UNEP

International Resource Panel

ASSESSING GLOBAL LAND USE:

BALANCING CONSUMPTION WITH SUSTAINABLE SUPPLY

United Nations Environment Programme

Acknowledgements

Editor
International Resource Panel

Working Group on Land and Soils

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About the International Resource Panel

This report was prepared by the Working Group on Land and Soils of the International Resource Panel (IRP). The IRP was established to provide independent, coherent and authoritative scientific assessments on the use of natural resources and its environmental impacts over the full life cycle and contribute to a better understanding of how to decouple economic growth from environmental degradation. Benefiting from the broad support of governments and scientific communities, the Panel is constituted of eminent scientists and experts from all parts of the world, bringing their multidisciplinary expertise to address resource management issues. The information contained in the International Resource Panel's reports is intended to be evidence based and policy relevant, informing policy framing and development and supporting evaluation and monitoring of policy effectiveness. The Secretariat is hosted by the United Nations Environment Programme (UNEP).

Since the International Resource Panel's launch in 2007, nine assessments have been published. This first series of reports covered biofuels; priority economic sectors and materials for sustainable resource management; metals stocks in society, their environmental risks and challenges, their rates of recycling and recycling opportunities; water accounting; city-level decoupling and finally the untapped potential for decoupling resource use and related environmental impacts from economic growth.

The assessments of the IRP to date demonstrate the numerous opportunities for governments and businesses to work together to create and implement policies to encourage sustainable resource management, including through better planning, more investment, technological innovation and strategic incentives.

Following its establishment, the Panel first devoted much of its research to issues related to the use, stocks and scarcities of individual resources, as well as to the development and application of the perspective of 'decoupling' economic growth from natural resource use and environmental degradation. Building upon this knowledge base, the Panel has now begun to examine systematic approaches to resource use. These include the direct and indirect (or embedded) impacts of trade on natural resource use and flows, and the city as a societal 'node' in which much of the current unsustainable usage of natural resources is socially and institutionally embedded. In a similar vein it has become apparent that the resource use and requirements of the global food consumption call for a better understanding of the food system as a whole, and in particular its role as a node for resources such as water, land, and biotic resources on the one hand and the varied range of social practices that drive the consumption of food on the other. The years to come will therefore focus on and further deepen these work streams.

Upcoming work by the IRP Land and Soils Working Group will focus on land potential evaluation systems and resilience.

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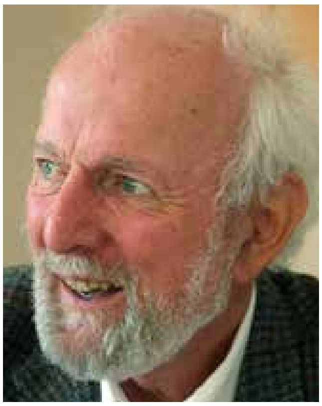
Preface

Dr. Ashok Khosla



Prof. Dr. Ernst Ulrich von Weizsäcker

Since its inception, UNEP's International Resource Panel (IRP) has focused its efforts on bridging the gap between science and policy to generate sustainable, effective and realistic solutions to challenges in global resource management. The Panel's report "Decoupling Natural Resource Use and Environmental Impacts from Economic Growth", shows that breaking the link between human well-being and resource consumption is both necessary and possible.

In its first report, Assessing Biofuels: Towards Sustainable Production and Use of Resources, the IRP Working Group on Land and Soils raised serious concerns about the environmental impacts of land use change induced by the growing demand for biofuels. In this second report, Assessing Global Land Use: Balancing Consumption with Sustainable Supply, the working group provides a comprehensive global assessment of increased pressures on natural resources from food, fuels and fibre, identifying the main drivers and providing innovative, practical options to mitigate their impacts.

There is a growing recognition that the complexity of today's resource management challenges calls for trade-off analysis and integrated solutions and this report responds to this call. A central question answered by the authors is the extent to which global cropland can expand to serve the growing demand for food and non-food biomass, while keeping the consequences of land use change, such as biodiversity loss, at a sustainable level.

Under business as usual conditions, the growing demand for food and non-food biomass could lead to a gross expansion of cropland in the range of 320 to 850 million hectares by 2050. Expansion of such magnitude is simply not compatible with the imperative of sustaining the basic life-supporting services that ecosystems provide such as maintaining soil productivity, regulating water resources, sustaining forest cover or conserving biodiversity.

The report finds that gross expansion of croplands by 2050 could be limited to somewhere between 8% and 37%, provided a multi-pronged strategy is followed for meeting the food, energy and other requirements of the global economy. Such a strategy would need to increase efficiency levels across the life cycle of agricultural commodities and also in the use and re-use of land-based resources.

This definitive report is the result of a thorough research and review process completed under the guidance of the Land and Soils Working Group. It benefited from several rounds of discussion with the members of the International Resource Panel, and its Steering Committee as well as from an external peer review process. Its conclusions give policy makers and practitioners a solid basis for immediate action on many fronts, both to reduce degradation of land and soils and also to initiate measures to regenerate areas that have been damaged or destroyed. Obvious ones would include the development of national programmes for resource efficiency (including global land use for domestic consumption) and the establishment of a fund for the regeneration of degraded soil. Others are referred to in the report.

The International Resource Panel is committed to continue providing cutting-edge scientific knowledge on sustainable land and soil management and the interrelated intricacies of global food systems. Two reports at early stages of preparation will contribute to this endeavour.

In its third report, the IRP Working Group on Land and Soils will zoom-in on improved land use planning and land management systems, one of the policy options recommended in this report to minimise cropland expansion. Specifically, it will assess the effectiveness of existing land potential evaluation systems in sustainably increasing landscape productivity, resilience being one of its key components.

The fourth report will look at current dynamics of natural resource use in global food systems and their environmental impacts, identifying opportunities to enhance resource efficiency throughout these systems.

We are very grateful to Professor Stefan Bringezu and his team for their tremendous effort in presenting a new and balanced perspective to understand the constraints and potentials of global land management. We are confident it will spark discussions on new approaches to ensure sustainability of our precious land resources.

Dr. Ashok Khosla,
New Delhi, India, January 2014
Prof. Dr. Ernst Ulrich von Weizsäcker
Emmendingen, Germany, January 2014
Co-Chairs, International Resource Panel (IRP)

Foreword

Humanity is at a critical juncture. Leaders worldwide have acknowledged the significant impact that today's stewardship of natural resources will have on the long-term sustainability of the Earth's capacities as we know them.

The International Resource Panel (IRP) was established by the United Nations Environment Programme (UNEP) to provide scientific answers to some very difficult questions. How can the world strike a balance between the economic and social prosperity of its people while better managing and strengthening its natural resource base? What are the priorities when confronted with short and long-term trade-offs emerging from the use of different natural resources?

In this era of unpredictable environmental changes and complex resource challenges, knowledge is power. Sound policy-making on natural resource management requires up-to-date, objective and accurate data. Transformation must be based on strong science if we are to get it right. The International Resource Panel proposes a new way of thinking by which natural resource use becomes more efficient and economic development is no longer synonymous with environmental degradation.

This report, *Assessing Global Land Use: Balancing Consumption with Sustainable Supply*, provides a comprehensive overview of the scientific options for sustainable land management. It points to an alarming reality. We are rapidly expanding global cropland at the expense of our savannahs, grasslands and forests, and the expected rise of demand for food, fibre and fuel will only increase the pressure on our land resource base. If current conditions continue, by 2050, we could have between 320 and 849 million hectares of natural land converted to cropland. To put things into perspective, the higher range of this estimate would cover an extension of land nearly the size of Brazil.

There is no way such an amount can be compensated by increasing yields alone. While productivity levels have experienced an impressive increase over the past 50 years, yield gains have started to stagnate in some regions. At the same time, land degradation continues to expand, affecting today an estimated 23% of global soils and in its severe form leads to the abandonment and shift of 2 to 5 million hectares of cropland a year.

This report examines the main causes for cropland expansion, proposes an estimated reference value for this expansion to occur within sustainable levels, and presents a set of realistic policy options to keep global cropland expansion within this safe operating space.

The authors believe global net cropland area could safely increase to up to 1,640 million hectares by 2020. While they recognize there is still great potential in increasing yields in regions like Sub-Saharan Africa, the authors highlight new opportunities to steer consumption towards levels of sustainability, particularly in high-consuming regions.

Overall, the combination of consumption-oriented measures such as the improvement of diets to enhance efficiency in biomass use and its substitutes, delinking the biofuels and food markets, the reduction of food loss and waste, the control of biomaterials consumption; with improved land management and restoration of degraded land, may allow us to save 161 to 319 million hectares of land by 2050.

Assessing Global Land Use: Balancing Consumption with Sustainable Supply offers a glimpse of hope. It is possible to feed a growing population, expand our cities to favour inclusive development, supply necessary fibre and fuel while at the same time protect our natural resources for generations to come. But to do this, we must become more efficient in the way we produce, supply, and consume our land-based products.

In 2014, the United Nations Open Working Group on Sustainable Development Goals will submit a proposal to the General Assembly that will set priorities for environmental stakeholders in the years to come. Hopefully, the rich data presented by this outstanding report will inspire a new dialogue and contribute to on-going discussions on targets and indicators for sustainable resource management.

I would like to extend my gratitude to the International Resource Panel under the leadership of Ashok Khosla and Ernst Ulrich von Weizsäcker as co-chairs and Stefan Bringezu for coordinating this remarkable work.

Achim Steiner
UN Under-Secretary General and UNEP Executive Director
Nairobi, Kenya, January 2014

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List of Accronyms

AL	Actual Level
APEC	Asia-Pacific Economic Cooperation
BAU	Business-as-usual
BMP	Best Management Practice
CAP	Common Agricultural Policy
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CHP	Combined Heat and Power
CORINE	Coordination of Information on the Environment
DM	Dry Matter
EEA	European Environment Agency
EF	Ecological Footprint
EU	European Union
EU-15	European Union prior to the accession of ten candidate countries in 2004
EW-MFA	Economy-Wide Material Flow Analysis
FAO	Food and Agricultural Organization of the United Nations
FFF	Food, Fibres and Fuels
G20	Group of Twenty Finance Ministers and Central Bank Governors
GHG	Greenhouse gas
GLUA	Global Land Use Agriculture
GLUF	Global Land Use Forestry
GMO	Genetically Modified Organism
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Developmnent
ICT	Information and Communications Technology
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRP	International Resource Panel
ISRIC	International Soil Reference and Information Centre
ISSM	Integrated Soil-crop System Management
IUSS	International Union of Soil Sciences
LCA	Life-Cycle Analysis
LUC	Land Use Change
LULCC	Land-Use and Land-Cover Change
MCI	Multiple Cropping Index

N	Nitrogen
N2	Molecular Nitrogen
N2O	Nitrous Oxide
NAI	Net Annual Increment
NGO	Non-Governmental Organisation
NIR	National Inventory Reports
NUE	Nitrogen Use Efficiency
OECD	Organisation for Economic Cooperation and Development
P	Phosphorous
p.a.	Per Annum
ppm	Parts Per Million
SCOPE	Scientific Committee on Problems of the Environment
SHARE	Share of Acceptable Capacity
SOLAW	State of the World's Land and Water Resources
SOS	Safe Operating Space
SRREN	Special Report on Renewable Energy Sources
SSM	Site-Specific Management
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
USDA	United States Department of Agriculture
WBCSD	World Business Council for Sustainable Development
WFB	World Food Bank
WTO	World Trade Organization

List of Units

ha	Hectare
kcal	Kilocalories
kg	Kilograms
kha	Thousand hectares
kW	Kilowatt
L	Litre
m^3	Cubic meter
m^2	Square meters
Mha	Million hectares
Mt	Million tonnes
W	Watt

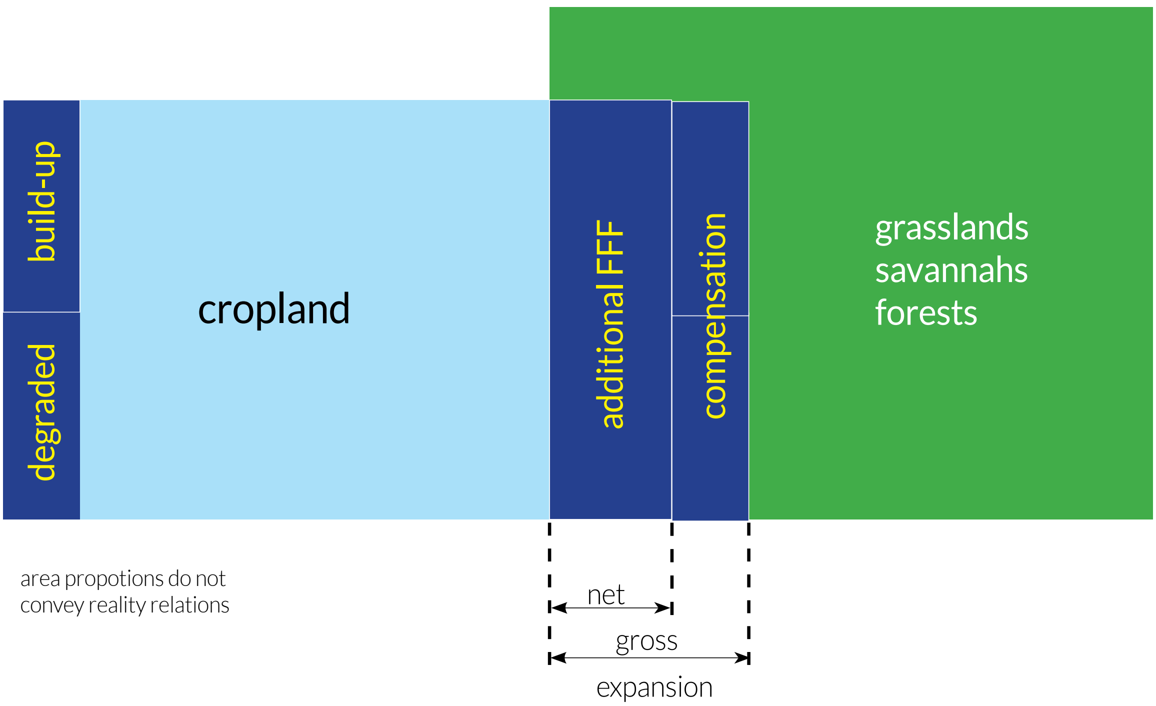
Executive Summary

Global cropland is expanding. Changing trends in both the production and consumption of land-based products are increasing pressure on land resources across the globe. This report discusses the need and options to balance consumption with sustainable production. It focuses on land-based products (food, fuels and fibre) and describes methods which enable countries to determine whether their consumption levels exceed sustainable supply capacities. Strategies and measures are outlined which will allow adjusting the policy framework to balance consumption with these capacities.

Cropland expansion

The report distinguishes between gross and net expansion of cropland. Net expansion is a result of rising demand for food and non-food biomass which cannot be compensated by higher yields. Gross expansion comprises also the shift of cropland to other areas due to losses by severe degradation and built-up land (Figure 0.1).

Figure 0.1 Net and gross expansion of cropland

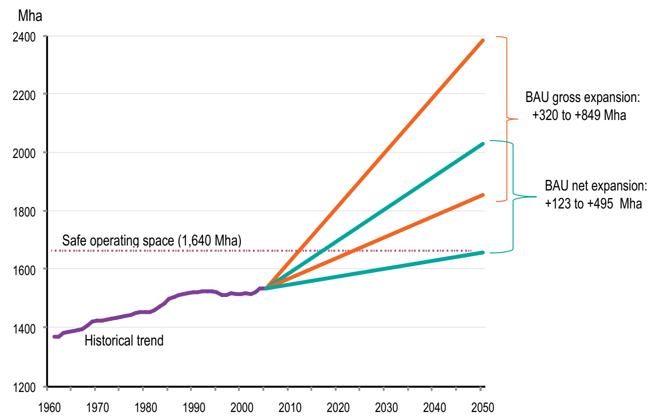


Note: Net expansion of cropland happens to meet increased demand of food, fibres and fuels (FFF); gross expansion comprises also the land shift to compensate for abandoned, degraded and built-up cropland.

Under business-as-usual conditions the ***net expansion of cropland*** will range from around 120 to 500 Mha between 2005 and 2050. Shifts to more protein-rich diets in developing countries and a growing demand for biofuels and biomaterials, in particular in developed countries, are especially increasing the demand for land. In addition, cropland will be shifted to compensate for the expansion of built-up land and land degradation, leading all in all to a ***gross expansion of cropland*** in the range of 320 to 850 Mha.

In the absence of the return to production on previously abandoned farmland, cropland expansion will occur at the cost of grasslands, savannahs and forests, in particular in tropical regions. As demand grows, the price for land and derived products will increase, with potentially negative consequences for food security.

Figure 0.2 Expansion of global cropland under business-as-usual conditions: overshoot of safe operating space



Note: Safe operating space depicted here is a preliminary and indicative value based on a cautious global target to halt the expansion of global cropland into grasslands, savannahs and forests by 2020; in this figure it comprises only cropland used to supply food and non-food biomass (net expansion).

A safe consumption level for global cropland

Land is a finite resource. The question is, how much more land can be used to serve the growing demand for food and non-food biomass, while keeping the consequences of land use change (e.g. deforestation) at a tolerable level? If the goal of halting global biodiversity loss until 2020 shall be reached, also cropland expansion, a key driver of this loss, will need to be halted. This implies that business-as-usual development could "safely" continue until 2020, at which time around an additional 100 Mha are expected for meeting future demand (net expansion) and 90 Mha are expected to be displaced (resulting in around 190 Mha of gross expansion). That means the global (net) cropland area available for supplying demand could safely increase up to 1,640 Mha. This value is taken as a reference for sustainable consumption of agricultural goods. Under business-as-usual conditions until 2050, the expected range of cropland expansion would overshoot the "safe operating space" in all cases (Figure 0.2).

As final consumption of food and non-food biomass and the required cropland should be used in an equitable manner in the future, potential target values are expressed on a per person basis. As an interim target, and for practical reasons one may orient towards 0.20 ha of cropland (1,970 m^2) per person in 2030.

Reducing land demand

On the supply side, world average yield growth in agriculture is slowing. Nevertheless, in regions with lagging yields (especially sub-Saharan Africa), the opportunity to increase agricultural productivity is large. Capacity building on best management practices, for example by integrating scientific and local know-how, investing in the remediation of degraded soils, and developing community infrastructure and organization are measures with strong potential.

In especially high-consuming regions, product-based approaches, like certification, are insufficient to keeping consumption at levels which can sustainably be supplied. For that purpose, responsible consumption is required, which includes a more efficient and equitable use of land-based products.

Major options to reduce cropland requirements and to relieve the social and environmental pressures associated with land use change include:

- Enhancing the efficiency of biomass use and its substitutes, in particular through a reduction of food waste, a shift towards more vegetal diets in countries and regions with an unhealthy overconsumption of food, and a reduction in the fuel consumption of car fleets;

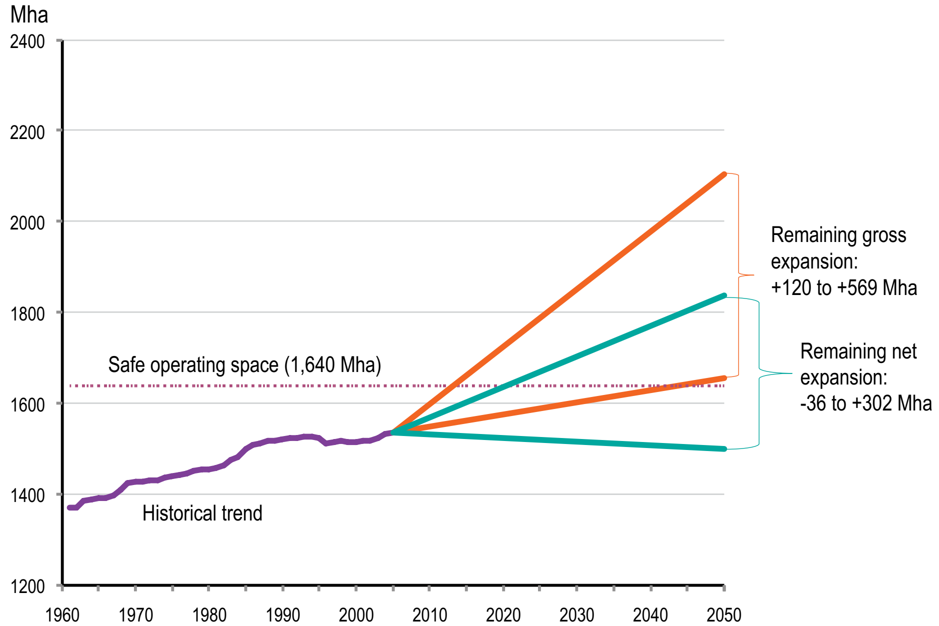
- Delinking the markets for fuels and food by reducing the direct and indirect subsidization of fuel crops (including the reduction and phase out of biofuel quotas in consuming countries);
- Controlling the consumption of biomaterials (from cropland and forests), in particular to avoid competition with food crops, and to not exceed levels of sustainable regrowth of forests;
- Improving land management and land use planning in order to minimize the expansion of built-up land on fertile soils and investing into the restoration of degraded land;
- Improving agricultural production practices to increase intensification in an ecologically and socially acceptable way;
- Monitoring of countries' global land use requirements for the total consumption of their agricultural goods, in order to allow comparisons with the global average and with sustainable supply, and to provide a signal for the need to adjust sectoral policies if necessary.

A combination of those measures would not halt the expansion of global cropland altogether, but it would limit gross expansion to an additional 8 - 37% until 2050 (Table 0.1). Then, in the best cases, the remaining net expansion of cropland by 2050 would be within the "safe operating space" (Figure 0.3).

