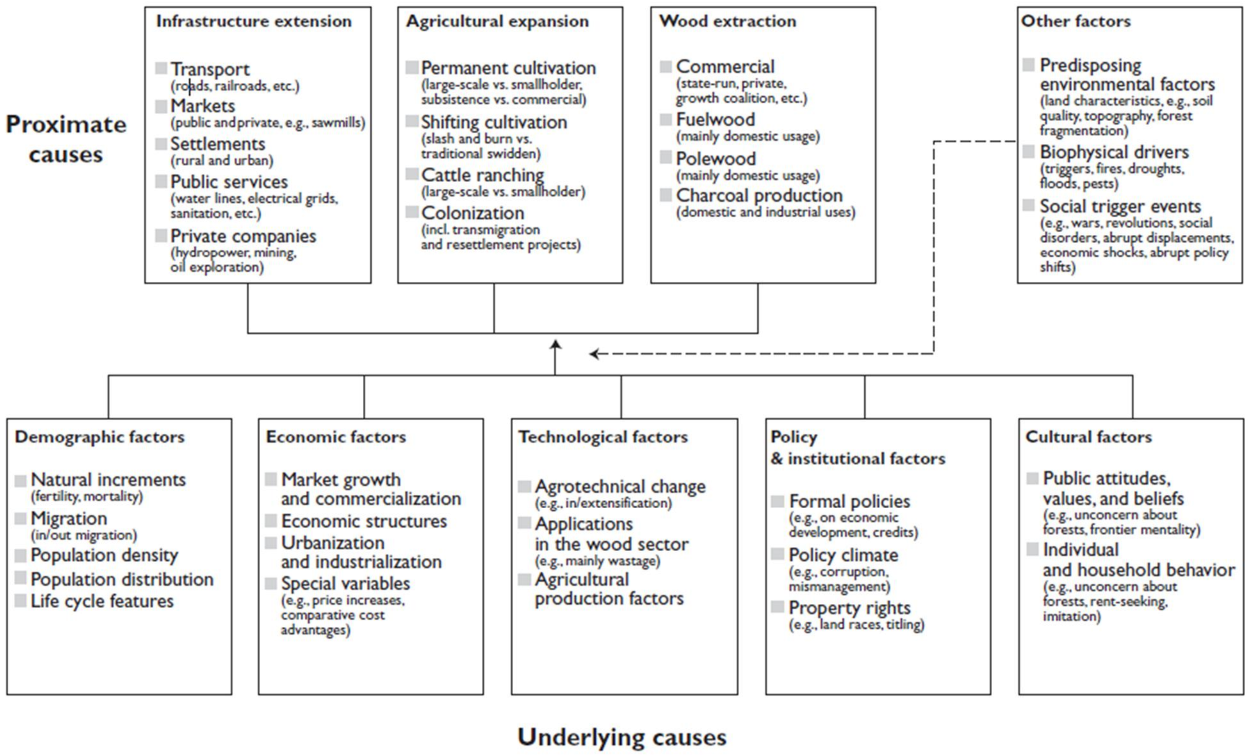
Other recent studies looked into the global land use implications of bioenergy and biofuels, and indicated that there is also some opportunity to avoid negative implications if non-arable land is used to cultivate biomass feedstocks. There are potential negative trade-offs on the biodiversity and social side, though, which would need respective safeguards.

3 Interpretation of Scenario Results Regarding Key Drivers

The disaggregation of the scenario and model results regarding key drivers for future negative (and positive) developments regarding land use cannot be easily done without running the models in analytical modes. Still, with a comparison of relevant scenario inputs, some first important insight can be gained.

With regard to land use modeling, the following figure provides a generic scheme which relates the key model components to input variables.