Table 0.1 Expansion of global cropland from 2005 to 2050 under BAU conditions and possible savings of reduced consumption and improved land management (Mha)

BUSINESS-AS-USUAL EXPANSION				POTENTIAL SAVINGS			
	Low estimate	High estimate	Source	Measures	Low estimate	High estimate	Source
Food supply	71	300	Based on Bruinsma 2009, RFA 2008, Bringezu et al. 2009a	Improving diet and reducing waste	96	135	Low: Wirsenius et al. (2010b) High: Stehfest et al. (2009)
Biofuel supply	48	80	Based on Fischer 2009, IEA 2011	Halving biofuel targets	24	40	
Biomaterial supply	4	115	Based on Colwill et al. 2011, Raschka and Carus 2012	Controlling biomaterials demand	0	57	High value halved
Net expansion	123	495		Saving range	120	232	
Compensation for built environment	107	129	Based on Electris et al. 2009	Land use planning	11	13	10% avoidance of building on fertile cropland
Compensation for soil degradation	90	225	Based on Scherr 1999	Investment programmes to regenerate degraded soils	30	74	Restoration of 1/3 of degraded and abandoned land
Gross expansion	320	849		Saving range	161	319	

Figure 0.3 Remaining expansion of global cropland with "land saving" measures: an opportunity to keep consumption levels within the safe operating space



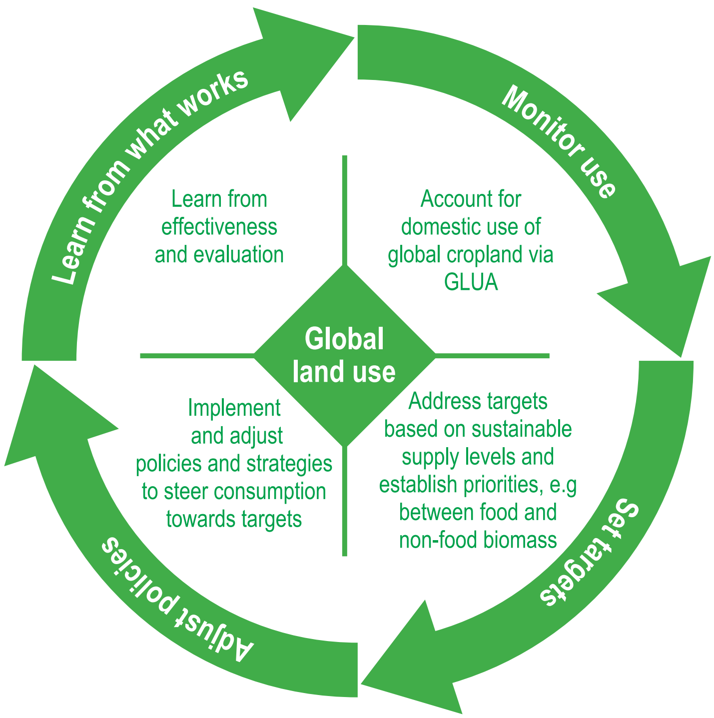
Note: Safe operating space depicted here is a preliminary and indicative value based on a cautious global target to halt the expansion of global cropland into grasslands, savannahs and forests by 2020; in this figure it comprises only cropland used to supply food and non-food biomass (net expansion); values from Table 0.1 are combined to show maximum realistic ranges for remaining net and gross expansion.

Policy options

This report is designed to increase awareness and understanding of the magnitude of the challenges facing society, and of the extent to which the challenges must be addressed through a consideration of both consumption and production. It presents policy options to balance consumption with sustainable production.

In order to cope with the dynamics and complexities of resource use in general, and land use in particular, governments may use a transition approach (Figure 0.4): (1) monitor actual land use (domestically and foreign) for domestic final consumption; (2) address targets for long-term resource consumption, (3) adjust existing policies and implement new ones if necessary, and (4) evaluate the effectiveness of the measures and learn from them.

Figure 0.4 Scheme of a transition approach to manage global land use of countries by final consumption of products



Securing sustainable supply of food and fibre, partially also fuels, while making the best use of, protecting and enhancing the natural resource base requires a policy design that fosters cross-level synergies and supports dynamic learning processes. Two major complementary strategies should be pursued in parallel: (1) improve stewardship and management of each square meter, including decisions on its optimal use and (2) keep the level of production and consumption within the limits of a safe operating space. To this end, systematic knowledge on strategic options for sustainable resource use across different policy levels is crucial, this includes:

- **Capacity building at the farm level** is a key prerequisite for improving food security, local livelihoods and environmental quality;
- **Supporting resource management in regions and cities** enables implementation of context-specific strategies. Urban gardening can be valuable for supplying local livelihoods and reconnecting people to the origins of their food;
- **Setting the framework for resource management** is needed at the country level to sustain land use and secure food supply. A number of issues are relevant:
  - *Improving statistics, especially to monitor domestic land use and foreign land use for domestic production and consumption;*
  - *Land use planning to help prevent the loss of high-value nature areas due to expanding agriculture and livestock production and to avoid the expansion of built-up area on fertile soils;*
  - *Programmes for economy-wide sustainable resource management could provide the context for "sustainable biomass action programmes", with the aim of harmonizing food security, energy, rural development and industrial policies;*
  - *Economic instruments to trigger sustainable supply and demand. One example is a "subsidy to sustainability" approach to foster long-term soil productivity;*
  - *Improved targeting of public investments,* *especially focused on the needs of smallholders to enhance food security and living conditions in rural areas;*
  - *Land tenure and ownership as important prerequisites for motivating people to invest in maintaining and improving their land and soil resources;*
  - *Reducing food loss at the production and harvest stage by e.g. investing in infrastructure, encouraging the build-up of storage facilities and encouraging co-operatives. Education and food waste prevention campaigns are also useful policy options for reducing avoidable food waste;*
  - *Programmes that foster a greater use of residues—after taking into account soil fertility needs—and the re-use of biomass to help reduce the demand for land;*

   - *Programmes promoting a healthy and balanced diet in high-consuming countries, especially as regards meat products, to help reduce obesity and land pressure. This is especially relevant for promoting a healthier diet in schools;*
   - *Family planning programmes to slow down population growth;*
- **Support by international institutions working on global resource management** can help to increase knowledge and improve the data basis for decision makers. Examples include the ISRIC (World Soil Information), the Global Soil Partnership, and the Land 2050 Initiative.

Key messages

- *Growing demand for food and non-food biomass will lead to an expansion of global cropland.*
- *Reducing excessive consumption provides high untapped potentials for "saving" land.*
- *Large areas with degraded soils are in need of restoration and better land use planning would help to avoid building on fertile land.*
- *Product certification cannot control the global expansion of cropland. For that, countries should monitor and control the level of their global land use.*
- *A more efficient use of biomass and its substitutes is necessary and possible; it requires enhanced efforts toward sustainable resource management at multiple scales.*
- *In light of global efforts to increase food security, markets for food and fuel should be delinked. This implies reducing biofuel quotas.*

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CHAPTER 1

Introduction

Introduction

Current and future food security, climate change and energy security are just three of the challenges humanity is facing in the 21st Century. None stands alone, there are mutual interferences among the problems, and there are trade-offs and synergies with the counter measures. Global land use and soil management play a central role in determining our food, material and energy supply.

So far, the dominant strategy for securing the availability of food, fibre and fuel has been to increase the supply. Indeed, various options exist to enhance the production of agricultural goods, in particular in regions with low harvest yields such as in sub-Saharan Africa. The recent "State of the World's Land and Water Resources" (SOLAW) report (FAO 2011a) shows what can be done to improve technological and institutional conditions to close the "productivity gap" and enhance efficient use of water, for instance, for irrigation. At the same time, that report observes that "land and water use in agriculture is caught in a policy trap. On the one hand, agricultural policies have been effective in responding to increasing demand, but on the other hand they have resulted in a set of unintended consequences, including over application of fertilizer and pesticides, and depleted groundwater storage. Equally, water policies have driven expansion of water supply and storage, but in some water-short areas, this has created excess demand and ´constructed´ scarcity" (FAO 2011a, p. 6).

Today, about one-third of cereal harvest is being fed to animals[1] and about one-third of agricultural production is wasted (Gustavsson et al. 2011). Many countries have started to support the use of biomass for biofuels and biomaterials, and, at the same time, are becoming concerned about the increasing consequences of land competition, land use change, and land use intensification. Cropland expansion, at the cost of tropical forests and savannahs, induces dramatic changes in the living environment with uncertain repercussions. The potential for intensification must be combined with ecological management to avoid trade-offs between meeting short-term needs and degrading the system humans rely on to supply those needs over the long term (Cassman 1999, Foley et al. 2005, Bommarco et al. 2010, Tilman et al. 2011).

The recent scientific foresight report of UNEP (2012a) ranked the issue of global food safety and security among the top three global challenges. The integration of the biodiversity theme into environmental and economic agendas and the new rush for land were within the top twelve. It is becoming more and more clear that securing food supply requires both improvements on the production *and* on the consumption side (Foley et al. 2011), the more so as the safe potentials for the expansion of production become used up. It has also become evident that an effective shelter for the remaining biodiversity must go beyond the demarcation of conservation areas and enhance structural changes in production and consumption systems (PBL 2010).

A central question is thus to what extent can global cropland expand to serve the growing demand for food and non-food biomass, while keeping the consequences of land use change, such as losses of biodiversity, at a tolerable level? To this end, further questions include:

- Can we survive and live decently on this planet without driving our non-human contemporaries to extinction and depriving us of our genetic treasure?
- What is the current safe operating space in terms of land use, which takes the risks of such losses into consideration?
- How can we implement the global objectives of eradicating hunger *and* halting the loss of biodiversity in concrete terms?
- How can we *avoid problem shifting*, for example between the consumption of biofuels by the rich, often leading to large-scale land acquisitions, and the needs of the poor for affordable food and continued access to land to support rural livelihoods?

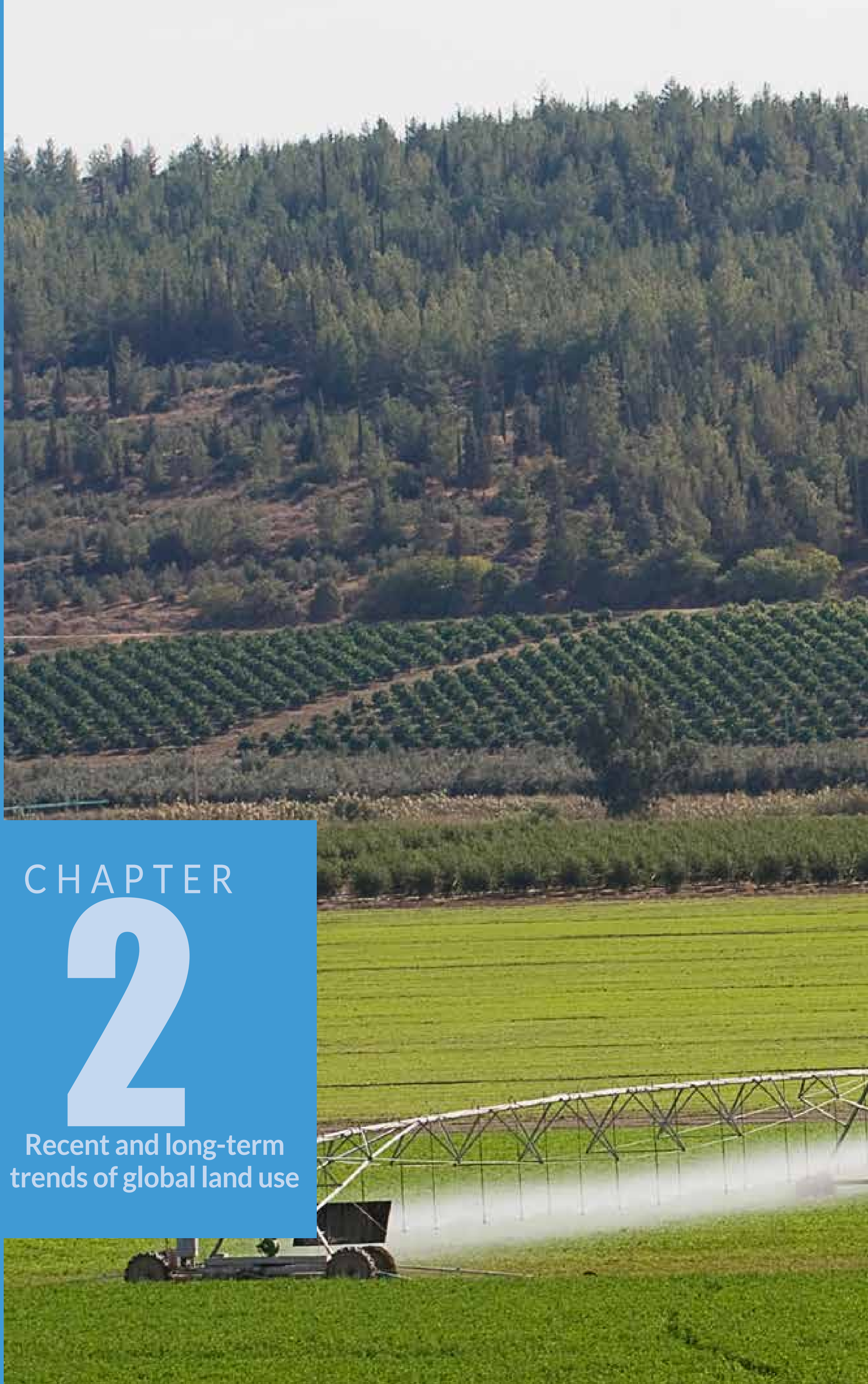
1 *FAOSTAT online database (http://faostat3.fao.org/), accessed 12.4.2012.*

This report begins to address these questions. It grapples with the complexity of issues facing agriculture across the production and consumption chain. Specifically, this report looks at the impacts of global trends—population growth, urbanization, and changes in diets and consumption behaviors—on global land use dynamics, considering the consequences for biodiversity, the supply of food, fibres and fuel, and the long-lasting implications for resource security. It explores how the management of land-based biomass production and consumption can be developed towards a higher degree of sustainability across different scales: from the sustainable management of soils *on the field* to the sustainable management of *global land use* as a whole. It argues that a sustainable policy package must become effective at different levels, and that the maxim "think globally, act locally" does not restrict the need for action to farmers and communities, but addresses regional stakeholders and federal governments as well. All in all, it shows that policies to enhance supply - although necessary - might not be effective if not complemented by policies to adjust consumption toward sustainable levels.

In short, the challenge is managing current cultivated hectares in a sustainable manner *and* managing demand in a way that the number of hectares needed does not exceed sustainable levels. These levels refer to the amount of land available for agriculture without encroaching on natural areas beyond acceptable thresholds or contributing to an over-use of limited land resources, which could escalate land use conflicts in the future. Indeed, the competing demands for land to support global and local consumption is one of the major conflicts that the world will face in this century. Through this report, the International Resource Panel proposes an orientation for managing land resources that could result in more equitable and low-conflict approaches to land-use change and the distribution of land-based products.

This report reflects the need formulated by the global change research community (De Friess et al. 2012) to bridge the information gap between the knowledge on planetary boundaries and the resulting opportunities and challenges for decision makers at various scales. It also corresponds to the development of land change science which increasingly considers the influences of the "human system" on land use (Turner et al. 2007). This report builds on the land management and land use concerns raised by the first report of the International Resource Panel "Assessing Biofuels" (Bringezu et al. 2009a). It complements the report on "Decoupling natural resource use and environmental impacts from economic growth" (UNEP 2011a), which focused on the global dynamics of material resource flows, and corresponds to the report "Assessing the Environmental Impacts of Consumption and Production" (UNEP 2010a), which showed that biomass based products and materials are associated with a major share of global environmental burden. It is intended to support the international discussion and to provide decision makers in national and regional governments and opinion leaders in NGOs with an overview of key challenges and possible options related to sustainable land use, including focused data and relevant background information.

Altogether, this report is split into 4 subsequent chapters. Chapter 2 focuses on major trends related to the production of land-based products. It identifies current and emerging problems concerning the environment (notably soil degradation and nutrient pollution) and social justice (notably food security and land tenure). Chapter 3 looks more intensely at the drivers of future land use change. It looks at both the production and the consumption side, and adds together the expected cropland demands of different drivers to generate a picture about the total magnitude of expected cropland expansion by the year 2050. Chapter 4 begins to address the question of sustainability. It asks how much cropland can expand under sustainable conditions, and presents a method that allows countries to monitor how much global cropland they currently use. Together, Chapters 3 and 4 raise two questions. First, is expected cropland expansion within the limit of sustainable cropland expansion? Second, how much global cropland and how much of the global sustainable supply capacity do specific countries use (e.g. are they overconsumers)? Chapter 5 addresses policy options for improving production and reducing overconsumption, and points to future research needs.



CHAPTER

2

Recent and long-term trends of global land use

Recent and long-term trends of global land use

Land use change has been associated with a profound alteration of land cover, a deprivation of natural capital such as shrinking extension of natural ecosystems and degraded soil functions, including fertility. This chapter will outline the main trends of land use change and proliferating soil degradation (section 2.1). While feeding a growing number of people, intensification and extension of agriculture has often led to environmental degradation, and sometimes to social deprivation (section 2.2). The widening of markets has driven agriculture to become a global industry competing on short-term economic margins rather than long-term productivity (section 2.3). A growing demand for food, feed and fibre exerts additional pressure on suppliers and consumers through higher level and volatility of prices, compromising food security in particular for the poor (section 2.4). Growing prices of food and non-food biomass render productive land a more precious asset, and have triggered private and state investors to realize larger land purchases in low cost countries with often less favorable social and environmental consequences (section 2.5).

2.1 Dynamics of land use change

Global land use change can mostly be characterized by the expansion of urban and infrastructure areas at the expense of agricultural land and by the expansion of agricultural land at the expense of grasslands, savannahs and forests (Holmgren 2006).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The global land area of the continents is around 14,900 million ha (Mha)[2]. Depending on the definition and method of measurement, around the year 2005, **built-up area** covered by settlements and infrastructure took up a relatively small amount of land – 1 to 3% of the total[3]. Without policy interventions, settlements and infrastructures are expected to expand by around 260 to 420 Mha by 2050 (Kemp-Benedict et al. 2002, Electris et al. 2009), then covering about 4 to 5% of the global land area (Figure 2.1), while strong policy action[4] may lead to only a 90 Mha increase (or 3%) (Electris et al. 2009). In both scenarios the expansion would occur on agricultural land. According to Seto et al. (2010), **urban areas** alone might expand altogether by between 40 and 143 Mha from 2007 to 2050. Holmgren (2006) assumes that 80% of urban expansion occurs on agricultural land.

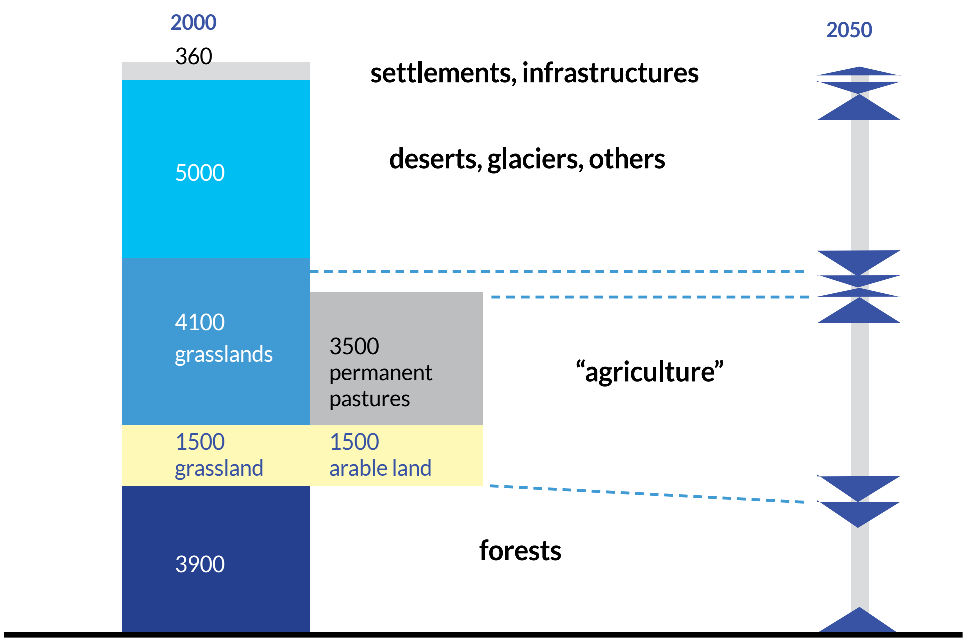
During the past 40 to 50 years agricultural land has expanded at the expense of forests in particular in tropical regions (e.g. Gibbs et al. 2010). A study on past trends and future development options based on various scenarios (Lambin and Geist 2006) indicates that the loss of forest will probably proceed in the tropics, whereas in temperate zones afforestation might prevail. Hurtt et al. (2011) developed land use scenarios by linking historic data with future projections for Earth System Models to predict future carbon-climate changes. Four integrated assessment models for 1500 to 2100 show declines of primary (previously undisturbed by human activities) forest as well as non-forest areas.

2 The number includes Antarctica.

3 Using night light data, the Global Urban Rural Mapping Project has estimated that roughly 3% of the Earth's land surface is covered by urban areas, which is 50% more than previous estimates; see Earth Institute News, www.earthinstitute.columbia.edu/news/2005/story03-07-05.html.

4 The Policy Reform scenario envisions the emergence of strong political will for taking harmonized and rapid action to ensure a successful transition to a more equitable and environmentally resilient future. It is a normative scenario constructed as a backcast from the future (Robinson 1990).

Figure 2.1 Major types and trends of global land use and land cover (Mha)



Source: Bringezu and Bleischwitz 2009

Note: development of settlements and infrastructures is referring to "built-up land" (see text).

Cropland currently comprises about 10% (around 1,500 Mha) of the world land area, whereas **agricultural area** in total makes up around 33% (around 4,900 Mha)[5]. From 1961 to 2007 overall land use for crops increased by some 11%[6], or approximately 150 Mha globally, with large regional differences. The EU-15 (in particular Italy and Spain), Eastern Europe (Poland, Bulgaria, Romania) and North-America (the US) showed a declining cropland use, whereas more cropland was used especially in South America (Brazil, Argentina, Paraguay), Africa (Nigeria, Sudan) and Asia (China, Indonesia) (Figure 2.2).