Figure 13 Drivers: "proximate" and "underlying" causes

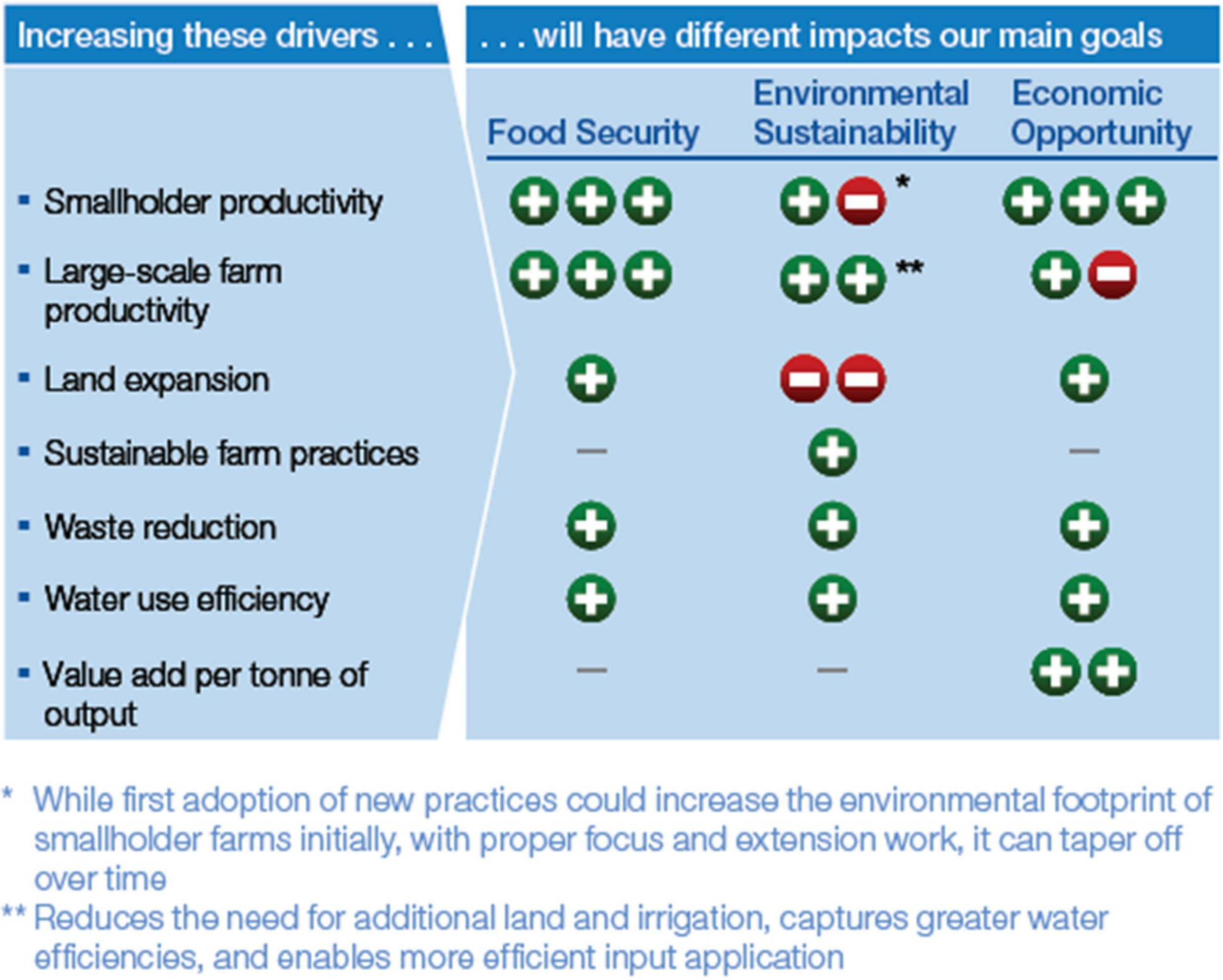


Source: Geist, Lambin (2002)

As it is not possible to test the influence of these parameters on model results without full access to the models (and significant time to perform such calculations), a comparative **qualitative analysis** of model inputs and scenario storylines should be seen as a first step.

For this, the following figure gives a causal relation pattern between changes in input variables (drivers) and model results for agricultural systems.

Figure 14 Drivers and impacts – example of agriculture



Source: WEF (2012)

Based on a meta-analysis of many scenario studies and models, the US-base Committee on 21st Century Systems Agriculture of the National Research Council (NRC) released a comprehensive report analyzing future options of the US (and Sub-Saharan Africa) agriculture to meet sustainability goals, and argued in its report:

"The committee concluded that if U.S. agricultural production is to meet the challenge of maintaining long-term adequacy of food, fiber, feed, and biofuels under scarce or declining resources and under challenges posed by climate change and to minimize negative outcomes, agricultural production will have to substantially accelerate progress toward the four sustainability goals. Such acceleration needs to be undergirded by research and policy evolution that are designed to reduce tradeoffs and enhance synergies between the four goals and to manage risks and uncertainties associated with their pursuit. (…)

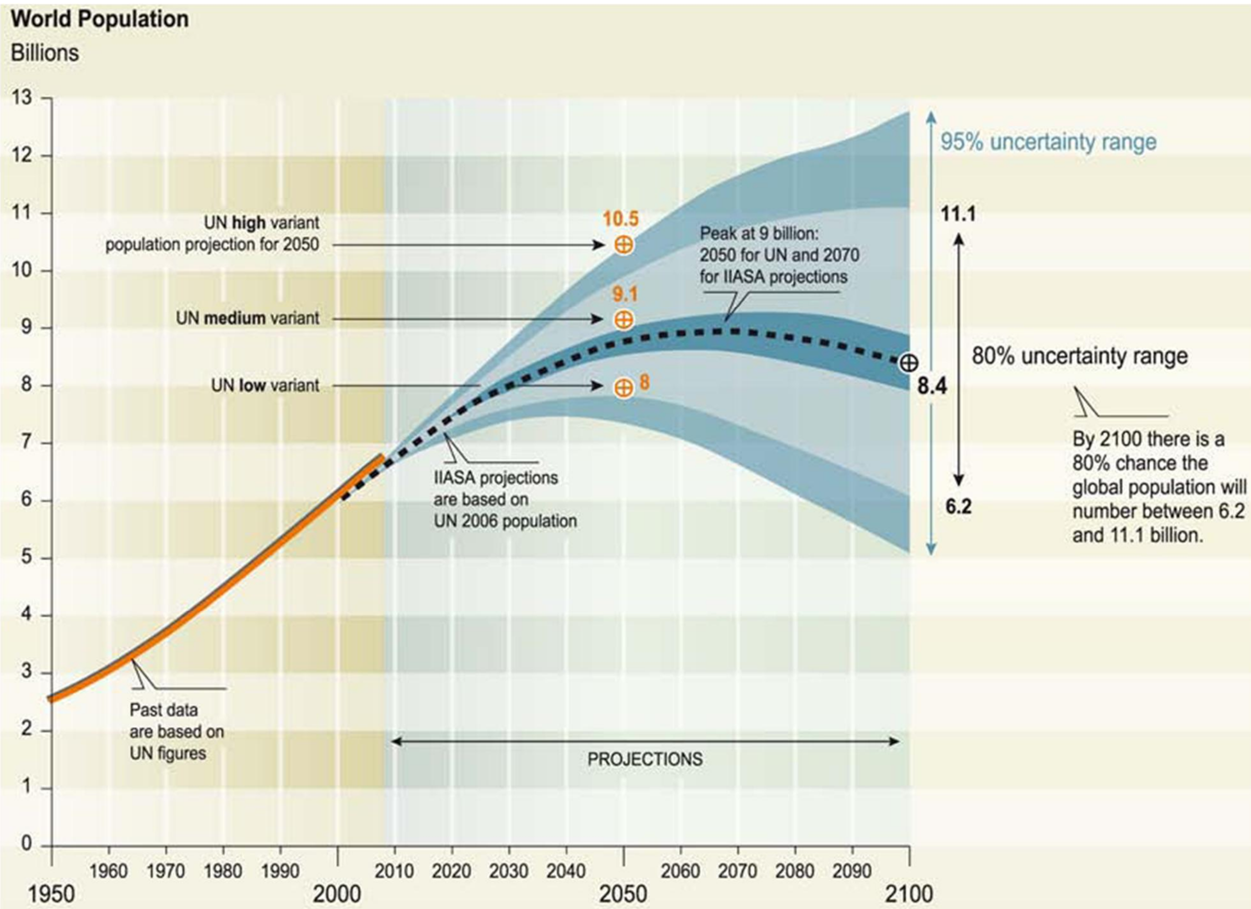
The committee proposes two parallel and overlapping efforts to ensure continuous improvement in the sustainability performance of U.S. agriculture: incremental and transformative. The incremental approach is an expansion and enhancement of many ongoing efforts that would be directed toward improving the sustainability performance of all farms, irrespective of size or farming systems type, through development and implementation of specific sustainability-focused practices, many of which are the focus of ongoing research and with varying levels of adoption. The transformative approach aims for major improvement in sustainability performance by approaching 21st century agriculture from a systems perspective that considers a multiplicity of interacting factors.“ (NRC 2010, pp. 520 + 552)

Similarly, the UK Foresight on Agriculture and Food (Foresight 2011) analyzed a variety of drivers and impact factors based on a very extensive research process. Its findings are taken up in the following sub-sections.

3.1 Population Dynamic

A fundamental driver of future land use is, without doubt, population growth. Still, population dynamics are subject to a broad variety of influencing factors, and some of those are correlated with outcomes of agricultural assumption (e.g. education level, food security, health, income, rural employment) so that there is an internal feedback loop. Not surprisingly, one can find a significant range of global population projections for 2050 and beyond, as indicated in the following figure.