The cropping intensity of land use can be expressed by the multiple cropping index (MCI)[7]. Cropping intensities continued to rise in the past with more multiple cropping and shorter fallow periods. An increasing share of irrigated land in total agricultural land is the major factor for the more multiple cropping. The overall cropping intensity in the world has risen steadily over the period 1961-63 to 2006-07. The highest growth is observed in Africa and Oceania (an increase by 25 percentage points and 16 percentage points, respectively), while there is a significant reduction in Europe (a decrease by 8 percentage points). Between 1961/63 and 2006/07, harvested area grew by 229.5 Mha (or 23.6%). About half of this growth is attributable to the expansion of arable land (135.6 Mha), and half to the increase of MCI (OECD-FAO 2009).

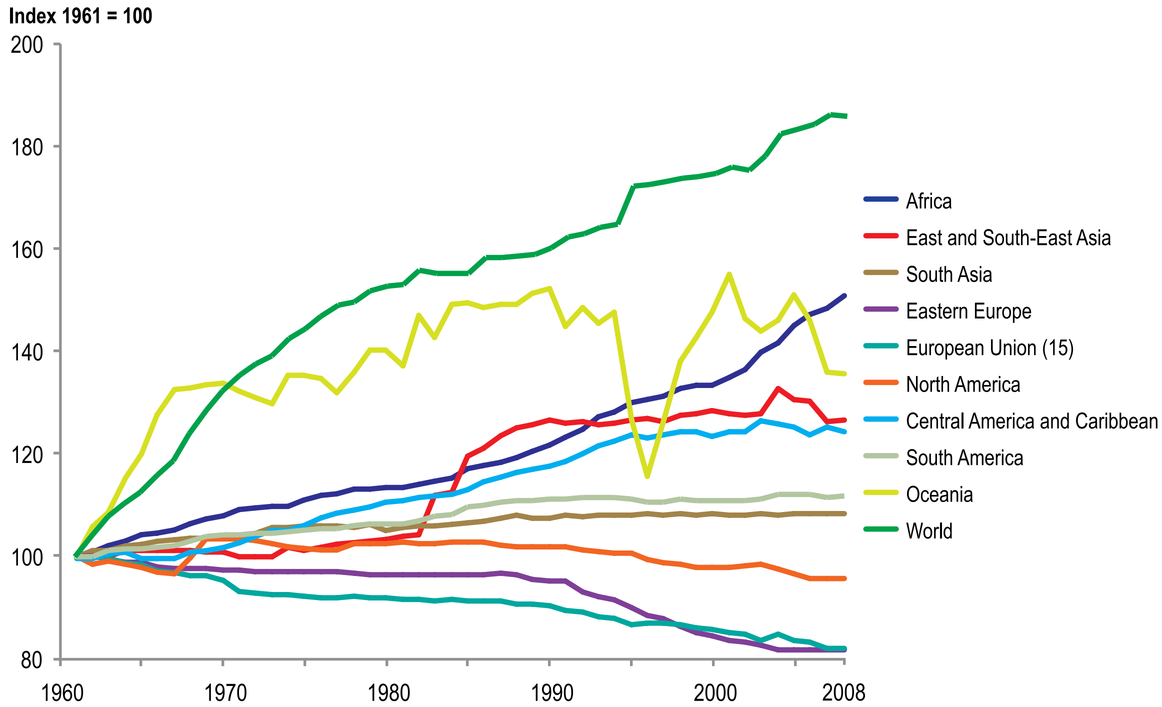
The shifts between countries and regions need to be interpreted against the background of global trends as well as of increased international trade. For instance, the decline of cropland in Europe is a consequence of largely replacing domestic feed production by import of soybean and soybean meal from Latin America (Dalgaard et al. 2008).

5 Note that one third of the ca. 15,000 Mha of all continents is covered by deserts, glaciers and other extreme habitats.

6 In terms of kcal absolute; if calculated as kcal per person the increase was by 27%.

7 Multiple cropping index (MCI): the sum of areas planted to different crops harvested during the year, divided by the total cultivated area. http://www.fao.org/docrep/V9926E/v9926e0a.htm

Figure 2.2 Changes in arable and permanent crop land use, 1961 - 2008 (in per cent)



Source: Bindraban et al. 2009 based on FAOSTAT online database

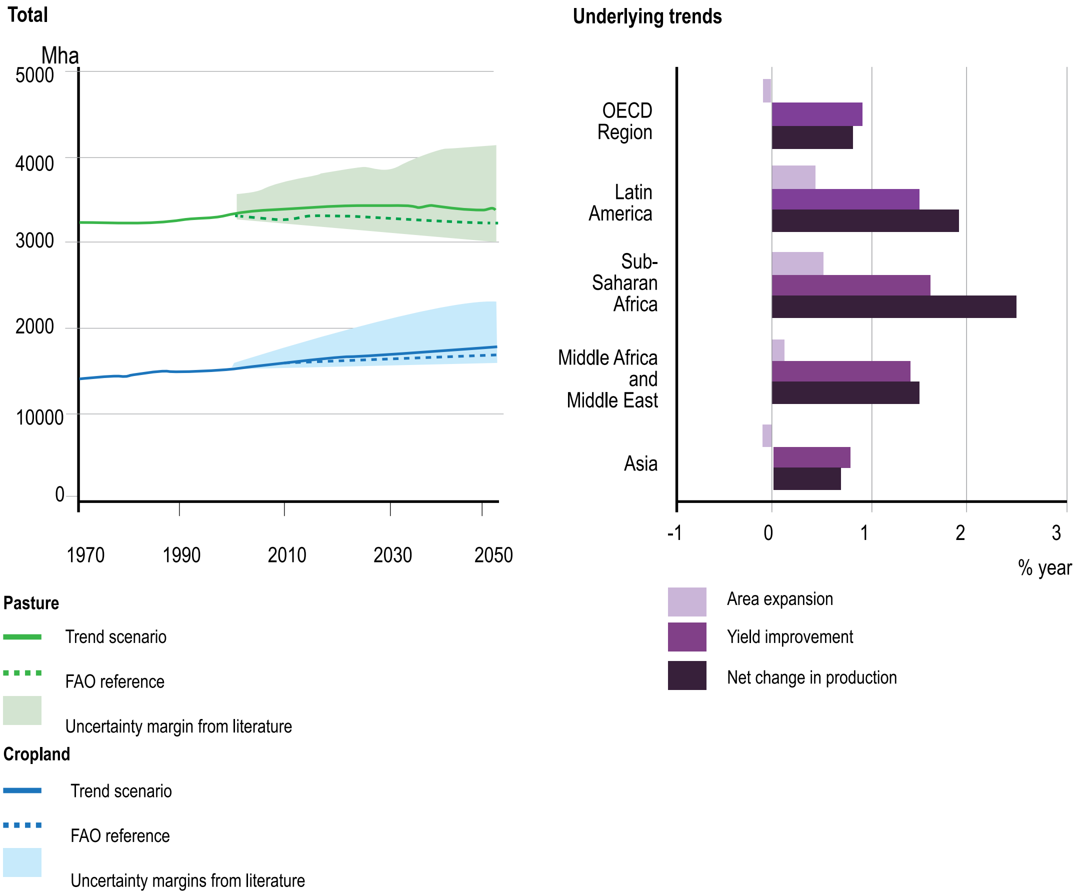
Notes: (1) EU-15 and Eastern Europe analyzed separately for the sake of continuing time series in historic borders; (2) increase for East and South-East Asia results from (original) FAOSTAT online database and is mainly for China; (3) fluctuations for Oceania results from (original) FAOSTAT online database and is mainly for Australia.

Regarding future trends, the OECD (2008b) estimates global agricultural land - both cropland and permanent pastures - to extend by roughly 10% until 2030 (respectively by 14% until 2050 or around 690 Mha). The United Nations (MEA 2005; UNEP 2007) outline the potential range of increase until 2050 between 7% and 31%, or roughly 350 to 1,500 Mha, depending on various boundary conditions and assumptions. Forest losses go hand in hand with the expansion of pasture and cropland, which is also growing at the expense of natural grasslands and savannahs.

Global land use scenarios developed by the Netherlands Environmental Assessment Agency (Van Vuuren and Faber 2009) expect a net expansion of cropland from around 1,500 Mha to more than 1,600 Mha by 2050 (Figure 2.3)[8]. The expansion would mainly occur in Africa, Latin America and Southeast Asia. During the same period, there would also be some decrease in agricultural areas in temperate zones. The FAO outlook trend (FAO 2006b) shows a very similar trend.

8 *"Increased food production can be achieved through improvement of yields and by expansion of agricultural land. In the last decades, yield improvements have been the most important factor, but at the same time agricultural areas expanded by about 5% since 1970. Under the Trend scenario, this trend of improving yields, but even faster increase in food demand, is expected to continue (Figure 2.3) (IAASTD 2008). About 70% of the production growth would come from yield increase." (Van Vuuren and Faber 2009).*

Figure 2.3 Global land use – trend scenario of cropland and pasture, 1970 – 2050



Source: Van Vuuren and Faber 2009 based on FAO 2006b, IAASTD 2008, Van Vuuren et al. 2008

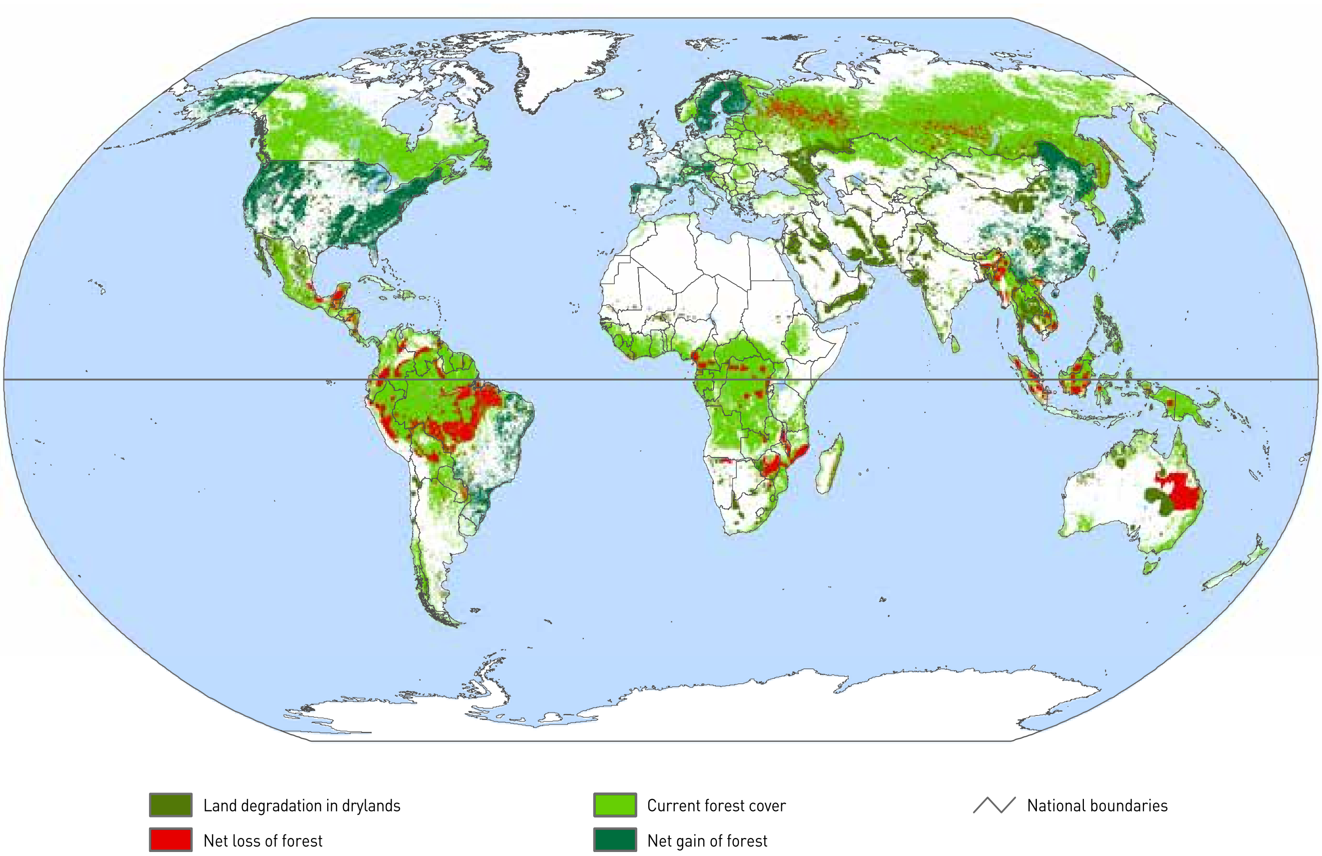
For **grassland** areas, Van Vuuren and Faber (2009) have described widely varying projections. Increasing meat consumption (see section 3.4) leads to a significant increase in the number of animals. Worldwide, there is a gradual shift from very extensive to intensive husbandry (see below). This mitigates the net expansion of pasture areas, but also leads to negative trade-offs, such as increasing use of nutrients and pesticides. Van Vuuren and Faber (2009) assume that some net expansion of pasture areas will occur, but that this growth will level off soon after 2025, consistent with the projections found in other studies.

For **agricultural land in total,** this implies a likely further net expansion compared to the level of 2010.

Besides meeting the demand for food supply, **cropland** will also expand (net) due to increased demand for biofuels and biomaterials, and move to new areas also to compensate for the expansion of built-up land and land degradation (as will be shown in Chapter 3).

Over the last five decades, **deforestation** has occurred at a rate of about 13 Mha per year on average, with cropland expansion being the main cause worldwide (e.g. Gibbs et al. 2010). Since 2000, **primary forest area** has decreased by around 40 Mha, whereas forest **plantations** have increased by about 5 Mha ***per year*** since 2005. Indeed, conversion to forest plantations accounts for 6 -7% of natural forest losses in tropical countries, and this trend has been especially prevalent in Indonesia (Cossalter and Pye-Smith 2003). In Europe, the forest area has increased since 1990, while South America, Africa and Southeast Asia continue to see high rates of net forest loss (Figure 2.4). This is especially problematic because of the hotspots of biodiversity that exist in these countries. It also means that the vital roles the forest plays in carbon storage and sequestration, as well as water regulation and filtering, are increasingly impaired (UNEP et al. 2009).

Figure 2.4 Forest transition and land degradation in drylands



Source: FAO 2006a based on MEA 2005

Land use change and climate change are strongly interlinked: around 20% of global carbon emissions were related to land use change in the 1990s (IPCC 2000). In fact, palm oil biodiesel produced on land converted from peat rainforest might release 2,000% more carbon than fossil-fuel based diesel (Beer et al. 2007). On the other hand, climate change can induce land degradation (IPCC 2007b), thus pushing agriculture to expand to new areas.

2.2 Agricultural production and environmental degradation

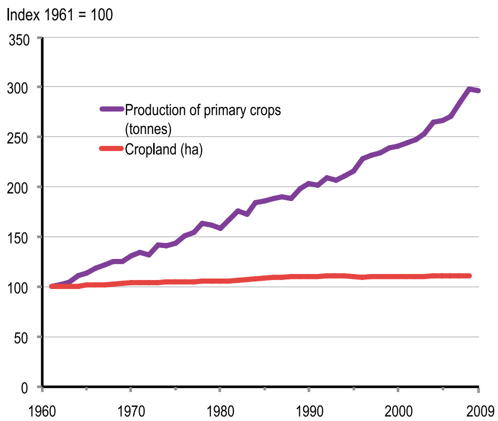
The productivity of agricultural land has increased significantly over the past five decades, but also rates of soil degradation, nutrient pollution, biodiversity loss and GHG emissions associated with both intensification and land use change have increased. This section looks at each of these trends in more detail.

2.2.1 Agricultural production

Intensification[9] of agriculture by use of high-yielding crop varieties, fertilization, irrigation, and pesticides has contributed substantially to the tremendous increases in food production over the past 50 years.

From 1961 to 2009 global production of primary crops almost tripled while cropland increased only slightly by around 12% (Figure 2.5). Hazell and Wood (2008) found a similar rate of increase for total food production while food production per person increased roughly only by about one third. This was primarily achieved with a technological development that increased yields through increased inputs—irrigation, improved seeds, fertilizers (mainly nitrogen), machinery and pesticides (Figure 2.6). Also negative environmental and health effects of agriculture increased significantly in terms of salinization, soil erosion, eutrophication, and agrochemical contamination (IAASTD 2009). Moreover, the rate of yield increase of cereals and primary crops in general has slowed down over the past few decades (see section 3.1).

Figure 2.5 Global production of primary crops and cropland development, 1961 - 2009

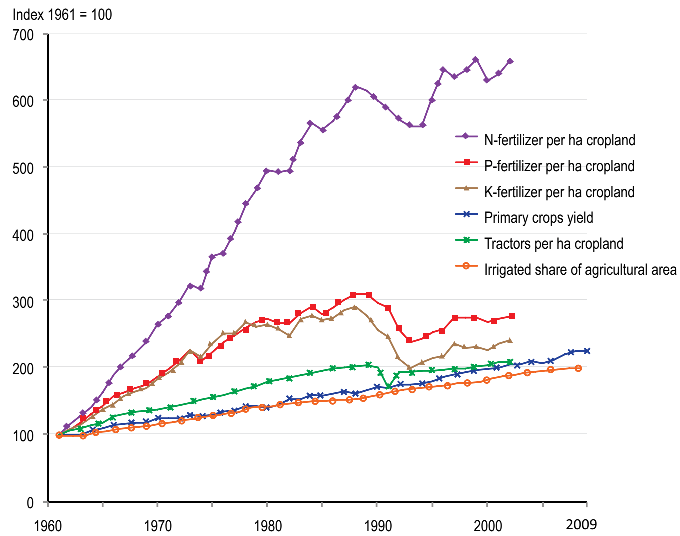


Source: Drawn from FAOSTAT online database

Note: primary crops as defined and reported by FAO (comprising: Cereals; Roots and tubers, Sugar crops, Pulses, Nuts, Oil bearing crops, Vegetables, Fruits, Fibres, Other crops [Spices, Stimulant crops, Tobacco, Rubber and other crops]); cropland comprises arable land and permanent crops.

9 *Agricultural intensification can be technically defined as an increase in agricultural production per unit of inputs (which may be labour, land, time, fertilizer, seed, feed or money) (FAO 2004). Expansion and intensification of cultivation are among the predominant global changes of this century (Matson et al. 1997).*

Figure 2.6 Global trends in the intensification of crop production, 1961 – 2002/2009



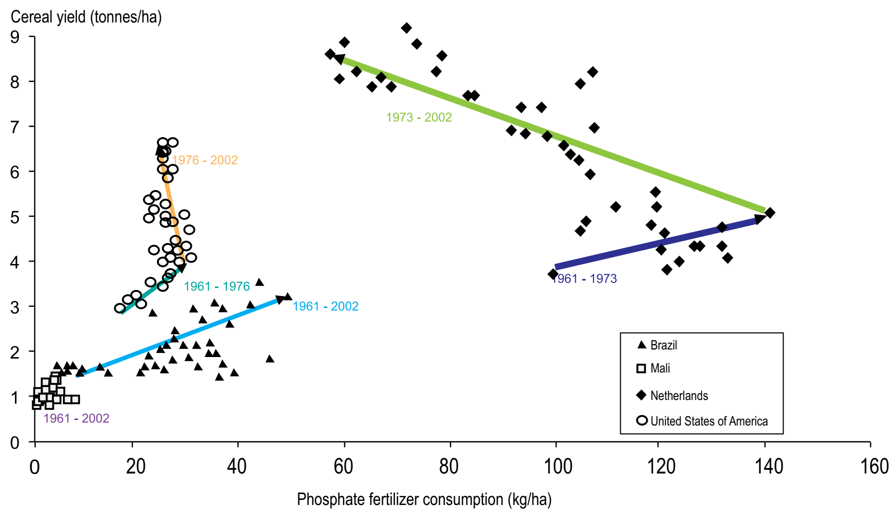
Source: Drawn from FAOSTAT online database.

Note: This graphic was constructed after a similar Figure in Hazell and Wood (2008) which in turn was based on Cassman and Wood (2005). The main differences are: (1) fertilizer was here split into N, P and K fertilizer respectively, (2) cereal yields here were replaced by primary crops yields, (3) irrigated share of agricultural area was used here instead of cropland because data for the latter were not available in the FAOSTAT online database.

Globally, the leveling off of the main inputs per hectare with growing primary harvest indicates the effect of a learning process, which has led to higher efficiency and at least some stabilization of the environmental load. However, there are still big differences in the efficiency of fertilizer use: the Netherlands uses about 3 times more phosphorus (P) fertilizers per ha than the US, while the yields are only 30 % higher in the Netherlands (Figure 2.7). Although soil properties vary and soil depletion of P might be more relevant in the US than in the Netherlands, there still seems to be room for even higher nutrient efficiency.

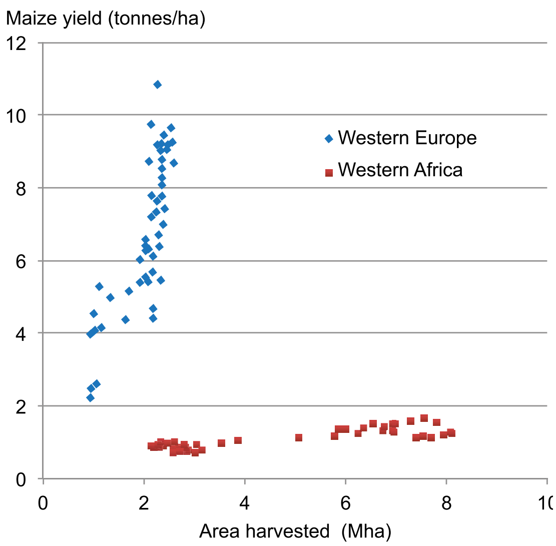
Agricultural production has reached different levels of intensification across the world. In Western Europe, a high level of technology allowed the total production volume, for instance of maize, to increase dramatically while the total agricultural area receded (Figure 2.8). In Western Africa, on the contrary, a low educational level of farmers and lack of fertilizers and other inputs, among other reasons, have constrained yields and the increase in production volume has been obtained from expansion of agricultural land.

Figure 2.7 Selected national rates of phosphate fertilizer consumption and cereal yield levels, 1961 - 2002



Source: Drawn by P. Bindraban from FAOSTAT online database

Figure 2.8 Different routes through which the increase in food volumes has been realized



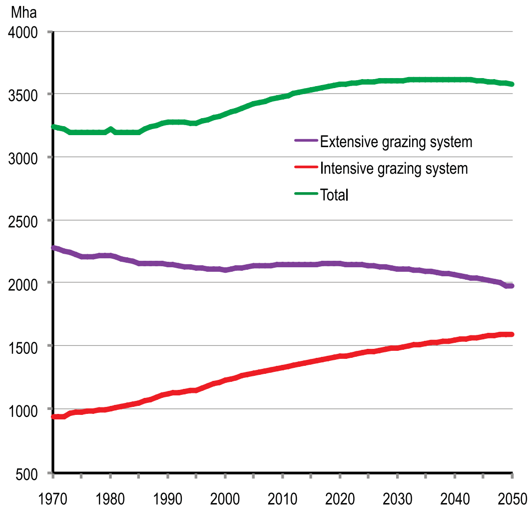
Source: Bindraban and Rabbinge 2011 based on FAOSTAT online database (2009)

The intensity of use of **grazing land** has also been increasing in the past, and is expected to further increase in the future (Figure 2.9). For example, data from the IMAGE model of the Netherlands Environmental Assessment Agency (PBL)[10] show a marked increase of intensive grazing systems since 1970 (by 37% to 2005) whereas extensive systems declined (by 7%) over the same period, and the overall grazing area slightly increased [11] (by 6% respectively). In 2005, intensive grazing area made up 38% of grazing land compared to 29% in 1970. Intensification of grazing systems mainly took place in South America, West- and East-Africa, and in China.

10 Based on personal communication with Stehfest, E., Netherlands Environmental Assessment Agency (PBL) on 30 August 2010 with reference to Goldewijk et al. (2007). Based on grassland productivity modeled by the IMAGE crop model, the authors classified grasslands into intensive and extensive pastures. Data for total grassland are in line with the FAOSTAT online database for permanent pastures and meadows. Reference to the productivity level definition of extensive and intensive grassland is in Bouwman et al. (2006).

11 The total grazing land from this depiction corroborates well with data of FAO for permanent meadows and pastures. However, a satellite data based study has claimed that significantly less pasture area exists than had been previously suggested by FAO data (Ramankutty et al. 2008).

Figure 2.9 Global trends of grazing land, 1970 - 2050



Source: Drawn from data provided by E. Stehfest (Netherlands Environmental Assessment Agency, PBL), based on the IMAGE model, cited in Bouwman et al. 2006

2.2.2 Soil Degradation

Land degradation refers to a deterioration in environmental quality and losses in the "resource potential" and "productive capacity" of the land (UNEP 1992, 1997). Besides the above ground resources of flora and fauna, the soil plays a key role in the potential and capacity of land. The *causes* of soil degradation include some combination of water erosion, wind erosion, soil fertility decline due to nutrient mining, waterlogging, salinization (often caused by irrigation systems), lowering of the water table and over-use of chemical inputs causing soil pollution (Scherr 1999), and the implications for society and ecosystems appear to be rather complex (Bai et. al. 2010).

Based on a review of 26 global and regional studies and 54 national/local studies in developing countries, the International Food Policy Research Institute (IFPRI) confirmed the generally used estimate of 23% of global soils being degraded (Scherr 1999). More significantly, 38% of agricultural land (as distinct from permanent pasture land and woodlands) was found to be degraded. Of the total of around 1,900 Mha of degraded land, around 1,200 Mha was estimated to be "seriously degraded". This means that 700 Mha is "lightly degraded" and can be restored at relatively low cost through changes primarily in farming practices and land management techniques (Scherr 1999). "Seriously degraded" land takes several years to restore and is a costly exercise. Between 5 Mha and 12 Mha of arable land have been lost due to degradation per annum (Scherr 1999).

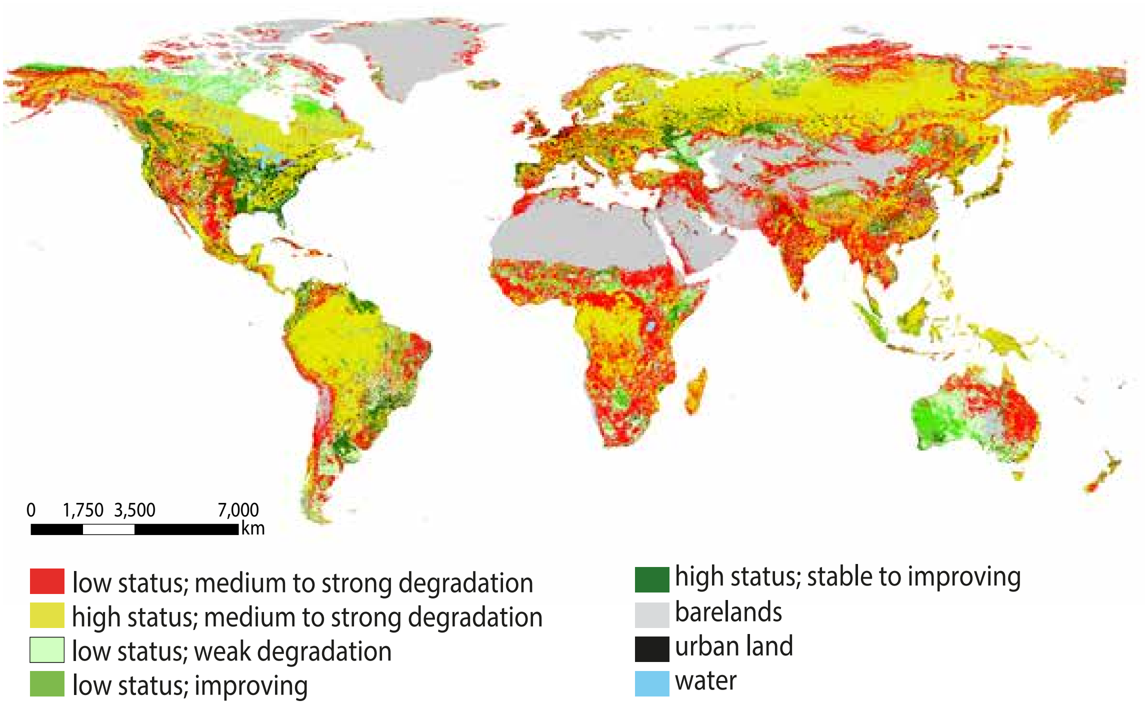
According to Lavelle et al. (2005) persistently high rates of erosion affect more than 1,100 Mha of land worldwide, redistributing 75 billion tons of soil per year (Pimentel et al. 1995) with 1.5 to 5% of carbon content (Lal 2001). Soil erosion mines soils and contributes to desertification and nutrient losses. Erosion results in a redistribution of nutrients. It affects nutrient cycling and results in a depreciation of land and soil quality.

Since the 1990s, land degradation is intensifying in many parts of the world, according to a study using data taken over a 20-year period (FAO 2008), enhancing the need to expand cropland to compensate for unproductive degraded land. If projected cropland expansion follows the patterns observed in the 1990s, it would come primarily from forest land in Latin America, Southeast Asia and sub-Saharan Africa, and primarily from grasslands elsewhere.

Half of the entire developing world's arable and perennial cropland is in just five countries – Brazil, China, India, Indonesia and Nigeria. The fact that China and India have land degradation problems similar to those in Sub-Saharan Africa indicates the challenge of global soil conservation (Scherr 1999).

Altogether, about one quarter (24%) of the global land area has already suffered declines in quality and productivity over the past quarter century as a result of unsustainable land use (Figure 2.10). The latest UNEP yearbook (UNEP 2012b) highlights assessments indicating that in certain areas conventional and intensive agriculture are triggering soil erosion rates some 100 times greater than the rates at which nature can regenerate soil.

Figure 2.10 Status of land in regard to capacity of ecosystem services, degradation and direction of changes



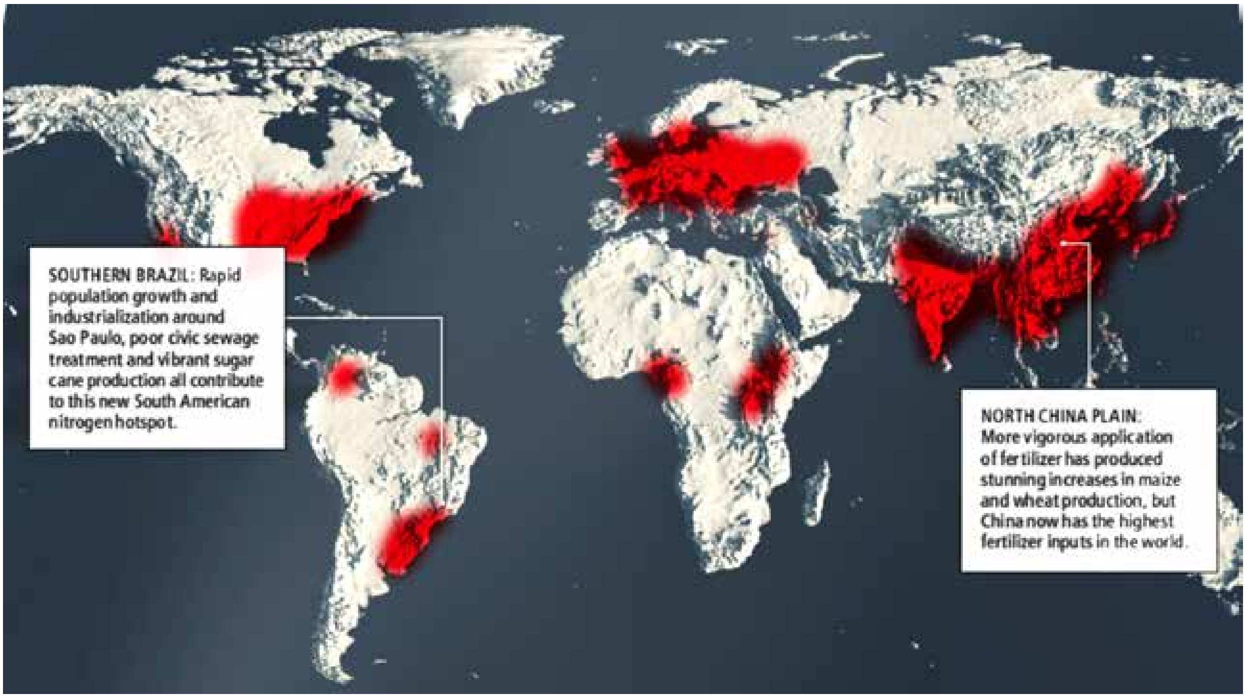
Source: UNEP 2012b from Nachtergaele et al. 2011

2.2.3 Nutrient pollution

Human activity has greatly accelerated the cycles of both nitrogen (N) and phosphorus (P) at global and regional scales over the past half century, causing significant damage and risk to environmental quality. The majority of change has been driven by large increases in use of fertilizer for the production of crops and livestock animals (Figures 2.11 and 2.12) (Howarth et al. 2005). Without doubt, synthetic N fertilizer has led to far less hunger, malnutrition, and starvation, but excess N has also led to serious pollution. Synthetic N fertilizer also freed farmers from the need to recycle N, allowing the physical separation of animal feedlot operations and human settlements from crop production, and leading to staggering amounts of pollution from these animal operations and urban areas (Howarth et al. 2002, 2005). The rate of change is dramatic, with more than half of the synthetic N fertilizer ever produced used just in the past 25 years or less (Howarth et al. 2005). Combustion of fossil fuels also contributes to N pollution globally and even dominates N pollution in some regions (Howarth et al. 2012).

Nutrient pollution has a wide array of consequences. Both N and P cause eutrophication of waters. In the temperate zone, eutrophication of lakes is linked more to P, while N is generally more responsible for eutrophication of coastal marine ecosystems (Schindler 1977, Howarth and Marino 2006, Howarth et al. 2011). Nonetheless, prudent management demands controlling both N and P (NAS 2000, Howarth et al. 2011). Aside from eutrophication, nitrogen has numerous and diverse impacts on the environment, leading to increased atmospheric ozone, fine particulate matter, acidification of surface waters (biodiversity loss), and greenhouse gas emissions (via N_2O production) (Galloway et al. 2004). Nitrate in drinking water poses a significant cancer risk (Townsend et al. 2003). Synergistic effects may further exacerbate the negative impacts of nitrogen pollution. For example, increased atmospheric carbon dioxide coupled with anoxic and hypoxic estuaries and coastal waters can accelerate the loss of coral reefs (Howarth et al. 2011).

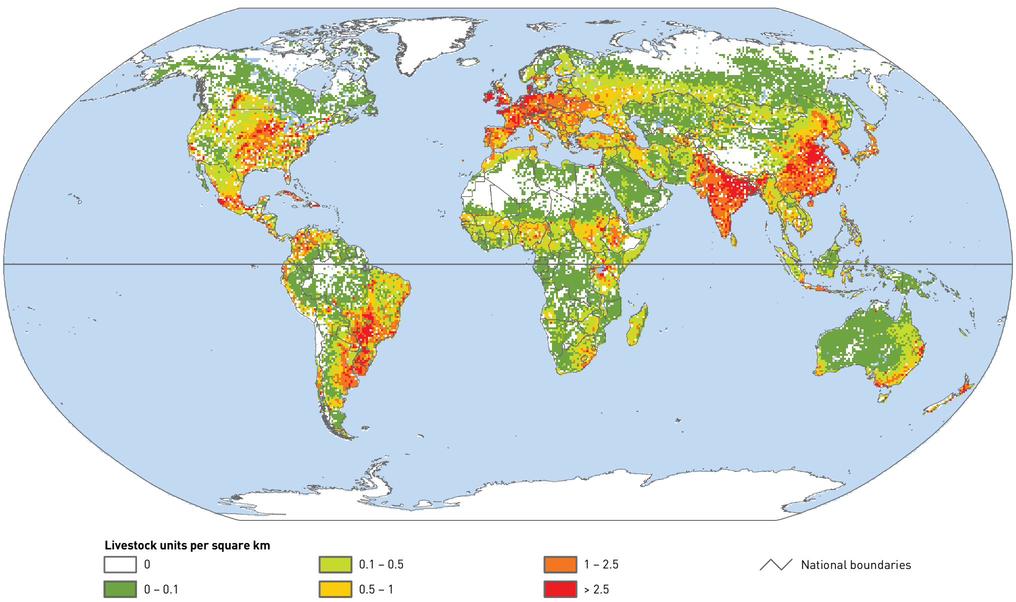
Figure 2.11 Hot spots of Nitrogen use by human society



Source: Townsend and Howarth 2010

Note: Hot spots of N use are shown here in a qualitative sense in red, largely reflecting agricultural use.

Figure 2.12 Global distribution of animal livestock



Source: FAO 2006a

Note: Livestock in this figure refers to the accumulated distribution of pigs, poultry, cattle and small ruminants based on data from the Food Insecurity, Poverty and Environment Global GIS Database (FGGD) and Digital Atlas for the Year 2000.

Thus, although fertilizer application has become more efficient in recent decades, the side effects of intensive agriculture in the form of nutrient pollution are still significant and increasing. Without drastic improvement of agricultural management practices, and/or shifts in consumption of nutrient-intensive goods, the environmental load of nutrient losses will grow with the expected growth of global production. And even with minimized proportion of fertilizer input lost to the environment of a field, a continuous increase of biomass production within a river basin would sooner or later conflict with quality requirements for the water bodies. In other words, there are certain environmental limits to growth of agricultural yields per hectare, which would finally require open field agriculture to "grow flat", i.e. to expand the production area for an increasing production volume, or to "grow vertical" in closed systems with full control of nutrient flows.

2.2.4 Biodiversity loss through agricultural land use change

Agricultural expansion and the conversion of natural habitats are known to be key causes of the worldwide loss of biodiversity and ecosystem services (Lepers et al. 2005, MEA 2005, Haines-Young 2009). In particular, tropical forests and temperate grasslands are severely affected (Figure 2.13). This affects above ground fauna and flora (Sala et al. 2009), as well as soil biodiversity (Turbé et al. 2010). In the literature, land-use changes are the first most commonly cited cause of general biodiversity extinction, as they are immediate and often take place on a large scale, thereby not allowing species to adapt, or to move away to other areas. Whereas in more developed regions with high population density, fragmentation of natural habitats due to the expansion of transport infrastructure puts an increasing pressure on biodiversity (EEA 2010), in less developed regions in the tropical belt, the expansion of cropland and pasture land into natural biomes exerts the highest pressure on biodiversity through land use change. In addition, the expansion of urban areas is expected to result in considerable loss of habitats in key biodiversity hotspots, with the highest rates of forecasted urban growth to take place in regions that had been relatively undisturbed so far[12] (Seto et al. 2012).

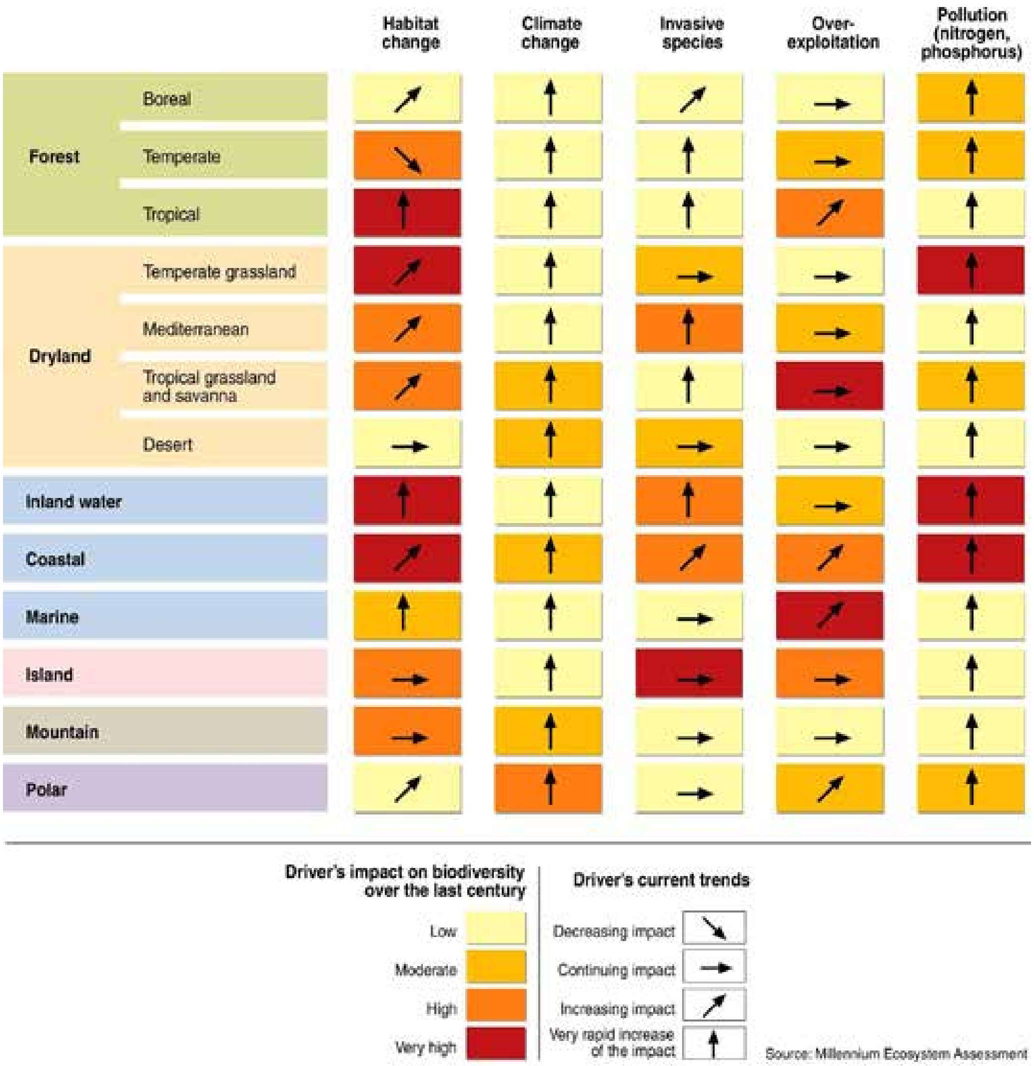
Although, from a methodological point it is not straightforward to measure biodiversity at a large scale, the accounting of changes in land cover can provide information about pressures on biodiversity (Eurostat 2010). Several land-cover changes including land conversion or changes in land-use intensity can affect the status of specific habitat types and species. In particular the change of natural grasslands, savannahs or forests into cropland which represents a rather intensive form of cultivation usually leads to a decisive decrease in species biodiversity (MEA 2005).

As Van Vuuren and Faber (2009) observe, global biodiversity is endangered through increasing pressure on land use for food production, biofuels and urbanization, which could result not only in the disturbance of biogeochemical cycles but also in significant losses of genetic capital. Halting biodiversity loss would require agricultural land to, at least, stabilize.

A key challenge here will be to develop the international institutional setting not only to value the protection and maintenance of natural areas and biodiversity hot spots but also to address the drivers for increased demand of agricultural products and related land use.

12 The Eastern Afromontane, the Guinean Forests of West Africa, and the Western Ghats and Sri Lanka hotspots.

Figure 2.13 Main direct drivers of change in biodiversity and ecosystems



Source: MEA 2005[13]

2.2.5 GHG emissions due to land use change by agriculture

According to the fourth Assessment Report of the IPCC, climate change is almost certainly caused by greenhouse gases and other radiative substances, emitted through human activities related to fossil-fuel combustion and land-use changes (IPCC 2007b).