Figure 15 Range of future population projections in global models

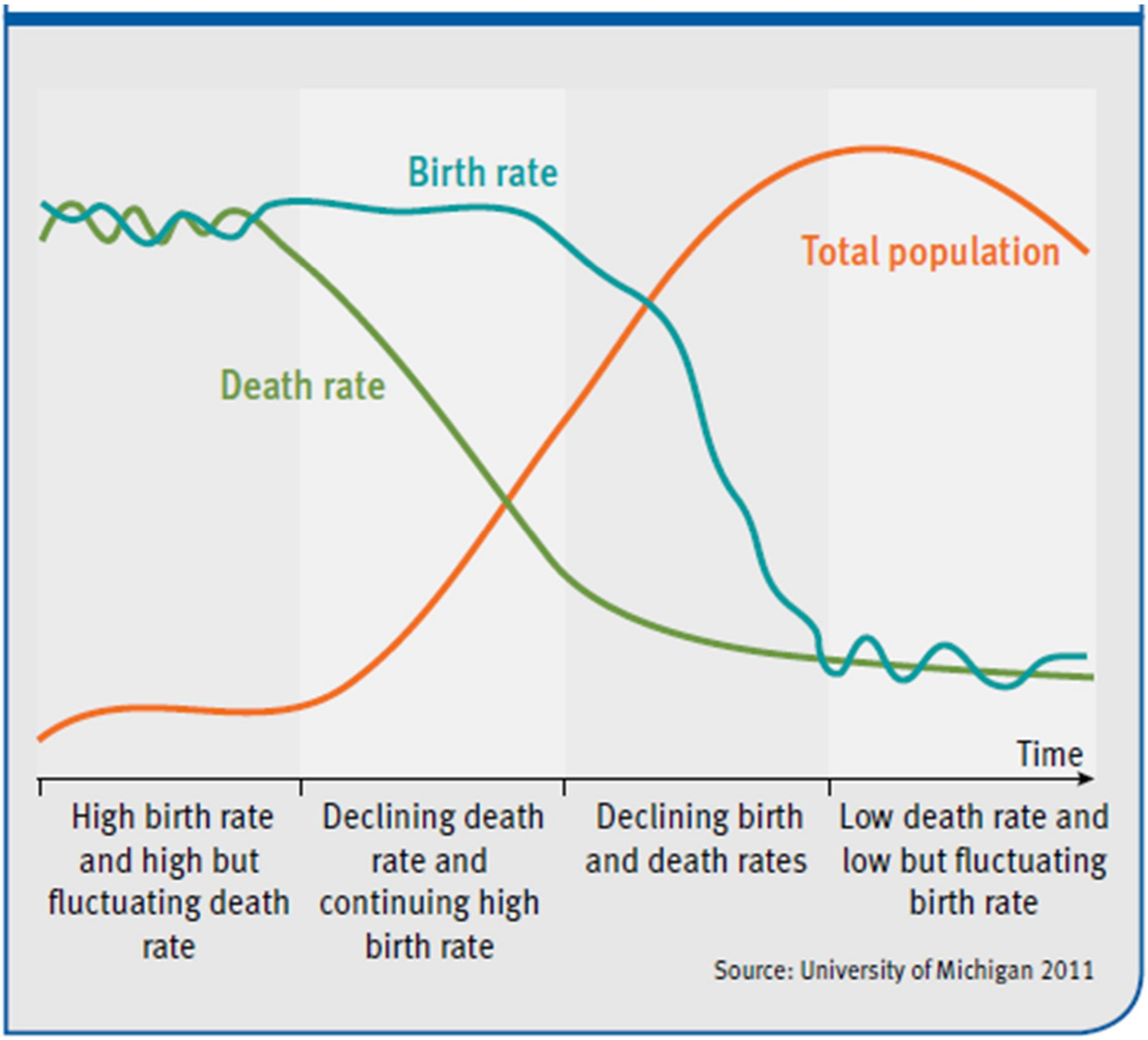


Source: EEA (2010a)

To take population as an **exogenous** variable which is independent of modeling and scenario assumptions seems arbitrary and inconsistent with the known factors influencing, for example, fertility. Thus, more analytical emphasis should be given to consistent projections of global population dynamics under "Great Transition" scenario assumptions, as preliminarily carried out by the GSG team (Tellus 2009+2010).

Key to this is the concept of the "Demographic Transition" (see following figure).

Figure 16 Scheme of the Demographic Transition



Education is recognized as a basic human right included in §26 of the Universal Declaration of Human Rights (UN 1948). Achieving universal primary education is also part of the Millennium Development Goals (MDG), 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[2]. Increasing investment in education has been correlated with declining fertility, rising incomes and greater longevity (Bulled, Sosis 2010), and an educated human population is also able to express greater concern about environmental matters (White, Hunter 2009).

Population growth will probably be most rapid in the Middle East, sub-Saharan Africa and Northern Africa, with a tripling of the population by 2050 and a quadrupling by 2100 likely. Owing to high population growth, the least developed countries have a large and rapidly expanding youth population. Today, about 60 per cent of their population is under the age of 25, and by 2050 the population in this age group will expand by an additional 60 per cent. An expanding youth population makes it difficult for countries to maintain or increase per-capita spending on young people – for example on health and education which is the key for sustainable development (UNFPA 2012).

In contrast, in Eastern Europe and the European part of the former Soviet Union, population will probably decrease over the coming decades. By 2050 the Pacific OECD countries and Western Europe are likely to experience little, if any, change in population size. This stagnation or shrinkage in population size in Europe and the Pacific OECD countries will be associated with significant ageing of the population, with the proportion above 60 likely to double from its current values (Lutz, Samir 2010).

Deriving it can be mentioned that the change in the size of populations is closely linked to changes in the age-structure of populations. The effect of age-structural changes on the environment is complex and strongly depends on the effects of these changes on overall economic growth (UNFPA 2012).

In summary it is important to include other population dynamics such as age structure and spatial distribution of population - and not just growth of populations - in the discussion on sustainable development.