13 *(http://www.millenniumassessment.org/en/GraphicResources.aspx). Cartographer/designer: Philippe Rekacewicz, Emmanuelle Bournay, UNEP/GRID-Arendal)*

Land-use and land-cover change (LULCC) plays a major role in climate change at global, regional and local scales (EEA 2010, Ellis and Pontius 2007). At the global scale, LULCC results in the release of GHGs to the atmosphere, thereby driving global warming (IPCC 2000). LULCC can increase the release of carbon dioxide (CO_2) by disturbing soils and vegetation, and the main driver of this is deforestation, especially when followed by agriculture, which causes further release of soil carbon as a result of disturbance by tillage and drainage of (peat) soils. LULCC is also associated with major changes in terrestrial emissions of other GHGs, especially methane from altered surface hydrology — wetland drainage and rice paddies, cattle grazing, and nitrous oxide from agriculture — the input of inorganic nitrogen fertilizers, irrigation, cultivation of nitrogen-fixing plants, and biomass combustion.

Globally, the conversion of land to cropland has been responsible for the largest emissions of carbon from land-use change (Houghton 2010). When grasslands, forests and wetlands are converted to other types of use, the level of organic matter and organisms in soil, as well as CO_2 sequestration capacity, generally decreases. This is particularly relevant for permanent grasslands such as pastures (EC 2010). An important driver for land use change and related impacts is the growing animal production wordwide (Herrero et al. 2009).

While the expansion of agricultural land into (semi-) natural vegetation is linked to various environmental pressures, agricultural intensification also affects biodiversity, water resources and soil quality, and contributes to GHG emissions (EEA 2006a, Ramankutty 2010).

Thus, altogether there are various environmental impacts of the further expansion and intensification of agricultural production. The observed trends underpin the necessity to have a closer look at the drivers behind the expansion and intensification trends and to study the options to reduce the pressure on the conversion of natural ecosystems while serving humanity with the necessary services and inputs from agriculture.

2.3 A global agricultural industry

During the last decades the agricultural sector and the food chain as a whole have experienced a dramatic transformation.

By the end of the 20th Century there were approximately 437 million farms in developing countries which, in turn, sustained the livelihoods of 1.5 billion people and provided food for two-thirds of the human population (Madeley 2002). By the start of the 21st century, 40% of these farms in the developing world were dependent on Green Revolution technologies (Madeley 2002), including application of nitrogen and phosphorous fertilizers, and many of these generated the surpluses required to finance urban-based modernization through industrialization (especially in Asia and Latin America, less so in Africa, although most certainly in South Africa). Many of the remaining majority were small farmers on marginal land, often the victims of land dispossessions to make way for cities and massive agribusiness operations on the best land. Those who were no longer living on the land had migrated to the burgeoning cities.

By 2005 the largest ten seed corporations controlled 50% of all commercial seed sales; the top five grain trading companies controlled 75% of the market; the largest ten pesticide manufacturers supplied 84% of all pesticides; and when it comes to vegetable seeds there is only one company – Monsanto - that completely dominates the market, which controls roughly 30% of the seed market for beans, cucumbers, hot peppers, sweet peppers, tomatoes and onions (Barker 2007).

The industrialization of agriculture coincides with a substantial restructuring of the political economy and technologies of global food production in response to declining yield growth, rising prices and expanding middle class demand in rapidly industrializing countries like India and China for more dairy and meat products. The introduction of neo-liberal modes of governance, globalization, de-regulation, privatization, the establishment of the WTO rules for agriculture, and financialization have all contributed to a transition from state-centered national agricultural development models to privatized agricultural systems structured to service global markets and the rapid expansion of trade (Barker 2007). The information technology revolution transformed logistics making the expansion of globally traded foodstuffs, fertilizers and pesticides possible on scales that would have been unimaginable in the mid-20th century (Reardon and Barrett 2000). It also gave birth to the biotechnology industry which, in turn, made possible the commercialization of genetically modified organisms (GMOs) as the new 'techno-fix' of the global food industry – the so-called 'gene revolution'.

Supermarket chains rapidly increased their grip on retail food sales between 1992 and 2002, with South Africa leading Africa with 55% of all food sold via supermarket chains by 2002, with Brazil reaching 75%, while South America as a whole and East Asia (excluding China) were at just over 50% and China just below 50% (Reardon et al. 2003).

This level of agribusiness concentration has led to greater margins and profits, squeezing input/product price ratios. All in all, international agricultural trade has increased 10-fold since the 1960s. This is a result of more open trade policies, market liberalization in many developing countries and advances in communications and transport systems (Hazell and Wood 2008). That said, still only about 16% (15% for cereals and 12% for meats) of world production entered international trade, with a wide variation among individual countries and commodities (Bruinsma 2009).

2.4 Food prices and food security

Elevated food prices have had dramatic impacts on the lives and livelihoods, including increased infant and child mortality, of those already undernourished or living in poverty. People that spend 70–80% of their daily income on food are most affected.

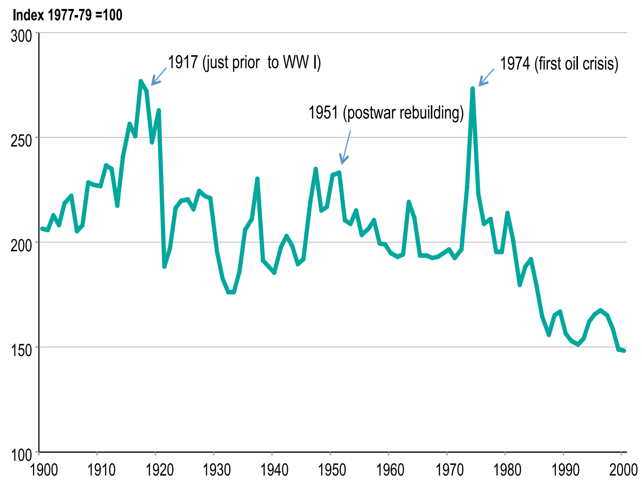
Food prices are driven by a complex combination of factors. Historically, long-term decline in prices (Figure 2.14) was largely due to massive increases in agricultural productivity and output, with key exceptions that mark moments of crisis (post-World War I, 1929 crash, post-World War II, 1973/74 oil crisis). Historical post-war peaks have been driven by various factors, in particular by increasing oil prices which led to higher production costs of agriculture such as for fuel and fertilizer, and in recent times enhanced by growing demand for biofuels (Headey and Fan 2008, Piesse and Thirtle 2009, FAO 2008).

The past trends kept ahead of rapidly rising demand due to population growth and diet changes caused by modernization and urbanization. The obvious question is whether the current peak will end at a point that replicates the long-term downward pattern or whether we are at the start of a long-term increase in food prices driven by a matrix of factors that have not been present in this form before. No other decade, except possibly just after World War II, exhibits a pattern of such steady and steep price increases. If predictions of several organizations, such as the OECD or FAO, turn out to be true, there will be two decades of steadily rising prices– something that has not happened before.

The financialization of food and agriculture has also had major implications for the distribution and cost of food. The financial institutions and instruments have become increasingly involved at all points of the agri-food system. In recent years, hundreds of investment entities have been established for the purpose of investing in farmland throughout the world (Burch and Lawrence 2009). When average prices of (food) commodities increase this gives rise to growing speculation (e.g. by trading of futures), which may also enhance price spikes.

Fluctuating prices are a core problem for stable food production. Agricultural price volatility increases the uncertainty faced by farmers and affects their investment decisions, productivity and income. Lagging investments can be a constraint in meeting changing consumer demands. Instability in prices is related to factors in the agricultural domain as well as in biomass processing and consuming sectors.

Figure 2.14 Food price development, 1900 - 2000

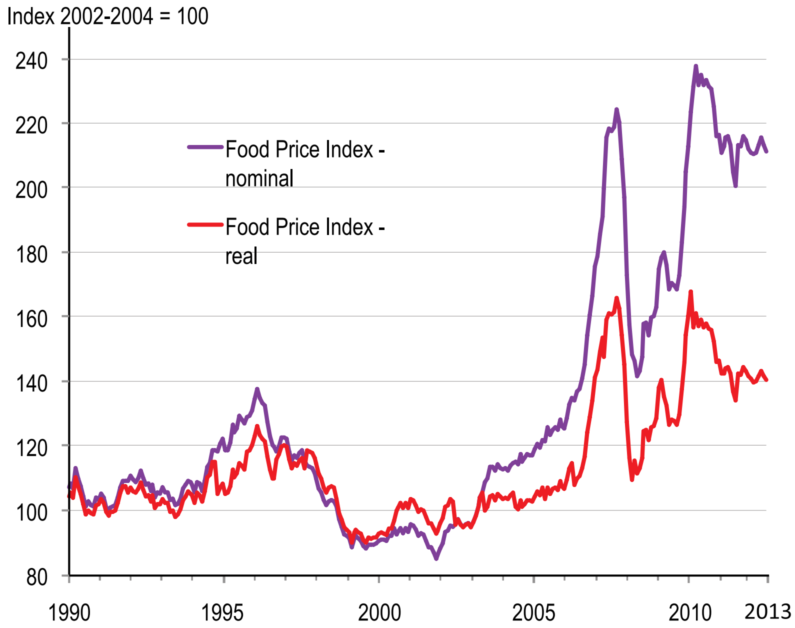


Source: Pfaffenzeller et al. 2007 and World Bank 2008a.

Note: The real price index is the nominal price index deflated by the World Bank Manufacturers Unit Value (MUV). This reflects the average level of production costs in the following industrial countries: France, Germany, Japan, United Kingdom, and United States. However it does not necessarily reflect the dynamics of purchase power in countries importing those food products.

Food prices today remain below their peak in 2008, having reached similar levels in 2011, but are higher than the pre-crisis levels in many developing countries (Figure 2.15). The food and energy crisis are working together to place a new set of pressures on the economic system as a whole. The food price rise creates macro vulnerabilities, particularly for countries with a high share of food imports and limited fiscal space, as well as increases in poverty. As a result of price rises since June 2010, there has been a net increase in extreme poverty of around 44 million people in low- and middle-income countries (World Bank 2011a).

Figure 2.15 Food price index, 1990 – 2013



Source: Drawn from FAOSTAT online database

Note: The real price index is the nominal price index deflated by the World Bank Manufacturers Unit Value (MUV). This reflects the average level of production costs in the following countries: Brazil, Canada, China, France, Germany, India, Italy, Japan, Mexico, South Africa, South Korea, Spain, Thailand, United Kingdom, and United States. However it does not necessarily reflect the dynamics of purchase power in countries importing those food products

The demand for food will continue to increase towards 2050 as a result of population growth and new demands (bioenergy, biomaterials), increased incomes and growing consumption of meat and dairy products. According to recent OECD-FAO medium term outlook projections, prices of crops and most livestock products will be higher in both real and nominal terms during the decade to 2019 than they were in the decade before the 2007/2008 price peak. If the rate of growth of agricultural production does not keep pace with demand, upward pressure on prices will result. A demand or supply shock in a situation where the supply-demand balance is already tight, can result in increased volatility. The demand for food and feed crops for the production of first generation biofuels is another significant factor[14]. Projections encompass a broad range of possible effects but almost all suggest that biofuel production will exert considerable upward pressure on prices in the future.

14 The OECD-FAO Agricultural Outlook 2011-2020 projects upward shares for biofuels production by 2020 of 15% for vegetable oils (with even 50% in EU27 and 70% in Argentina), 30% for sugar cane, and 9% for cereals, wheat and coarse grains.

Besides the global challenges, local implications for food security may differ between world regions. Cropland expansion for international trade supply is affecting local food production and putting food supply at the local level in developing countries at risk (Altieri and Pengue 2006). In developed countries with net import of biomass products, food security is not at risk due to high purchasing power, although low-income households may suffer disproportionately should food prices increase in the long run.

Besides the negative effects of increasing agricultural commodity prices on the demand side, income from the export of agricultural products may support national economic development (Dawson 2005). This implies also positive effects on the supply side, as shown by information from the World Bank for some Latin American countries (Table 2.1). In the first decade of the 2000s, these countries have experienced real improvements in terms of their trade due to the effect of increasing commodity prices and greater shares of food exports.

Table 2.1 Increase of food exports of Argentina, Brazil and Mexico (compared with China), 2000 - 2010

COUNTRY	FOOD EXPORTS (% of merchandise exports)			INDEX EXPORT [15] (2000=100)	
	2000	2005	2010	value	volume
Argentina	43.8	46.6	51.2	260	174
Brazil	23.4	25.8	31.1	366	186
Mexico	4.8	5.4	6.1	179	133
China	5.4	3.2	2.8	633	563

Source: Drawn from World DataBank online database

15 *UNCTAD's Handbook of Statistics and data files, and the IMF's International Financial Statistics, as cited by the World Bank, indicate that export value index is "the current value of exports (free on board) converted to U.S. dollars and expressed as a percentage of the average for the base period (2000)." Furthermore, export volumen indexes "are derived from UNCTAD's volume index series and are the ratio of the export value indexes to the corresponding unit value indexes. Unit value indexes are based on data reported by countries that demonstrate consistency under UNCTAD quality controls, supplemented by UNCTAD's estimates using the previous year's trade values at the Standard International Trade Classification three-digit level as weights." (http://data.worldbank.org/indicator/TX.VAL.MRCH.XD.WD; http://data.worldbank.org/indicator/TX.QTY.MRCH.XD.WD)*

In the period 2000 to 2010, the value of Argentina's exports rose from US$ 23.3 to $ 68.1 billion, with exports of food increasing from 44% to 51% of the total. For the first time in recent history the index of export volume was well below the value index indicating rising prices for the traded commodities. This same pattern was observed in Brazil and to a lesser scale in Mexico. In the same period, Brazil raised the value of its exports of US$ 60 to $ 202 billion, in which the weight of food exports increased from 23 % to 31 % of exports, and gains were even more significant in terms of trade. For comparison, the share of food products in exports from China decreased while the absolute volume grew more significantly than in Latin America, indicating that China´s exports are becoming more dominated by non-food products.

This export profile of those countries supported a relatively quiet transition through the global economic crisis affecting the world since 2008. In the case of Brazil, it became a creditor of the International Monetary Fund. This change has allowed these countries to adopt important macroeconomic policies which have been converted into significant social gains for its population. Nevertheless, the environmental externalities and costs for environmental regeneration programmes have not yet been included in these socio-economic benefits.

In the case of Argentina, innovations in the agricultural sector during the same period allowed the country to take advantage of the rising demand for its "cash crops" (soybean and corn). "Environmental taxes" that the Argentine government takes from cash crops (around 35% of farmers' earnings), are being used to finance programmes for poverty alleviation, education, health care and external debt payment.

2.5 Large-scale land investments

Large-scale land acquisitions, both purchased and leased, are a result of increased demand for land, and a factor contributing to intensification and, in some cases, land use change. The term 'land grabbing' is commonly used to refer to those acquisitions that are illegal, underhanded or unfair; and it has been mainstreamed in both scientific literature and popular forums[16]. The term "land rush" has also emerged recently (Anseeuw et al. 2012).

Large-scale acquisitions of land increased significantly between 2005 and 2008 (Answeeuw et al. 2012). In the 1990s, worldwide foreign direct investment in agriculture was around US$ 600 million annually;

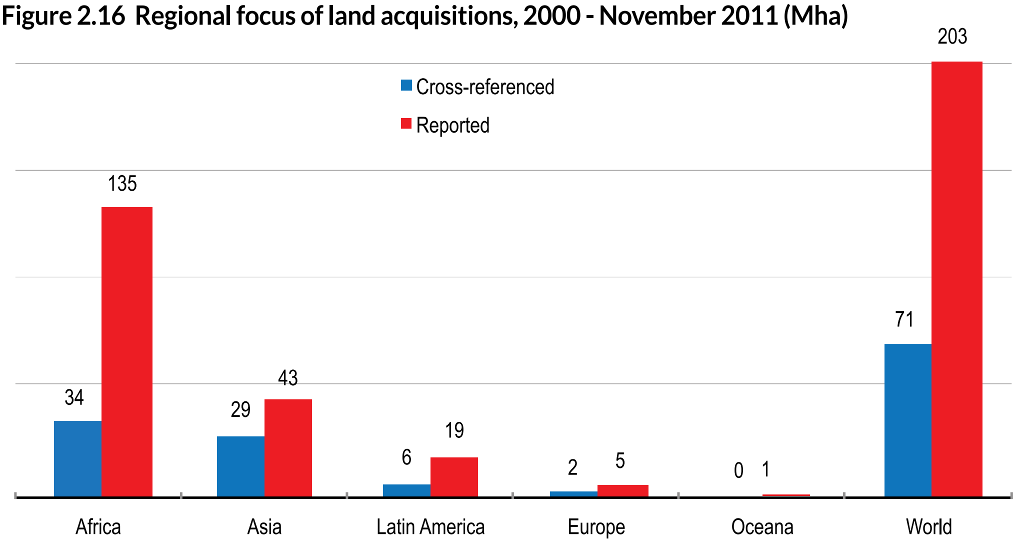
16 *The amount of information on land grabbing has increased significantly over the past year with a multitude of scientific and popular mediums: see the documentary "Planet for Sale" released by ARTE, 3 May 2011 (http://farmlandgrab.org/post/view/18542); the blog run by GRAIN with daily news updates (http://farmlandgrab.org/); Featured media by the Oakland Institute (http://media.oaklandinstitute.org/-land-deals-africa/featured-media); Volume 38 of the Journal of Peasant Studies dedicated to issues of land grabbing, 24 March 2011 (http://www.informaworld.com/smpp/title~db=all~content=g935339693); or the international conference on global land grabbing, 6-8 April 2011 (http://www.futureagricultures.org-/index.php?option=com_content&view=category&layout=blog&id=1547&Itemid=978).*

between 2005 and 2007 it averaged US$ 3 billion (UNCTAD 2009, De Schutter 2011). In Africa, the demand for land in the year 2009 alone was equivalent to the cropland expansion of more than the 20 previous years (Deininger 2011).

Around 56 Mha (approximately the size of France) were recently acquired by investors in less than 1 year (until August 2009), according to estimates from the World Bank (2011b). Around two-thirds of this acquisition occurred in Sub-Saharan Africa, although foreign land buys were also promoted in Latin America, Russia and other world regions (see Figure 2.16). Monitoring land deals between August 2008 and April 2010, the Global Land Project estimated that between 51 and 63 Mha were acquired or under negotiation in Africa alone (Friis and Reenberg 2010). Clearly, large land acquisitions are occurring at rapid and unprecedented levels, with many of these transfers qualifying as 'land grabbing'.

This boom, or land rush, is generally thought to be a result of three triggers -- the food crisis, the economic recession and biofuel targets – rooted to deeper concerns about securing food supply or securing 'safe' and profitable assets, especially related to the new 'green' energy market (Mann and Smaller 2010, Friis and Reenberg 2010). Some host governments are also actively trying to attract investors because they view land deals as a chance to gain funds for development of agriculture and infrastructure (Friis and Reenberg 2010).

Figure 2.16 Regional focus of land acquisitions, 2000 - November 2011 (Mha)



Source: Answeeuw et al. 2012 based on the Land Matrix[17]

Note: "Reported" (red columns) indicates that the land acquisition was reported by at least one source (published research and media reports). "Cross-referenced" (blue columns) indicates that more than one source of information reported the same land acquisition . Numbers have been rounded.

The food crisis of 2007/2008 enhanced concerns about food security, especially in countries dependent on food imports[18]. For instance, Saudi Arabia aims to phase out its own wheat production by 2016 because it is significantly depleting its fresh water resources and has established an agricultural fund to invest in agricultural production overseas (Mann and Smaller 2010). This type of investing represents a shift from investing in domestic agriculture to produce crops for the domestic and global markets to investing in land and water resources abroad to supply domestic markets with food and energy. Instead of serving international markets, these investors aim to circumvent them (Mann and Smaller 2010, De Schutter 2011).

17 *(www.landmatrix.org). The Land Matrix is a global and independent land monitoring initiative that promotes transparency and accountability in decisions over land and investment.*

18 *The concept of acquiring land abroad to ensure food supply is not new. Japan, for instance, has been outsourcing food production for many years and is estimated to have overseas holdings three times the size of its domestic arable land and China has been buying or leasing land abroad since the 1990s, especially in countries like Cuba and Mexico (De Schutter 2011).*

Many private companies are focusing on investing in biofuels, especially because political targets have made biofuel markets a secure, long-term investment opportunity, and also perhaps because the housing market collapse of 2008 created a vacuum for investment (Friis ad Reenberg 2010). Agricultural investment funds have been set up by a number of hedge funds and investment banks[19] (Mann and Smaller 2010). International financial institutions may play a role in facilitating land acquisitions as a strategy to raise productivity and knowledge transfer (Daniel and Mittal 2009). However, financial investors are mainly interested in – often short-term – profit rather than long-term maintenance of the physical capital, e.g. in the form of soil quality. When financial investors take the reins there is a division of parties between the land managers, operators, and farmers (stakeholders) on the one hand, and the shareholders on the other hand. Moreover, in contrast to traditional farmers who own and oversee their land, financial investors are distant and have no personal impression, relation or commitment to the acreage from which they draw their profit. Correspondingly, they tend to invest less in sustainable land management practices, such as agroforestry (Arbuckle et al. 2010).