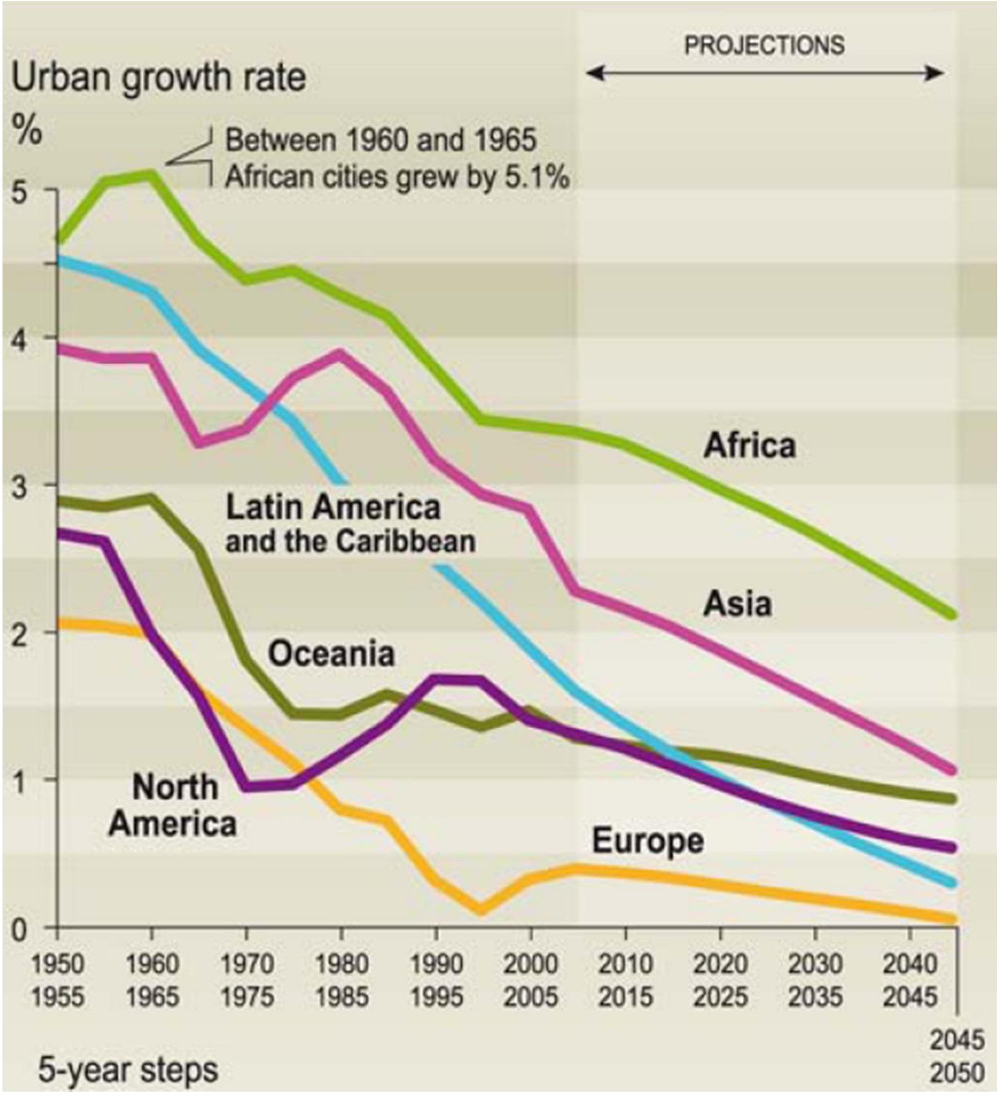
3.2 Urbanization Trends

Human settlements are another key driver of land use – both directly in terms of buildings and infrastructure footprints, and indirectly through the demand for agri-

[2] The Demographic and Health Survey for Ethiopia, for instance, shows that women without any formal education have on average six children, whereas those with secondary education have only two (see http://www.measuredhs.com). Significant differentials can be found in most populations of all cultural traditions (Lutz 2010).

cultural and forest land to provide for sustenance, and structural materials. The long-term projections in most global scenarios assume a **downward trend** for the urbanization **rate** – this means that the growth in urban areas will slow down, as shown below.

Figure 17 Urban growth rate dynamics and projections for world regions



Source: UNEP (2012)

Up to 2050, the net growth of human settlements (in absolute terms) might come to a hold in Europe and (nearly) in Latin and North America, but especially for Africa and Asia, the net growth is assumed to continue.

The “Great Transition” scenarios show that assumptions for a more sustainable agriculture and positive rural development – where bioenergy could play some role – together with more inclusive national policies on GDP distribution and overall income could reduce this pressure significantly, also providing a "dampening" factor for overall population growth (Tellus 2009+2010).

Furthermore, there is a growing interest in "urban agriculture" which could provide a rising share of food supply for urbanized populations, thus lowering the pressure on other agricultural land. The respective opportunities for global land use have not been researched much, though.

Urbanization has progressed at an extraordinary rate - for the first time in history over half the world's population is living in towns and cities, and by 2030 this number **is** expected to rise to about two-thirds of the global population, with urban growth concentrated in Africa and Asia[3] (UNFPA 2012).

The number of Megacities with 10 million or more residents is increasing worldwide. In the year 2015, there will be a total of around 26 Megacities worldwide, 22 of which will exist in developing and newly industrialised countries. Furthermore, there are numerous large cities and metropolitan areas, which are on the cusp of becoming Megacities of tomorrow (BMBF 2010).

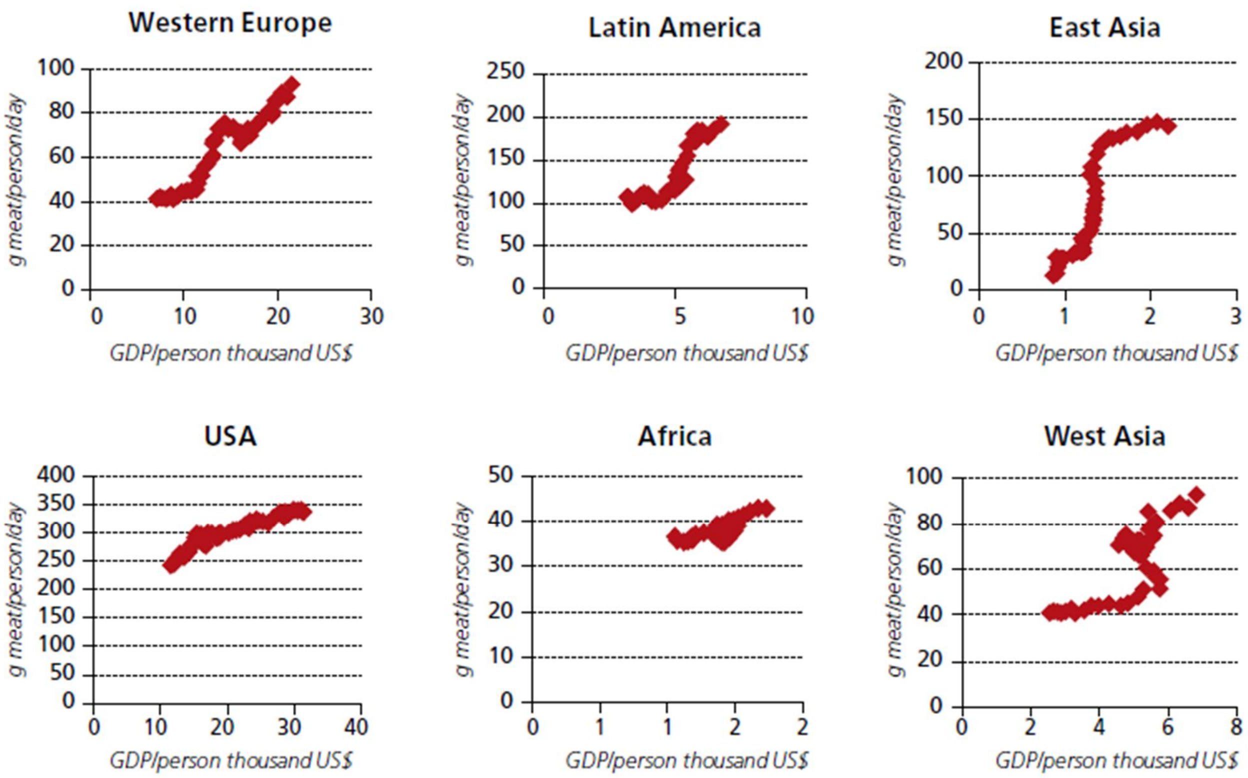
Despite the challenges that are associated with urbanization, it can be a powerful driver for sustainable economic, social and environmental development. As populations are growing, it makes economic and environmental sense for people to move closer together in urban areas. The concentration of people, material flows and residential districts makes it possible to reduce the consumption of resources through modern governance approaches and strategies for the provision of services. People can be supplied more economically using the same amount of transport, energy and space even allowing material cycles to be partly closed in many cases.

3.3 Food Consumption and Diets

Given the dominant role of the agricultural system in global land use, a key driver is the overall demand for and composition of food. There is clear empirical evidence on the relation between income (measured in GDP) and meat consumption, as indicated in the following figure.

[3] Almost all urban population growth in the next 30 years will occur in cities of developing countries. By the middle of the 21st century, it is estimated that the urban population of these counties will more than double, increasing from 2.5 billion in 2009 to almost 5.2 billion in 2050 (WHO 2013).

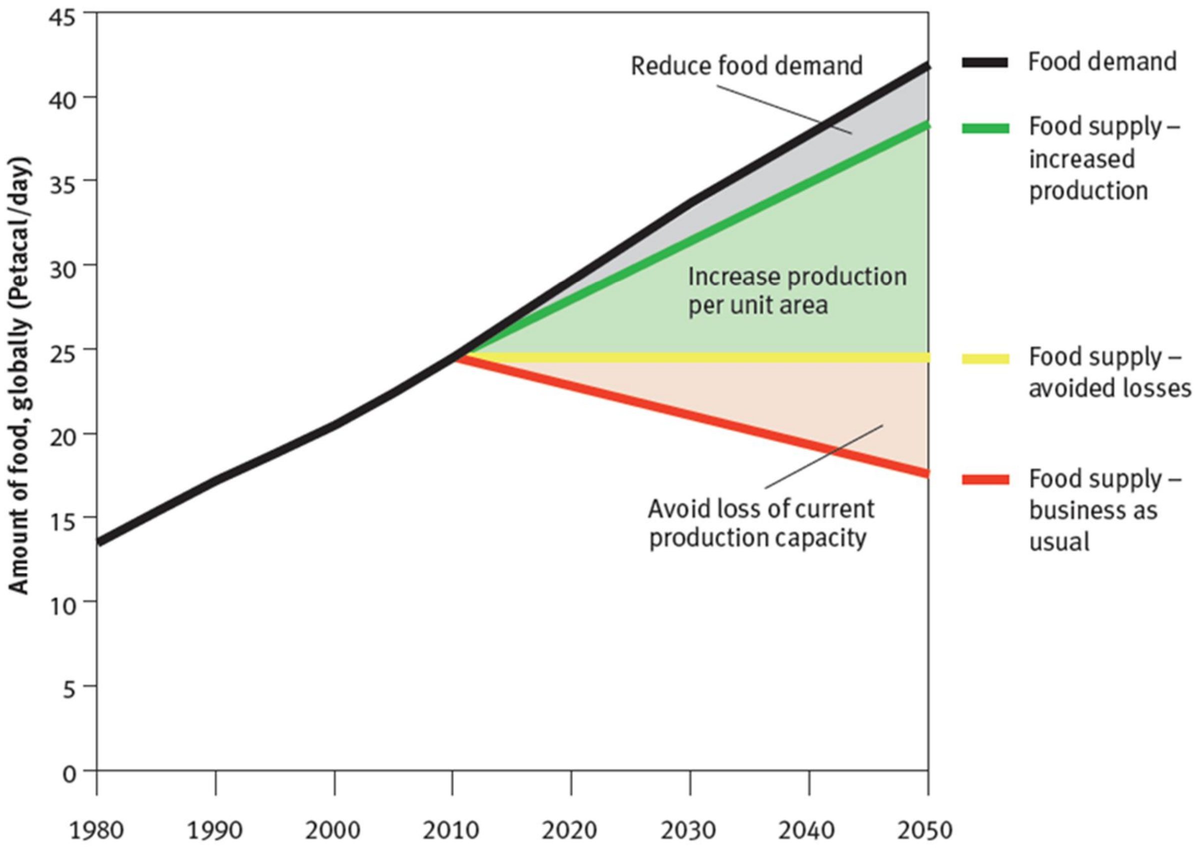
Figure 18 Relationship between GDP and meat consumption in world regions