Anseeuw et al. (2012), the World Bank (2011b) and Friss and Reenberg (2010) provide actual data on the scope and scale of the recent land acquisitions. However, they are all based on the scanning of media coverage posted on blogs[20] because data is otherwise not publically available or globally comparable. Indeed, there seems to be a 'veil of secrecy' surrounding details about the scope and conditions of land deals and a reluctance of both host governments and investors to publish the contents of their contracts and investor-state agreements[21] (Cotula et al. 2009, GRAIN 2010, Mann and Smaller 2010). Anseeuw et al. (2012) provide estimates that large-scale land deals between 2000 and November 2011 amounted to 203 Mha of land worldwide, with around one-third of these deals confirmed through cross-referencing. The World Bank (2011b) analysis revealed 464 projects between October 2008 and August 2009; 203 of the projects included area information totaling 56.6 Mha. The median project size was 40,000 ha with 37% focused on food crops, 21% on industrial cash crops and 21% on biofuels. The World Bank highlighted the fact that these projects are in different stages of development, with 30% in an exploratory stage, 18% approved but not yet started, 30% at an initial development stage, and 21% started (World Bank 2011b). De Schuter (2011) points out that this might suggest large-scale land acquisitions are driven, in part, by investor speculation and not on robust economic analysis of project viability.

Friss and Reenberg (2010) have developed a database of 177 land deals in African Countries covering the period 13 August 2008 to 15 April 2010. The top 3 countries as regards number of deals were Ethiopia, Madagascar, and Sudan (see also Table 2.2). Friss and Reenberg especially focused on ascertaining the magnitude, purpose (or motivation for investment) and where the investors came from. They found that in the Democratic Republic of Congo, land deals would comprise 48.8% of existing farm acreage, making it likely that land deals may cut into forest area (land deals comprise 7.1% of 'available' land area if forest area is considered). Table 2.2 shows that investments in Madagascar seem to be primarily motivated by biofuels with private businesses comprising the majority of investors. Land deals in Sudan appear mostly motivated by food production, with the majority of investors stemming from Gulf States. Jatropha is the main crop for deals in Madagascar while wheat is dominant in Sudan (Friss and Reenberg 2010).

19 See also the Oakland Institute for a list of investors in Africa (http://media.oaklandinstitute.org/meet-millionaires-and-billionaires-suddenly-buying-tons-land-africa-0) and "The new farm owners table" with information on investments worldwide from GRAIN (http://www.grain.org/m/?id=266).

20 Anseeuw et al. (2012) is based on the "Land Matrix Project", which sources data from the Commercial Pressures Land Portal (www.commercialpressuresonland.org) and cross-checks it based on fieldwork, confirmation from known in-country partners and official land records. The World Bank report is based on the open blog launched by Grain (http://farmlandgrab.org/) and cross-checked with inventories in the field. Friss and Reenberg (2010) is based on screening of the Commercial Pressures Land Portal and triangulation of GRAIN (2008), Von Braun & Meinzen-Dick (2009) and Görgen et al. (2009).

21 This contradicts transparency improvements made, for instance, in the mining industry with initiatives such as the Extractive Industries Transparency Initiative, Publish What You Pay and the Revenue Watch Institute promoting public disclosure of industry payments and host government earnings.

Table 2.2 Large-scale land acquisitions in Africa: magnitude, purpose and investor countries for the top three recipient countries, August 2008 - April 2010

		ETHIOPIA	MADAGASCAR	SUDAN
Number of acquisitions		26	24	20
Magnitude	Min (Mha)	2.9	2.7	3.2
	Max (Mha)	3.5		4.9
	% of agricultural area	8.2%	6.7%	2.3%
Purpose	Food production	8	3	11
	Biofuels		16	2
	Industrial production	1	3	
Investors[a]	Gulf states	2	1	14
	Asian countries	6	6	1
	Private businesses	11	14	1
	Others	1	2	4

Source: Drawn from Friss and Reenberg 2010

Note: [a] Investors in the following categories stem primarily from: Gulf States—UAE, Jordan, Kuwait, Qatar and Saudi Arabia; Asian countries—India, China, Japan, Malaysia and South Korea; Private businesses—Europe, the US, Australia and Israel; Others—Egypt , Syria, Brazil, Djibouti and Syria

Impacts: a positive opportunity or a resource curse

Proponents of large-scale land investment regard it as an opportunity for infrastructure development and increasing agricultural productivity on land which has seen little industrialized agriculture. Opponents see it as a new form of the resource curse, crowding out or displacing small-holders and exacerbating food insecurity for the world's most impoverished.

To-date, most reported case studies reveal more negative than positive impacts. Large-scale land acquisitions are associated with a lack of transparency and well-documented cases of violations of human rights, exacerbated environmental consequences and corruption (GRAIN 2008, Cotula et al. 2009, FIAN 2010, World Bank 2011b). Early experiences with biofuel production in countries like Tanzania, Mozambique, India and Colombia have show-cased land acquisitions through illegitimate land titles, water access denied to local farmers, inadequate compensation agreements and displacement of local communities by force (Cotula et al. 2008). In Argentina, 14 Mha have been sold on such conditions to individuals or companies, affecting rural peasants, indigenous people and townships (Pengue 2008). Land and water use rights are often based on local traditions or are not formalized under 'modern' law in many of the places where large-scale land acquisitions take place; land is sold by governments as unoccupied, when in reality it is used to grow food or graze animals by the people who live there. These countries have some of the highest percentages of undernourished people in the world, including the Democratic Republic of Congo (75%), Ethiopia (44%), Mozambique (37%), Kenya (30%), Madagascar (35%), and Sudan (20%) (FAO 2009c). While some argue that industrialized agriculture will boost productivity and spill-over to the local population, the crops being grown by the investors are largely meant to be exported. This may do little to reduce local hunger, and instead increase the vulnerability of local communities to the volatility of international food prices. As large-scale land acquisitions favor industrialized, high-tech agriculture, it often means a retreat for small-scale farming. The Hunger Task Force of the UN Millennium Project and IAASTD support peasant agriculture as a fundamental effort in the struggle against poverty and hunger. Moreover, industrialized agriculture increases soil erosion if it is applied to lands unsuitable for agriculture, or if appropriate conservation practices are not applied. Displacement of local people may force them to farm and graze elsewhere, perhaps encroaching on forest or other high-value nature areas.

Many studies focus on improving governance as the way to do better. Indeed, better governance and oversight is important, especially as weak recognition of land rights at the country level was shown to be associated with higher levels of land demand by investors, and raising significant concerns (Deininger 2011). According to the World Bank (2011b), "Data from country inventories highlight serious weaknesses in institutional capacity and management of land information… In many countries where demand has recently increased, limited screening of proposals, project approvals without due diligence, rivalries among institutions with overlapping responsibilities, and an air of secrecy all create an environment conducive to weak governance. Official records on land acquisitions are often incomplete, and neglect of social and environmental norms is widespread." Mann and Smaller (2010) also report weak or absent environmental management regimes relating to chemicals as well as labor laws on farms. Moreover, they have found no studies on the amount of water resources involved in large-scale land acquisitions, although water security at the local level has already become a source of conflict in some places.

The bigger picture: do large-scale land acquisitions fit into the context of sustainable agriculture?

In 2008, the FAO argued that US$ 30 billion were needed to eradicate hunger, while US$ 1,200 billion were spent on arms alone in 2006[22]. Where and how to direct investment in agriculture is a question that needs to be answered across the globe; meanwhile, the land rush is accelerating the commodification of land[23] and, as De Schutter (2011) notes, bringing with it risks that go far beyond what the current proposals for regulating it seem willing to recognize.

When demand for land-based resources such as food and non-food biomass grows, so will the price for land, and therefore investments into land will grow as well. If this affects the relationship of small-scale to large-scale farming, it will exacerbate the frictions which are already known to exist around such dynamics. This does not per se determine whether that land is going to be cultivated in a sustainable manner. Nevertheless, the divide between investors and land-rooted farmers tends to grow with external rent seeking capital, and thus the need to provide information on the agricultural performance of those fields for investors and purchasers also increases.

The ownership of the land does neither - per se or finally - determine the proportion of produce meeting domestic demand. On the one hand, export income from agricultural products may support national economic development (as shown in section 2.4 for Latin American countries). On the other hand, a focus only on export markets may leave a supply gap in countries struggling to feed their population (such as in African regions). Thus, there is also a need for improved information on the security of food and non-food biomass supply in terms of domestic and foreign land used to supply the consumption within a country.

On the way forward: voluntary guidelines on land tenure

In an attempt to address these issues, a series of international negotiations resulted in the development of a set of voluntary guidelines on land tenure, which were endorsed by the 38th Session of the Committee on World Food Security[24] on 11 May 2012. These guidelines, while non-binding, provide guidance for both domestic and international investments, and for the development of national policies related to land tenure. The guidelines are explicitly based on the premise that "eradication of hunger and poverty, and the sustainable use of the environment, depend in large measure on how people, communities and others gain access to land, fisheries and forests" and that "the livelihoods of many, particularly the rural poor, are based on secure and equitable access to and control over these resources" (Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests[25] 2012). While suffering from the typical limitations of a consensus-based negotiated document, the guidelines do address many of the issues discussed in this paper.

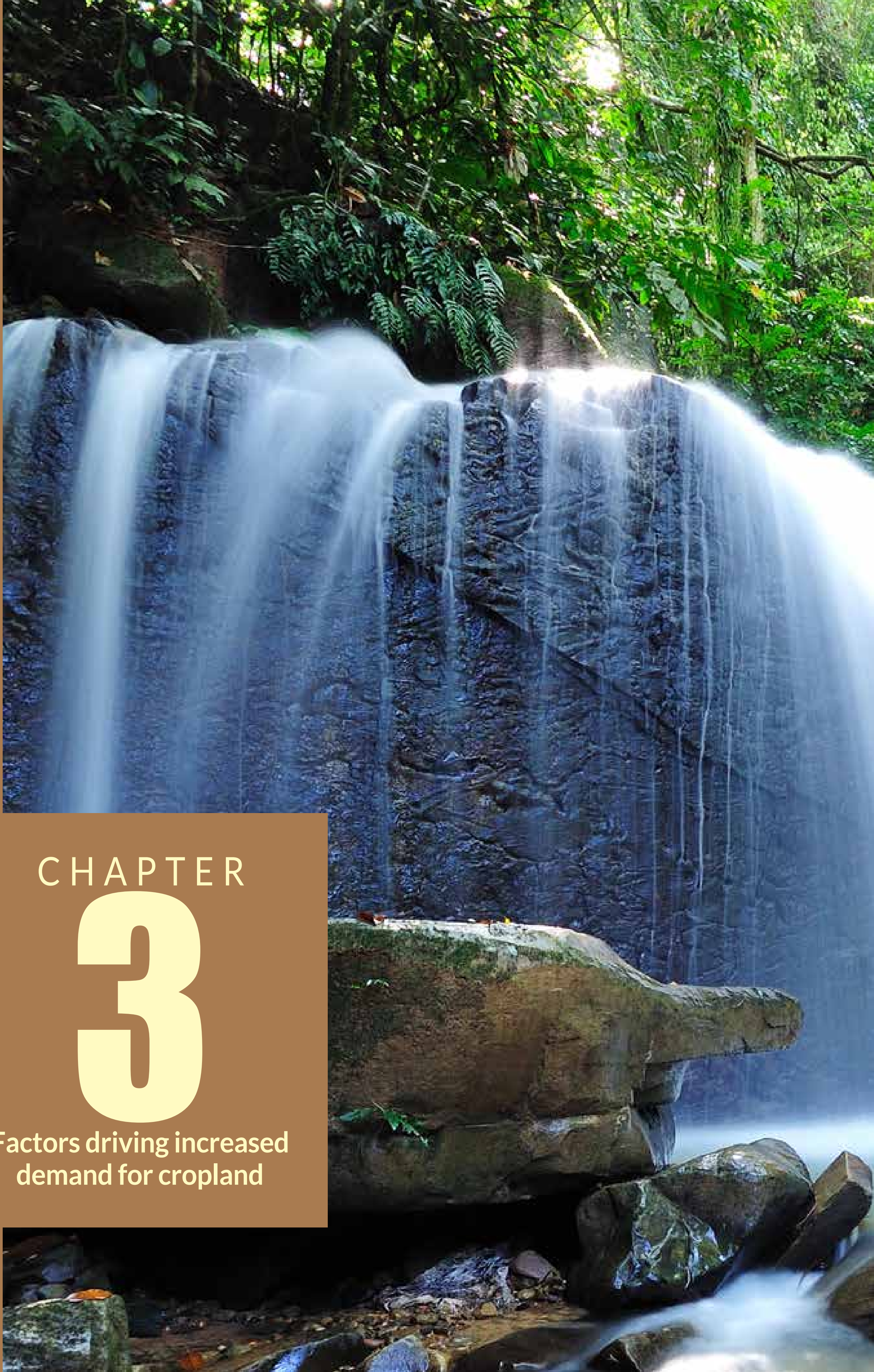
Still, these guidelines might not affect the level of growing consumption of agricultural goods in the world regions and will not control critical driving forces of land use change.

22 See FAO Director-General Jacques Diouf's speech opening the 2008 Rome Summit (http://www.fao.org/newsroom/en/news/2008/1000853/index.html).

23 In other words, land is becomming a financial asset in international markets

24 http://www.fao.org/cfs/en/

25 See http://www.fao.org/fileadmin/user_upload/nr/land_tenure/pdf/VG_Final_May_2012.pdf



CHAPTER

3

Factors driving increased demand for cropland

3

Factors driving increased demand for cropland

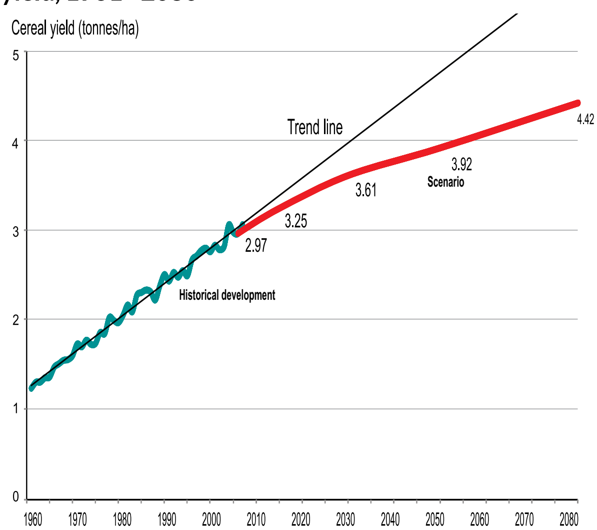
Until the middle of the 1990s, increases in yield productivity exceeded or mirrored population growth, making it possible to supply the growing population with food from the same amount of land[26]. In the future, demand might grow faster than supply, thus increasing environmental pressures through intensified and enlarged agriculture, which itself will experience growing pressure from environmental and technological constraints. This chapter will review available evidence showing that yield increases are slowing, whereas population is still growing and has more resource intensive dietary demands. Thus, more land is needed for food and feed. At the same time, agriculture is loosing fertile soil to expanding cities and infrastructures. Moreover, agriculture and forestry are expected to supply energy and materials to a greater extent than ever before. Finally, we will add the different cropland requirements together, indicating rather clearly that continuous demand trends might not be fulfilled without either dramatic losses of environmental capital or significant increases in the efficiency of food and non-food biomass use.

3.1 Constrained yield increases

Worldwide, yield increases of cereals and primary crops in general have been slowing down since the 1960s, and most experts expect a continued decline in comparison with past achievements (Bruinsma 2011). For instance, von Witzke et al. (2008) estimated that annual yield growth rates are currently down to around 1% with a continuing tendency towards further decline. Bruinsma (2009) projected worldwide annual yield growth rates of 0.8% until 2050. A UNEP assessment of food security (Nellemann et al. 2009), which considers ecological constraints, concludes that yield growth could drop to 0.87% per annum by 2030 and to 0.5% per annum between 2030 and 2050. Based on a detailed modeling exercise, Hubert et al. (2010) also concluded that yield growth will continue to slow; yield growth for cereals is expected to drop from an average of 1.96% per annum for the period 1980-2000 to 1.01% in 2000-2050, with even slower growth rates for developed countries[27].

All these reports conclude that food prices are set to steadily rise in response to declining yield growth in the context of rising demand to 2050, thus confirming the argument that we have passed the era of long-term decline in food prices. In absolute terms, cereal yield growth is projected to detach from linear growth rates of the past, so that the current level of around three tonnes/ha might increase to (only) ca. 4.4 tonnes/ha in 2080 (Figure 3.1).

Figure 3.1 Historical and projected world cereal yield, 1961 - 2080



Source: Adapted from Bruinsma (2011)

Note: Cereals are reported in units of kg/ha with the exception of rice, which is in rice- milled unit in kg/ha. The FAO provides the following explanation for rice - milled: "White rice milled from locally grown paddy. Includes semi-milled, whole –milled and parboiled rice. The default multiplication factor applied is 0.67. No other cereals are included in this unit."

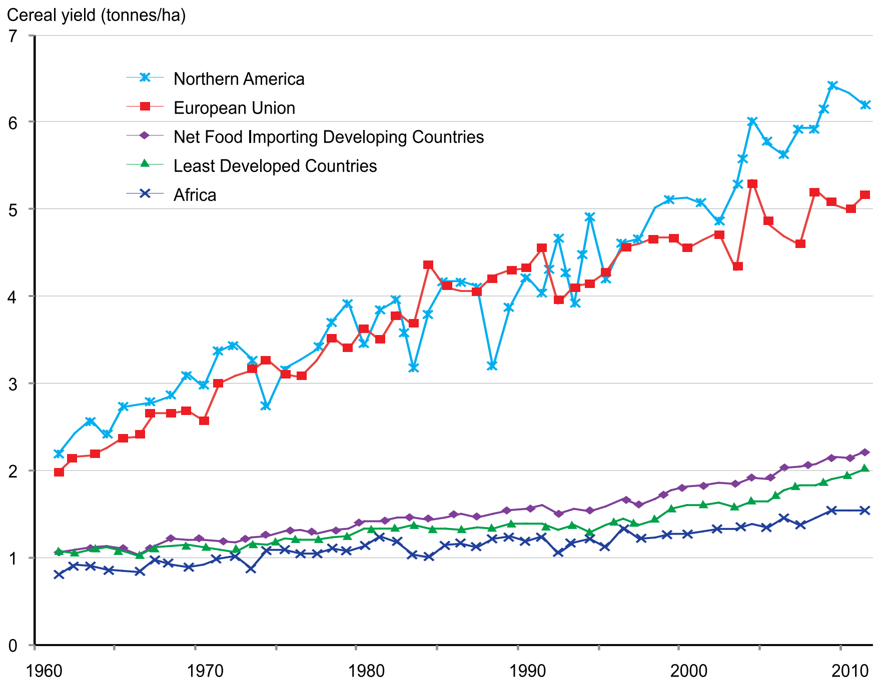
26 *This meant that while 0.45 ha of cropland per person were needed in 1960, only about 0.23 ha were used in 2005*

27 *0.9% for developed countries and slightly faster growth rates for the Middle East and North Africa (1.16%), Latin America and the Caribbean (1.24%) and Sub-Saharan Africa (1.59%).*

Global yield trends aggregate considerable differences between both regions and crops (based on FAOSTAT online database). Because yield increases have been most pronounced in developed countries, little potential is seen for significantly increasing yields in those regions (Figure 3.2). There is still, however, considerable potential in certain developing countries, which could be realized through improved agricultural practices. Of the three big cereals[28], annual yield increases of wheat and rice are decreasing (below 1%) while that for maize is 1.6% with no evidence of falling; consequently, large potential is seen for maize, particularly in sub-Saharan Africa (Fischer et al. 2009). On a global scale, according to FAO modeling (Bruinsma 2011), the area for maize is projected to increase until 2080 while wheat and paddy rice cultivation lands are supposed to decrease instead (Table 3.1). With assumed rates of yield growth, the global production of maize is expected to grow by 76% until 2080 and make it by far the dominant crop worldwide. In these projections the demand for biofuels was not taken into account. It remains uncertain if and to what extent first generation biofuels based on those feedstocks will still be relevant in 2050 or even in 2080.

28 *Rice, wheat and maize are expected to provide about 80% of the increase in cereal consumption in 2050 (Rosegrant et al. 2008).*

Figure 3.2 Cereal yields by selected world regions, 1961 - 2011



Source: Drawn from FAOSTAT online database

Note: Data for regions are as derived originally from FAO. See FAOSTAT online database country classifications for more information[29]

29 *(http://faostat3.fao.org/)*

Table 3.1 Historical and projected land and yield for major crops in the world to 2080

WORLD	2005/07	2050	2080	1961/63	2005/07	2080	1961-2007	2005/07-2080
	Harvested land (Mha)			Yield (ton/ha)			Yield increase	(% p.a.)
All crops	1256	1392	1368				1.73	0.60
Cereals (rice milled)	704	766	719	1.29	2.94	4.48	1.90	0.57
Wheat	222	230	211	1.14	2.77	4.31	2.11	0.60
Rice (paddy)	158	155	138	1.94	4.07	6.00	1.80	0.53
Maize	155	194	191	1.99	4.74	6.78	1.98	0.48
Soybean	94	124	136	1.14	2.32	3.48	1.54	0.55
Groundnut	24	35	42	0.87	1.52	2.15	1.57	0.47
Cottonseed	36	38	38	0.92	1.97	2.86	1.71	0.51

Source: Bruinsma (2011)

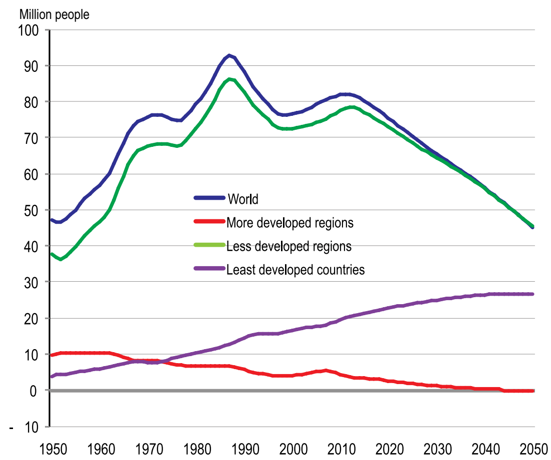
Estimates on future yields are rather uncertain for a number of factors (see Bringezu et al. 2009a). For instance, climate change is expected to lead to a higher frequency of extreme weather events increasing yield shocks. This could further exacerbate the productivity gap between world regions: Cline (2007) estimated that developing countries will experience a 9 to 21% decline in overall agricultural output potential by 2080 due to global warming while industrialized countries will face a 6% decline to an 8% increase. Another uncertainty is the rate and degree of soil degradation versus its potential for recovery. These uncertainties might have high impacts on yields and consequently on land as well.