Source: FAO (2011a)

Still, more detailed research on food demand and respective policy options - including reduction of food waste – shows opportunities of changes in demand and diets, and has been confirmed by recent studies, as shown in the following figure.

Figure 19 Balancing global food demand and supply by 2050



Source: Beddington et al. (2012)

3.4 Agricultural Change and Land Use Practices

The most relevant land use driver on the supply side clearly is the productivity of agricultural land and forests which strongly depends on cultivation systems and management practices. Regarding longer-term land use models, not only potential yield increases (e.g. through irrigation, improved breeding etc.) are of interest, but also the effects on ecosystem services which substantiate a fair share of overall productivity (e.g. pollination, soil fertility, water retention). The MA scenarios (Carpenter 2005) have provided some insight into those factors, followed by the IAASTD study (IAASTD 2009), and respective studies of FAO (2009-2012).

Given the climate change feedbacks which influence agricultural and forestry systems in different ways depending on the region, there is a high uncertainty embedded in most of the global scenarios, though.

4 Outlook on Next Steps

The preliminary findings presented in this paper need further breakdown into the (quantitative) multi-dimensional matrix to allow for substantiating the identified key drivers. Furthermore, the role of biomass (for energy and materials) should be further elaborated – given the large amount of recent research, this is just a matter of time. In addition, the discussion of regional dynamics taking into account the findings of AP-1.1 and the top-down analysis of studies (AP-1.2) will be needed to prepare for the AP-2 country studies.

As a general finding of the scenario analysis, though, another issue is of relevant for the further work: Practically all newer studies on global scenarios have used the participatory approach suggested by Alcamo (2001) which was highlighted as a key tool in consistent and politically relevant scenario work by a recent EEA report (EEA 2011). The science-based use of data and tools need “embedding” with relevant stakeholders, as indicated in the following figure.

Figure 20 Scenario building as a participatory approach

Source: EEA (2011)

This substantiates the participatory approach suggested for the GLOBALANDS AP 3 and 4, and underlines the need for outreach to prepare for these APs.

References

Alcamo J 2001: Scenarios as tools for international environmental assessments; European Environment Agency Environmental issue report No. 24; Luxembourg: Office for Official Publications of the European Communities http://www.eea.europa.eu/publications/environmental_issue_report_2001_24/at_download/file

Anderson K 2010: Globalization's effects on world agricultural trade, 1960–2050; in: Phil. Trans. R. Soc. B (2010) 365, 3007–3021

Berndes G et al. 2012: Bioenergy and land use change - state of the art; in: WIREs Energy Environ 2012 doi: 10.1002/wene.41

BMBF (Federal Ministry of Education and Research) 2010: Megacities – Shaping of a Sustainable Future World. Bonn, Berlin 2010 http://www.bmbf.de/pub/megastaedte.pdf

Carpenter S et al. (eds.) 2005: Ecosystems and Human Well-being: Scenarios, Volume 2; Findings of the Scenarios Working Group of the Millennium Ecosystem Assessment; Washington DC: Island Press http://www.maweb.org/en/Condition.aspx

Beddington J et al. 2012: Achieving food security in the face of climate change; Final report from the Commission on Sustainable Agriculture and Climate Change; CGIAR Research Program on Climate Change, Agriculture and Food Security; Copenhagen http://ccafs.cgiar.org/sites/default/files/assets/docs/climate_food_commission-final-mar2012.pdf

EEA (European Environment Agency) 2010a: SOER 2010 - Assessment of global megatrends; Copenhagen http://www.eea.europa.eu/soer/europe-and-the-world/megatrends/at_download/file

EEA (European Environment Agency) 2010b: The territorial dimension of environmental sustainability; EEA Technical report No 9/2010; Copenhagen

EEA (European Environment Agency) 2011: Knowledge base for Forward-Looking Information and Services (FLIS) - A platform to support long-term decision-making; Copenhagen http://www.eea.europa.eu/publications/knowledge-base-for-forward-looking/at_download/file

FAO (Food and Agriculture Organization of the United Nations) 2011a: World Livestock 2011 - Livestock in food security; Rome http://www.fao.org/docrep/014/i2373e/i2373e.pdf

FAO (Food and Agriculture Organization of the United Nations) 2011b: Global food losses and food waste - extent, causes and prevention; Gustavsson J et al.; Rome http://www.fao.org/fileadmin/user_upload/ags/publications/GFL_web.pdf

Foley J et al. 2005: Global Consequences of Land Use; in: Science vol. 309, pp. 570-574

Foresight UK 2011: The Future of Food and Farming: Challenges and choices for global sustainability. Final project report; London: The Government Office for Science http://www.bis.gov.uk/assets/foresight/docs/food-and-farming/11-546-future-of-food-and-farming-report.pdf

Fritsche U et al. 2012: Biofuels: What role in the future energy mix? Facts, trends and perspectives; prepared for Shell Germany; Darmstadt, Heidelberg, Hamburg http://www.iinas.org/tl_files/iinas/downloads/IINAS_IFEU_2012_Shell_Biofuels_en.pdf

Gornal J et al. 2010: Implications of climate change for agricultural productivity in the early twenty-first century; in: Phil. Trans. R. Soc. B (2010) 365, 2973–2989

HFFA (Humboldt Forum for Food and Agriculture e. V.) 2011: Rediscovering productivity in European agriculture - Theoretical background, trends, global perspectives, and policy options; Kirschke D, Häger A, Noleppa S; HFFA Working Paper 02/2011; Berlin http://hffa.info/files/hffa_wp022011.pdf

IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development) 2009: Agriculture at a Crossroads - Global Report; Washington DC

INRA (French National Institute for Agricultural Research), CIRAD (French Agricultural Research Centre for International Development) 2009: Agrimonde: Scenarios and Challenges for Feeding the World in 2050 - summary report; Montpellier, Paris

Lutz W 2010: Dimensions of global population projections: what do we know about future population trends and structures? The Royal Society; London http://rstb.royalsocietypublishing.org/content/365/1554/2779.full

Lutz W, Samir KC 2010: Dimensions of global population projections: what do we know about future population trends and structures?; in: Phil. Trans. R. Soc. B (2010) 365, 2779–2791

NRC (National Research Council) 2010: Toward Sustainable Agricultural Systems in the 21st Century; Committee on Twenty-First Century Systems Agriculture; Washington DC http://www.nap.edu/catalog.php?record_id=12832

OECD (Organisation for Economic Co-operation and Development) 2012: OECD Environmental Outlook to 2050 The Consequences of Inaction; Paris

PBL (Netherlands Environmental Assessment Agency) 2011: The Protein Puzzle - The consumption and production of meat, dairy and fish in the European Union; Westhoek H et al.; The Hague: PBL http://www.pbl.nl/sites/default/files/cms/publicaties/Protein_Puzzle_web_0.pdf

PBL (Netherlands Environmental Assessment Agency) 2009: Growing within Limits; The Hague, Bilthoven: PBL http://www.pbl.nl/sites/default/files/cms/publicaties/500201001.pdf

Reilly M, Willenbockel D 2010: Managing uncertainty: a review of food system scenario analysis and modeling; in: Phil. Trans. R. Soc. B (2010) 365, 3049–3063

Smith P et al. 2010: Competition for land; in: Phil. Trans. R. Soc. B (2010) 365, 2941–2957

Tellus (Tellus Institute) 2009: The Century Ahead: Four Global Scenarios - Technical Documentation; Electris C et al.; Boston http://www.tellus.org/publications/files/TheCenturyAhead_TechDoc.pdf

Tellus (Tellus Institute) 2010: The Century Ahead: Searching for Sustainability; Raskin P, Electris C, Rosen R; in: *Sustainability* vol. 2 no. 8, pp. 2626-2651

Turner B, Lambin E, Reenberg A 2007: The emergence of land change science for global environmental change and sustainability; in: PNAS vol. 104 no. 52, pp. 20666–20671

UNEP (United Nations Environment Programme) 2011: Keeping Track of Our Changing Environment - From Rio to Rio +20 (1992-2012); Nairobi http://www.unep.org/geo/pdfs/Keeping_Track.pdf

UNEP (United Nations Environment Programme) 2012a: Keeping Track of Our Changing Environment - From Rio to Rio +20 (1992-2012); Global Environment Alert Service (GEAS) Bulletin

UNEP (United Nations Environment Programme) 2012b: The Fifth Global Environment Outlook (GEO-5); Malta: Progress Press Ltd http://www.unep.org/geo/pdfs/geo5/GEO5_report_full_en.pdf

UNFPA (United Nations Population Fund) 2012: Population matters for sustainable development. http://www.unfpa.org/webdav/site/global/shared/documents/publications/2012/UNFPA%20Population%20matters%20for%20sustainable%20development.pdf

WEF (World Economic Forum) 2012: Putting a new vision for agriculture into action: A transformation is happening; Geneva http://www3.weforum.org/docs/WEF_FB_NewVisionAgriculture_HappeningTransformation_Report_2012.pdf

WHO (World Health Organisation) 2013: Urban population growth; Global Health Observatory (GHO); Geneva http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

Witzke HP et al. 2008: Modelling of Energy-Crops in Agricultural Sector Models - A Review of Existing Methodologies; EUR 23355 EN; Seville http://ftp.jrc.es/EURdoc/JRC42597.pdf