3.2 Population growth

The UN (UN 2010, 2013) predicts the world's population will increase from around 7 billion people in 2012 to around 9.6 billion people in 2050 (+35%; with a range between 8.3 and 10.9 billion people). Less developed regions will contribute the most to this increase with their total population increasing from 5.8 to 8.2 billion over the same period (+41%).

Between 2005 and 2010 average annual population growth was about 1.2%. However, regional trends look quite different. Population of the more developed regions is rising at an annual rate of 0.4%, that of the less developed regions is increasing more than three times as fast (1.4%) and the least developed countries are experiencing rapid population growth of about 2.3% per year. Such differences, albeit dampened, are expected to persist until 2050, with more developed regions reaching negative annual growth rates around the year 2050 (Figures 3.3 and 3.4).

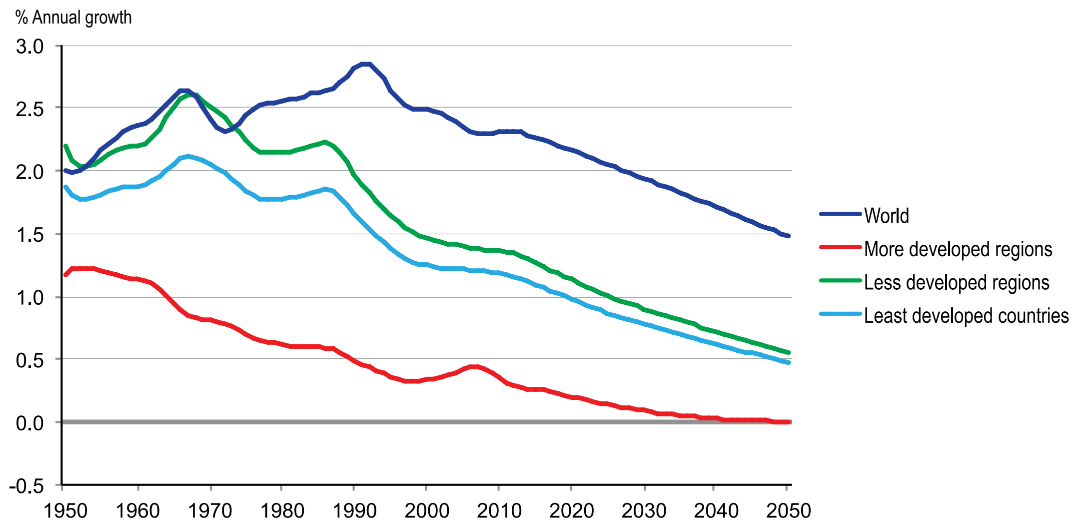
Figure 3.3 World population trends, net growth by regions, 1950 - 2050 (medium variant)



Source: Drawn from UN World Population Propects, the 2012 Revision (UN 2013)

Note: More developed regions comprise Europe, Northern America, Australia/New Zealand and Japan. Less developed regions comprise all regions of Africa, Asia (except Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia. The least developed countries, as defined by the United Nations, include 49 countries: 34 in Africa, 9 in Asia, 5 in Oceania and one in Latin America and the Caribbean. These countries are also included in the less developed regions. More information at www.esa.un.org.

Figure 3.4 World population trends, annual growth rate by regions, 1950 - 2050 (% annual growth; medium variant)



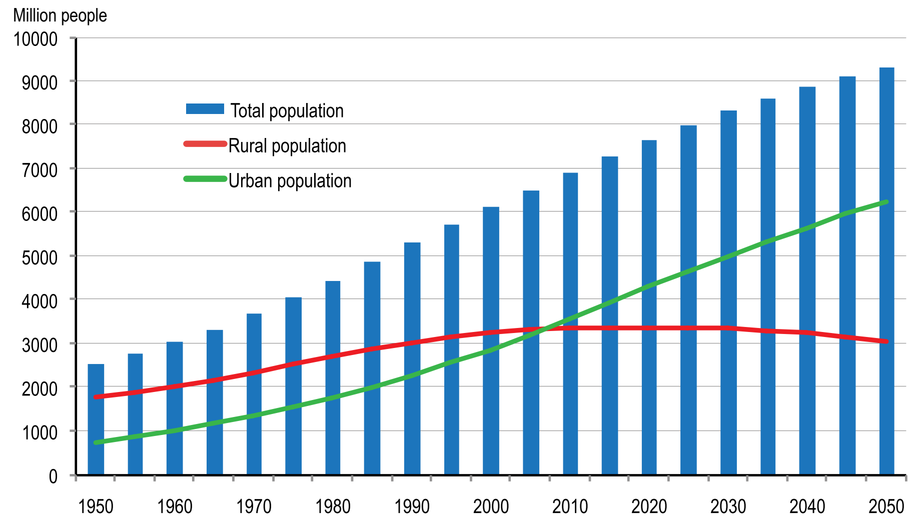
Source: Drawn from UN World Population Propects, the 2012 Revision (UN 2013)

Note: See Figure 3.3 for a description of more, less and least developed countries.

3.3 Urbanization

Urban population has increased about 4.8 fold between 1950 and 2010, while rural population has grown only around 1.9 fold (Figure 3.5). In 2010, around half of the world population lived in cities and this share is expected to grow further to almost 70% in 2050 (UN 2012). The UN expects that "urban areas will absorb all the population growth over the next four decades".

Figure 3.5 World population trends, 1950 - 2050 (medium variant)

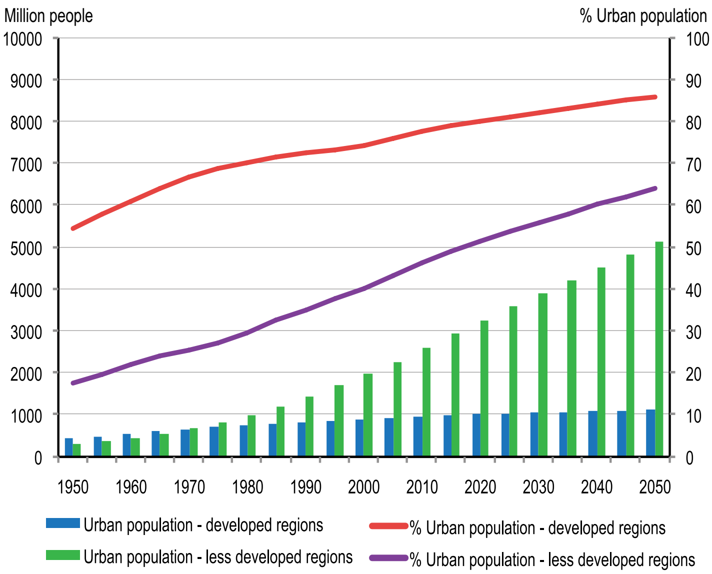


Source: Drawn from World Urbanization Prospects, the 2011 Revision (UN 2012)

Urban expansion itself has been subject to different trends in different parts of the world (Figure 3.6). In 1970 urban population in less developed countries for the first time exceeded urban population in developed countries, and in 2010 the former was already about three times more numerous than the latter. Moreover, urban population in developing countries is projected to nearly double between 2010 and 2050. Around 50% of the world's urban population in 2010 lived in Asia, with the highest concentrations in China (19%) and India (11%). However, the highest relative increase from 1950 to 2010 occurred in Africa with a 12 times rise in urban population. With a projected continuing trend, Africa will host almost 20% of the urban world population in 2050 (up from 11% in 2010) while 53% of urban population in 2050 will be concentrated in Asia.

The share of people living in urban areas is higher in developed countries than in less developed ones, and projected to increase as well towards 2050, though at more moderate rates than in less developed countries. This is because population densities of cities differ, with those in developing countries being about 3 times higher than those found in industrialized countries (Angel et al. 2005). However, densities of cities in all regions have been decreasing associated with urban sprawl.

Figure 3.6 Urban population trends, 1950-2050 (medium variant)



Source: Drawn from World Urbanization Prospects, the 2011 Revision (UN 2012)

As urban areas expand, transform, and envelop the surrounding landscape, they impact the environment at multiple spatial and temporal scales through loss of habitats and biodiversity, and greater demand for natural resources. The size and spatial configuration of urban areas directly impact energy and material flows, such as carbon emissions and infrastructure demands, and thus have consequences on Earth system functioning. Intensification and diversification of land use and advances in technology have led to rapid changes in biogeochemical cycles, hydrologic processes, and landscape dynamics (Seto et al. 2010).

Urban sprawl is commonly used to describe physically expanding urban areas. The European Environment Agency (EEA) has described sprawl as the physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas. Sprawl is the leading edge of urban growth and implies little planning control of land subdivision. Development is patchy, scattered and strung out, with a tendency for discontinuity. It leap-frogs over areas, leaving agricultural enclaves. Sprawling cities are the opposite of compact cities — full of less or not used spaces that indicate the inefficiencies in development and highlight the consequences of uncontrolled growth (EEA 2006b). The peri-urban areas – the space around urban areas which merges into the rural landscape – is growing rapidly across Europe. There is about 48,000 km^2 of built development in peri-urban areas in Europe, almost equal to that in urban areas. But while most urban areas are now slow growing (at 0.5-0.6% per year), built development in peri-urban areas is growing at four times this rate (Piorr et al. 2011).

A general analysis for European cities by EEA (2006b) shows that residential sprawl and the development of economic activities are strongly linked to the development of transport networks. The intrinsic causes of expanding cities are largely the high prices of already urbanized land versus the low prices of rural land associated with relatively low transport costs. The consequence is increasing passenger and freight transport throughout Europe.

In most areas, new urban expansion is likely to take place in prime agricultural land, as human settlements have historically developed in the most fertile areas (Seto et al. 2010; del Mar Lopez et al. 2001). In turn, the conversion of existing agricultural land to urban uses will place additional pressures on natural ecosystems. There is evidence that urban growth is indeed taking a toll on agricultural lands and that loss of fertile plains and deltas are being accompanied by the conversion of other natural vegetation to farmland (Döös 2002).

Data showing the physical extent of annual land use/ land cover change to settlement areas are partly available from National Inventory Reports (NIR) to the UNFCCC or from monitoring programmes like the CORINE land cover of the European Commission (EEA 2010). For example, in 2007 about three-quarters of the new settlement area in the EU-27 was on former agricultural land (NIR data base of UNFCCC).

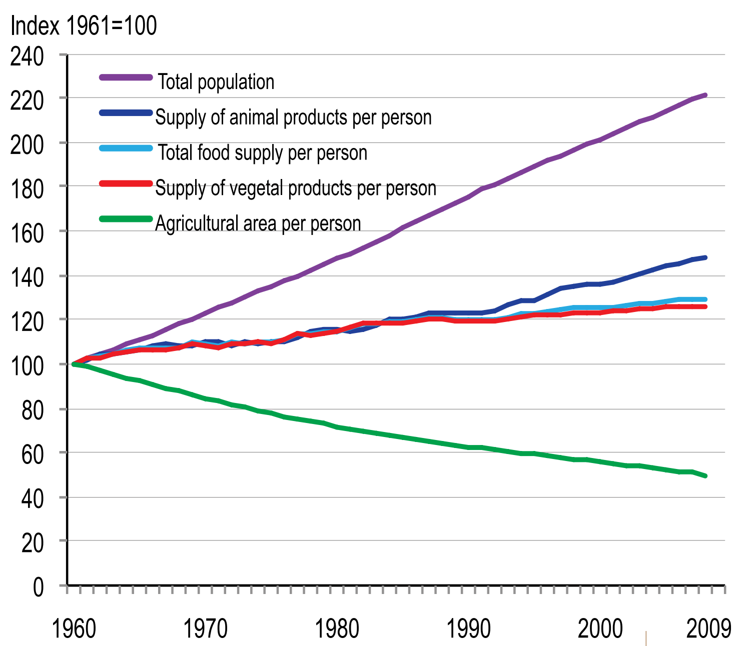
Globally, if urban populations increase as expected and average densities continue to decline, the built-up areas of developing-country cities will increase 3-fold by 2030 while their population doubles. Industrialized-country cities will increase their land area 2.5 times while their population increases by 20% (Angel et al. 2005). The peri-urban development patterns are reviewed in more detail by UNEP (2013).

3.4 Changing Diets

A combination of rising income and urbanization are changing diets, and increasing the demand for land. For instance, Bringezu et al. (2009a) conclude that only to satisfy the food demands of the growing world population an up to 20% increase of global cropland - about 300 Mha - between 2004 and 2030 will be required under business-as-usual assumptions about production and consumption. Rapidly rising incomes in the developing world have led to an increase in the demand for livestock products (Msangi and Rosegrant 2009). As animal based food requires nearly 5 times more land per nutrition value than the consumption of plant based food (Bringezu et al. 2009a), change to more meat-based diets will result in a significant increase in the need for agricultural land. Moreover, urbanized populations consume less basic staples and more processed food (Rosegrant et al. 2001). Also this contributes to higher land requirements, since processed and industrially prepared food requires more agricultural land for a given number of calories than basic home made food (von Witzke and Noleppa 2010). Dietary change may override population growth as the major driver behind land requirements for food in the near future (Kastner et al. 2012). These trends are reinforced by the spreading of fast food chains and supermarkets and the global advertisement of a Western style of (over-) consumption.

Much of the current structural change in diets is occurring in developing countries, as diets in developed countries are already high in processed food and livestock products. Since the early 1990s, global consumption patterns began to change towards higher consumption of animal products whereas the consumption of vegetal products stagnated (Figure 3.7). More recent analyses based on FAO data show that from 2003 to 2007, the consumption of beef, pork, poultry, sheep meat and milk increased, and many developing countries posted well over 10% growth. In contrast, EU meat consumption was stagnant and EU dairy consumption fell slightly. The increase of meat consumption in some key regions is expected to slow somewhat, but to remain strong in developing countries despite the lingering effects of higher feed costs (FAO 2008b).

Figure 3.7 Global population, agricultural land and food supply, 1961 - 2009



Source: Drawn from FAOSTAT online database and UN World Population Prospects, the 2012 Revision (UN 2013)

By 2030, the global meat consumption per person is projected to increase by around 22%, milk and dairy by 11% and vegetable oils by 45% compared to the year 2000. This increase means a doubling of the demand for these commodities in absolute terms. Also, the consumption of cereals, roots and tubers, sugar and pulses is expected to increase up to 2030 in developing countries by more than world average annual rates, though at lower rates than the animal-based commodities (based on FAO 2006b).

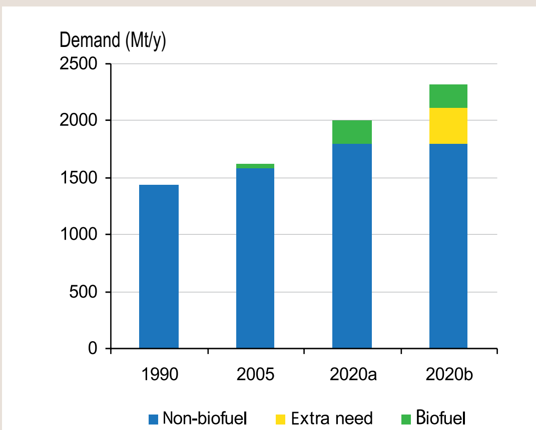
By 2020, changing diets *and* demand for biofuels are estimated to increase demand for cropland by 200 - 500 Mha, even taking into account anticipated improvement in yields (RFA 2008). This area would equal 12% to 31% of global cropland in 2020. Of the total increased demand, 144 to 334 Mha is estimated to be due to changing diets. The expansion of agricultural land often occurs at the expense of natural ecosystems.

Conversely, a global food transition to less meat, or even a complete switch to plant-based protein food would have a dramatic effect on land use. Stehfest et al. (2009) have estimated that in such cases up to 2700 Mha of pasture and 100 Mha of cropland could be relieved from farming. This would have many other positive implications as well, like increased carbon uptake and substantial reductions of methane and nitrous oxide emissions (Stehfest et al. 2009), as well as reduced nutrient pollution (Sutton et al. 2011). More strategies to reduce resource intensive food consumption and to lower land demands are addressed in chapter 5.2.3.

Box 1. Extra demand for food by those without "economic demand"

The OECD-FAO Agricultural Outlook 2008-2017 provides estimates of the economic demand for two groups of crop commodities in 2005 and those projected for 2017 (Figure 3.8 and 3.9). The demand in 1990 has been added to this figure to illustrate the increase over the past 15 years (1990 – 2005) for comparing with the estimated increase in the coming 15 years (2005 – 2020). Bindraban et al. (2009) have estimated the extra need to supply poor consumers outside of markets by calculating the contributions of an extra kg of grain and an extra 20 g of vegetable oil per day for 850 million people (the estimated number of undernourished people in 2006), in order to raise the average consumption of the world population in 2020 to a more moderate diet (e.g. Luyten 1995, WRR 1995).

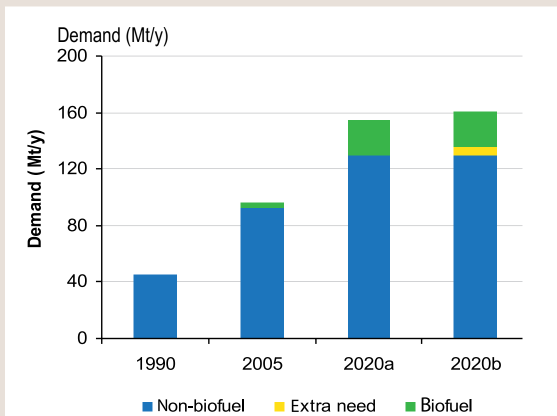
Figure 3.8 Demand for wheat and coarse grains in million tonnes of crop product in 1990, 2005 and projected for 2020



Source: Drawn from FAOSTAT online database and OECD-FAO Agricultural Outlook 2008-2017

Note: The projection in 2020 is based on a linear extrapolation of the trend given for 2005 – 2017 in the OECD-FAO Agricultural Outlook 2008-2017. "Extra need" refers to the non-economic demand (see text).

Figure 3.9 Demand for vegetable oils (palm oil, rapeseed oil, soybean oil and sunflower oil) in million tonnes in 1990, 2005 and projected for 2020



Source: Drawn from FAOSTAT online database and OECD-FAO Agricultural Outlook 2008-2017

Note: The projection in 2020 is based on a linear extrapolation of the trend given for 2005 – 2017 in the OECD-FAO Agricultural Outlook 2008-2017. "Extra need" refers to the non-economic demand (see text).

In 2020 the demand for biofuels expressed as percentage of the non-biofuel demand is 11% for wheat/coarse grains and 19% for vegetable oils (see Figures 3.8 and 3.9, '2020a'). All biofuel projections from the OECD-FAO are based on policies in mid-2007 (i.e. before the US Energy Independence and Security Act or the EU proposal for a biofuel directive) and are therefore underestimations of the total biofuel demand from current policies. The values of the OECD-FAO for global biofuel production correspond to approximately 4% of the transport fuel energy in 2020 and should therefore more than double to realize a 10% blending target. Without biofuels the demand for wheat and coarse grains (mainly food and feed) has grown by 0.7% per year during the period 1990-2005 and is projected to grow by 1.0% for the coming 15 years until 2020. The corresponding figures for the total demand (including biofuels) are 0.9% and 1.6% respectively. The **extra need of non-market consumers** represents an additional increase of 1.3% per annum (see '2020b').

For vegetable oils (only partly used for food and feed) growth rates for non-biofuel demand growth equaled 6.9% (past) and will grow by 2.7% (future) and total demand (including biofuels) has grown by 7.5% (past) and is projected to grow by 4.1% (future). The **extra need for vegetable oils** only represents 0.4% extra growth per annum during 2005-2020.

It becomes clear that the **extra need for wheat/coarse grains** is significant compared to the demand for (non-) biofuels, whereas for vegetable oils the extra need is relatively small. It is unrealistic to assume that in 2020 the extra need will be developed into an economic demand. Thus the projections of future demand based on market modeling alone are not sufficient to estimate the overall requirements for land needed for a more adequate diet for the world population.

3.5 Renewable energy and land use

Land use demand for renewable energy projects varies with the technology. On-shore wind turbines and related access roading take up only a small portion (2-5%) of the total land area used for a wind farm. Off-shore wind uses only a very small land area for grid connection. By contrast, hydropower reservoir projects can cause flooding of a significant land area behind the dam, although run-of-river schemes utilize little land area. Solar PV and concentrated solar power require land for mounting the technologies (other than roof-top mounted or building-integrated). Some of these projects use agricultural land but others are located in arid and semi-arid areas where there is little competition for land use.

For biomass, land use varies with the source. Considerable areas of land are required for dedicated energy crop production, more per unit of energy than for all other technologies. Energy crops have to compete with food and fibre crops for land, water and nutrients. Conversely no or rather low additional land use is associated with crop and forest residues, organic wastes or aquatic macro-algae harvested from sea. Land requirements for the artificial breeding installations of micro-algae production are likely to be large, but remain uncertain, as does the feasibility of commercial applications.

The challenge for renewable energy is the low power densities of energy flows compared with fossil fuels and with the relatively high power density demands of many industrial and commercial end-uses. Solar insolation has the highest energy flows of all renewable energy resources with a global mean energy density of around 170 W/m^2. Solar power or solar thermal systems make use of 9 to 24% of the radiation input (Green et al. 2007; WEC 2007; Lightfoot and Green 2002). In contrast, biomass in the open field usually captures about 1% of the radiation input with maximum values of up to 5-6% (Woods et al. 2009). Hence, crops grown for biofuels, at no more than 1 W/m^2, can require more than 1,000 fold the land area to produce the same energy output as an oil-field at around 1 kW/m^2 energy density (Smil 2006). When biomass is grown for liquid transport fuels, typical land use efficiencies range from 700 l/ha for soy bean biodiesel up to 4,900 l/ha for sugarcane ethanol (IEA 2011), noting that co-products are also produced, such as high-protein meal or crop residues (bagasse, straw, stover) that can be used as a feedstock for combined heat and power (CHP) plants.

Whereas the performance and efficiencies of renewable energy technology systems, such as solar power and wind power, as well as the supply chain and conversion technologies for bioenergy, are continually being improved and further developed, increasing the productivity of energy crops is more limited, though advances through plant breeding and management continue.

Various analyses, including the IPCC Special Report on Renewable Energy (SRREN 2011a), show biomass used for heat and power has a high technical potential with conversion efficiencies of biomass to electricity typically around 32%, or up to 80% if converted to heat in efficient burners or stoves, over 80% if for CHP (assuming all available heat is utilized), and up to around 60%[30] if to liquid fuels. In the Blue Map scenario of the IEA Energy Technology Perspectives (IEA 2008), in order to be on-track to limit global temperature rise to below 2°C[31], biomass is assumed to provide around 23% of primary energy by 2050. This would require producing a sustainable supply of around 1500 Mt/year with around half arising from crop and forest residues, the remainder coming from energy crops grown on around 375-750 Mha of land. This includes 100 Mha (estimated to be 7% of current total arable land area) for biofuel production (IEA 2011), increasing from the present level (Figure 3.10) which IEA (2011) estimated at 30 Mha in 2010, whereas Bringezu et al. (2009a) calculated 38 Mha already in 2008. That range may indicate the uncertainty range of the data.

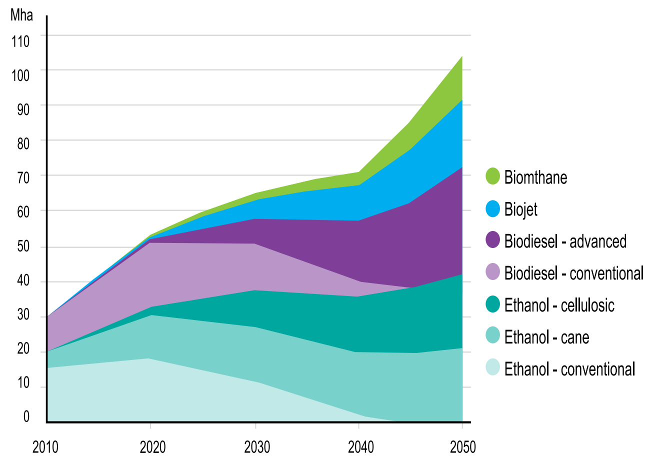
Growing concerns about energy supply security, the peak of cheap conventional oil resources, climate change and the uncertainty over future reserves of oil and gas, coupled with the interest in rural development, have increased the demand for producing liquid and gaseous biofuels. However, the International SCOPE Biofuels Project strongly recommended that societies consider using solid biomass for direct combustion to cogenerate heat and electricity rather than producing liquid biofuels, because of the far greater efficiencies and lower environmental consequences (Howarth et al. 2009).

Over 2% of total arable land area in the world has been used to grow energy crops for liquid fuels in recent years (Bringezu et al. 2009a, IEA 2011). These crops, mainly sugar cane, maize and oilseed rape, are used to produce the liquid biofuels that around 2009 contributed around 2% of world transport fuels (Howarth et al. 2009). This share could rise significantly over the next few decades (IEA 2011). Note that solid, mainly wooden biomass used for traditional cooking and heating, supplies a little more than 10% of global primary energy use, or more than 25-fold more energy than do liquid biofuels (Howarth et al. 2009). There is much variation in the key assumptions for future development of crops for biofuels. For example, Fischer (2009) calculated that meeting all current targets for biofuels by 2030 (including advanced biofuels coming on stream commercially by around 2015), would provide around an 8% share of transport fuels, which would require around 20-50 Mha of additional arable land plus 50 Mha from non-cultivated land for advanced biofuel crops. By way of contrast, Ravindranath *et al.* (2009) calculated that, depending on the feed-stocks used, between 118 and 508 Mha of cropland extension would be needed to provide 10% of liquid transport fuels from 1st generation biofuels in 2030. Advanced biofuels from ligno-cellulosic feedstocks are unlikely to become commercially available for a decade or more (Sims et al. 2008). Moreover, also a growing use of forest harvest to produce biofuels may have negative consequences (Schulze et al. 2012).

30 SRREN (2011a) indicated that this could be high.

31 To avoid exceeding the 2oC temperature rise target (as agreed at the 15th Conference of Parties, Copenhagen, 2009), an atmospheric GHG stabilization level of around 450 ppm will be necessary.

Figure 3.10 Land demand projected for future transport biofuel production, 2010 - 2050



Source: IEA 2011

Note: Assuming 50% of biofuels will use organic wastes and residues and excluding land-use reduction for biofuel co-products."Biojet" is advanced, synthetic aviation fuel

Land and biomass resource management practices impact the sustainability of bioenergy projects, in particular in terms of life-cycle GHG emissions (Howarth et al. 2009, SRREN 2011a). The use of residues from agricultural and forest products, and organic wastes as biomass feedstocks for electricity, heat generation or transport biofuels do not cause changes of land use and related carbon emissions whereas biomass produced from energy crops is far more land-use intensive.

Impacts on the GHG balance of bioenergy projects can result from both direct and indirect changes in the use and management of agricultural land and forests. The volume of indirect GHG emissions depends partly on the prior condition of the converted land and the crops historically grown on it. GHG emissions resulting from land use change (LUC) can be offset by using the biomass to displace fossil fuels and improving the uptake of carbon into soils and above-ground biomass. However, if the growing of energy crops displaces existing crop production, which then moves to other regions, particularly if this encourages deforestation, such land use change may take decades before overall net savings are achieved, if ever (Searchinger *et al.*, 2008). Recovery of biodiversity may take centuries (e.g. Sala et al. 2009). Increased fluxes of nitrous oxide to the atmosphere from increased use of nitrogen fertilizer in crop production can add to the total GHG emissions and may turn the balance to become unfavorable (Crutzen et al. 2008, Howarth et al. 2009).

Depending on the future developments of energy cropping systems, crop yield improvements, global food demand and the needs for cropland expansion, sustainable biomass production could make a greater contribution to the future global energy demand than at present, though to what degree is uncertain (SRREN 2011b). Assessing the net GHG effects of growing energy crops requires measurements of LUC impacts and the attribution of any resulting GHGs between co-products. The GHG emissions can vary with the specific situation and are often based upon several causes. A full assessment of the land use change including indirect effects, however, requires the consideration of land use for all agricultural or forestry products (see section 5.1). As growing demand for food will already lead to an expansion of global cropland (see sections 3.1-4), further production of fuel crops will enhance the impacts of land use change (see Chapter 2).

3.6 Biomaterials

Both the US and EU regard products based on biomass as one of the most promising future markets[32], with a high potential for innovation (BRDI 2006, EU 2007). Whereas energy from fossil fuels can be replaced by other kinds of renewable energy, so far only biogenic raw materials can replace fossil raw materials in, for instance, the chemical industry (SRU 2007), although organic waste may provide the basis for improved carbon recycling in the future (Bringezu 2009). Elbersen et al. (2011) estimate the demand for biomass by the chemical industry in the EU-27 to be between 14 and 43 million tonnes (Mt) of biomass (Dry Matter - DM) in 2020, increasing to between 28 and 66 Mt (DM) in 2030; the total biomass demand - for energy and chemicals - is assumed to range between 400 and 700 Mt in 2020, increasing to between 550 and 800 Mt in 2030.

Material uses are claimed to directly support 5 to 10 times more employment and 4 to 9 times the value added compared with energy uses[33]. Nevertheless, increasing use of biomass for energetic and material purposes may lead to competition for land resources on a global scale with the risk of shifting environmental pressures between regions (Bringezu et al. 2008).

Although the chemical industry is a 'small user' of petroleum[34], the economic value of the sector is high[35], making the use of biomass both likely and lucrative. In recent years, around 8% to 10% of the materials used in the European chemical industry as raw material for organic chemistry production are bio-based (Rothermel 2008[36]). The US also estimates an 8% share of biomass in the chemical industry's raw material base and is targeting increasing its use by around 215% by 2030 (BRDI 2006). Forest and chemical industries are the dominant users of non-food biomass[37]. Existing products (paper, pulp, detergents, and lubricants),

32 *Bio-based products have been selected as one of six 'lead markets' under the EU's Lead Market Initiative*

33 *These comparisons relate to the same raw material or the same-farmed area, respectively. This is due to the significantly more complex and longer supply chains arising from material uses (Carus et al. 2010). This is even true for traditional applications of wood: Using wood for particle boards or pulp & paper supports greater employment and value added compared to the production of energy pellets (Pöyry Forest 2006).*

34 *Using around 4% of total consumption in Germany (according to Rothermel 2006 as cited in SRU 2007)*

35 *It is approximately equal to the food sector in the EU (Langeveld et al. 2010)*

36 *In 2003 it was estimated that the use of renewable raw materials in industry would be about 9 Mt (excluding wood). The chemical industry was estimated to use around 6.4 Mt and other industries 2.6 Mt (Schmitz 2008). The raw materials are divided into vegetable oils and fats (31 %), starch (35 %), sugar (14 %), chemistry and natural cellulose fibres (16 %) and other (4 %) (Schmitz 2008).*

37 *The chemical industry uses around 70% of the biomass, excluding wood, produced for biomaterials in the EU (Jering et al. 2010)*

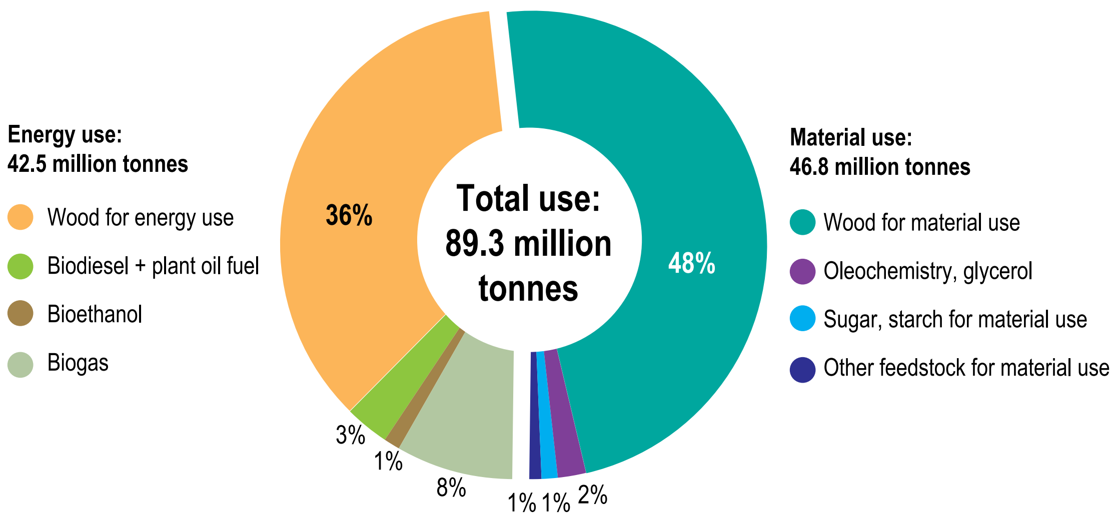
modern biomaterials (pharmaceuticals, industrial oils, biopolymers and fibres) and innovative, high-value added products (wood-plastic-composites, bio-based plastics, pharmaceuticals, etc.) are markets with varying degrees of growth. For instance, the EU market for bio-based plastic has doubled in size between 2005 and 2008[38](Jering et al. 2010).

Unlike the case of biofuels, little literature exists on the potential environmental consequences of an extended biomaterials industry. Weiss et al. (2012) addressed the environmental impacts of bio-based materials in a meta-analysis of 44 life-cycle assessment (LCA) studies. The variability in the results highlights the difficulties in drawing general conclusions. While bio-based materials save, relative to conventional materials, primary energy and GHG emissions, they may increase eutrophication and stratospheric ozone depletion. Common to most bio-based materials are impacts caused by the application of fertilizers and pesticides during agricultural biomass cultivation. Additional land use impacts, such as the potential loss of biodiversity, soil carbon depletion, soil erosion, deforestation, as well as greenhouse gas emissions from indirect land use change were not quantified in the studies reviewed by Weiss et al (2012). Clearly these impacts should be considered when evaluating the overall environmental outcome of a growing use of bio-based materials. The authors propose three strategies that could be pursued in order to make best use of biomaterials: (1) expanding the feedstock base by utilizing organic wastes as well as forest and agricultural residues; (2) deploying integrated biorefineries that allow a more complete use of the biomass for producing bio-based materials, energy, fuels, and heat; and (3) carbon cascading by using biomass first for material purposes and second for energy at the end of products' life cycles (see also Chapter 5.2.3).

A serious limitation for assessment is the lack of solid monitoring data on biomass for material use. According to Carus et al. (2010), having analyzed data available on industrial material uses of biomass in the EU, the best available data came from Germany (Figure 3.11) and show that the share of biomass used for industrial material use has been decreasing in Germany. During the last ten years the cultivation area for bioenergy increased over ten times, whereas the area for bio-based products showed no increase at all (Carus et al. 2011).

38 *Bio-based plastics and fibres are estimated to represent approx. 1.4% of the total production of plastics worldwide. In the EU, shares of emerging bio-based plastics relative to petrochemical plastics in 2007 were estimated at 0.3%; under BAU conditions this is expected to increase to 1.1% in 2020 (Shen et al. 2009). As consumer awareness is rapidly increasing in this area, bio-based plastics certainly seem to be the segment poised with highest potential for growth.*

Figure 3.11 Use of renewable raw materials in Germany, 2008



Source: Carus et al. 2010.

The growing use of biomaterials will require land: A total of 2.27 Mha of cropland were cultivated for material use[39] in Europe (EU-25) compared to 2.8 Mha for biofuels in 2005. According to Carus et al. (2010), about 64% of the biomass used for material purposes in Germany is imported. Bringezu et al. (2009b) have shown that the ongoing increase of production and material use within Germany may reach 11% of the country's global cropland requirements in 2030. On a global scale, Raschka and Carus (2012) estimated that around 100 Mha cropland were occupied for biomaterials production in 2008, equivalent to around 6.6%[40] of total cropland.

Until 2050 the cropland requirement for biomaterials may increase substantially. Colwill et al. (2011) estimated consumption of bioplastics use in 2050, based on historic data for world production of plastics from 1950 to 2005, and leading to increases of consumption as compared with 2010 by 39% (low), 186% (mid) and 431% (high).

3.7 Interim conclusion

Altogether, the growing demand for food, feed, fuel and materials is increasing the demand for land resources. At the same time, mismanagement and degradation are reducing the amount of land available. Sub-Saharan Africa will play a crucial role in the future, with a high potential for yield improvement and significant expansion of cropland expected. At the same time, climate change may critically hamper productivity and land-acquisitions by foreign investors may do little to improve food and energy security in a region where it is desperately needed.

Based on a literature review, and relying on rather moderate projections, Lambin and Meyfroidt (2011) estimated worldwide additional land demand in 2030 (Table 3.2). They concluded that additional demand might be fulfilled mainly by a combination of deforestation and the conversion of "productive unused" land. The latter covered around 400 Mha in 2000 and included all savannahs with low tree cover and low population density. For instance, a significant share of the Brazilian Cerrado belongs to that category. Using the area of the "unused land" for the additional demand in 2030, would leave a maximum of 71Mha (20%) of the savannahs or lead to its complete conversion, which would not even suffice but require 347 Mha more from other types of land. Thus the authors regard further deforestation as rather likely. Assuming a business-as-usual rate of deforestation of 152 - 303 Mha between 2000 and 2030, the savannah and grassland area would shrink between 37% and 100%, and even in the latter case this may not even suffice and require an additional deforestation of 44 Mha.

In its recent yearbook, UNEP (2012b) concludes, that by 2030, without changes in the way land is managed, over 20% of terrestrial habitats such as forests, peatlands and grasslands in developing countries alone could be converted to cropland, aggravating losses of vital ecosystem services and biodiversity.

39 Starchcrops (900 kha), cotton (460 kha), oilseed crops (425 kha), sugar crops (137 kha), medical plants (113 kha), fibre crops (135 kha).

40 Mainly cotton (2.1%), maize (1.1%), natural rubber (0.6%), bamboo (0.6%), wheat (0.5%), coconut (0.5%).

Table 3.2 Low and high estimates of land use in 2000 and additional land demand in 2030

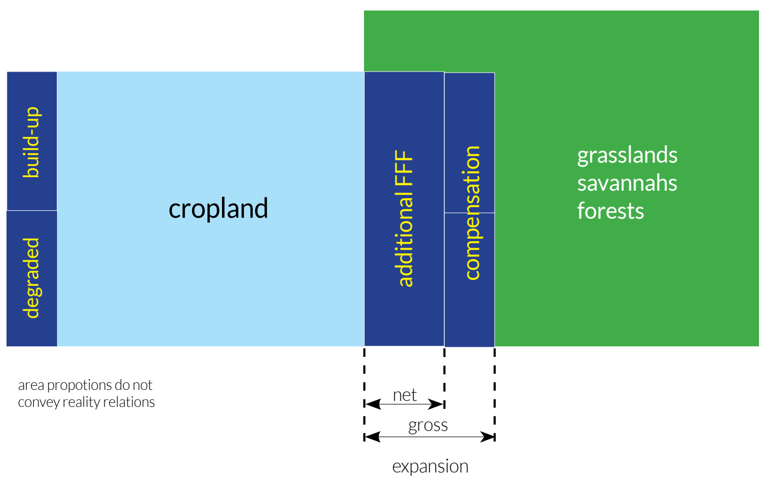
LAND USE CATEGORY	LOW ESTIMATE (Mha)	HIGH ESTIMATE (Mha)
Land use in 2000		
Cropland	1,510	1,611
Pastures	2,500	3,410
Natural forests	3,143	3,871
Planted forests	126	215
Urban built-up area	66	351
Unused, productive land	356	445
Projected land use for 2030		
Additional cropland	81	147
Additional biofuel crops	44	118
Additional grazing land	0	151
Urban expansion	48	100
Expansion industrial forestry	56	109
Expansion of protected areas	26	80
Land lost to land degradation	30	87
Total additional land demand for 2030	285	792
Balance (unused land in 2000 – land demand in 2030)		
With no deforestation	+71	-347
Clearing of natural forests	152	303
With deforestation	+223	-44

Source: Lambin and Meyfroidt 2011

Box 2. Simplified scheme of net and gross expansion of cropland

Degradation and loss to built-up land needs to be compensated, thus, although there is no net expansion, cropland is shifted to more natural areas. Additional demand for food, fibre and fuels (FFF), however, leads also to a net expansion of cropland. Together, additional demand and compensation lead to gross expansion of cropland.

Figure 3.12 Net and gross expansion of cropland



When focusing on the development of cropland and adopting a long-term perspective, the requirements become even more pronounced. Taking ***modest*** estimates of additional land requirements by 2050 (base year 2005), one may estimate that cropland would expand between around 320 to 849 Mha into grasslands, savannahs and forests (gross expansion, see Box 2 and Table 3.3).

Table 3.3 Expansion of cropland from 2005 to 2050 under BAU conditions for various demand and compensation factors

BUSINESS-AS-USUAL EXPANSION	LOW ESTIMATE (Mha)	HIGH ESTIMATE (Mha)	SOURCE
Food supply	71	300	Based on Bruinsma 2009, RFA 2008, Bringezu et al. 2009a
Biofuel supply	48	80	Based on Fischer 2009, IEA 2011
Biomaterial supply	4	115	Based on Colwill et al. 2011, Raschka and Carus 2012
Net expansion	**123**	**495**	
Compensation for built environment	107	129	Based on Electris et al. 2009
Compensation for soil degradation	90	225	Based on Scherr 1999
Gross expansion	**320**	**849**	

Net cropland expansion for global food supply is projected by FAO (Bruinsma 2009) with 71 Mha until 2050, consisting of an increase by 120 Mha in the developing countries and a decline by 48 Mha in the developed countries. From modelling forecasts, Tilman et al. (2011) concluded that if current trends of greater agricultural intensification in richer nations and greater land clearing in poorer nations were to continue, about 1 billion ha of land would be cleared globally by 2050, whereas a moderate intensification focused on existing croplands of under-yielding regions, adapation and technology transfer could keep the land clearing for food demand at around 200 Mha. From the Gallagher report (RFA 2008) Bringezu et al. (2009a) concluded that already until 2020 between 144 - 334 Mha of additional cropland would be required for world food supply, so that under the assumption of projected trends an estimate of 300 Mha (net expansion) for 2050 may be still regarded as realistic. This order of magnitude is corroborated by the review of modelling trends in Smith et al. (2010).

One strategy that could reduce cropland expansion is to increase the productivity of existing rangelands and pasturelands, thereby reducing demand for grain for livestock consumption. Although there seem to be no reliable global estimates on the potential benefits, a number of strategies have been experimentally demonstrated to increase livestock production, including better breeding, and better adapted and more productive breeds, and increased availability and use of veterinary services (Thornton 2010), more effective grazing management (Sollenberger et al. 2012), including increased shrub utilization (Estell et al. 2012).

Biofuel crops are expected to cover 68 - 100 Mha in 2050. The lower value is based on Fischer (2009) and the higher value on IEA (2011) (see section 3.5, Figure 3.10). Assuming a base level of 20 Mha in 2005, the additional net cropland required for biofuels would range between 48 - 80 Mha in 2050. Note that the Blue Map scenario assumes 375-750 Mha for energy crops, including 100 Mha for transport biofuels.

For biomaterials, we estimated the global net cropland requirement in 2050 to range between 104 -215 Mha, corresponding to the low and mid consumption levels described by Colwill et al. (2011). The estimate is based on global land use data from Raschka and Carus (2012), and assumes that yields would increase over the same period by 0.8% p.a. (Bruinsma 2009). Colwill et al. calculated combinations of their three consumption scenarios with three productivity scenarios (low, mid, high) and came to even higher land requirements for bioplastics in 2050, with

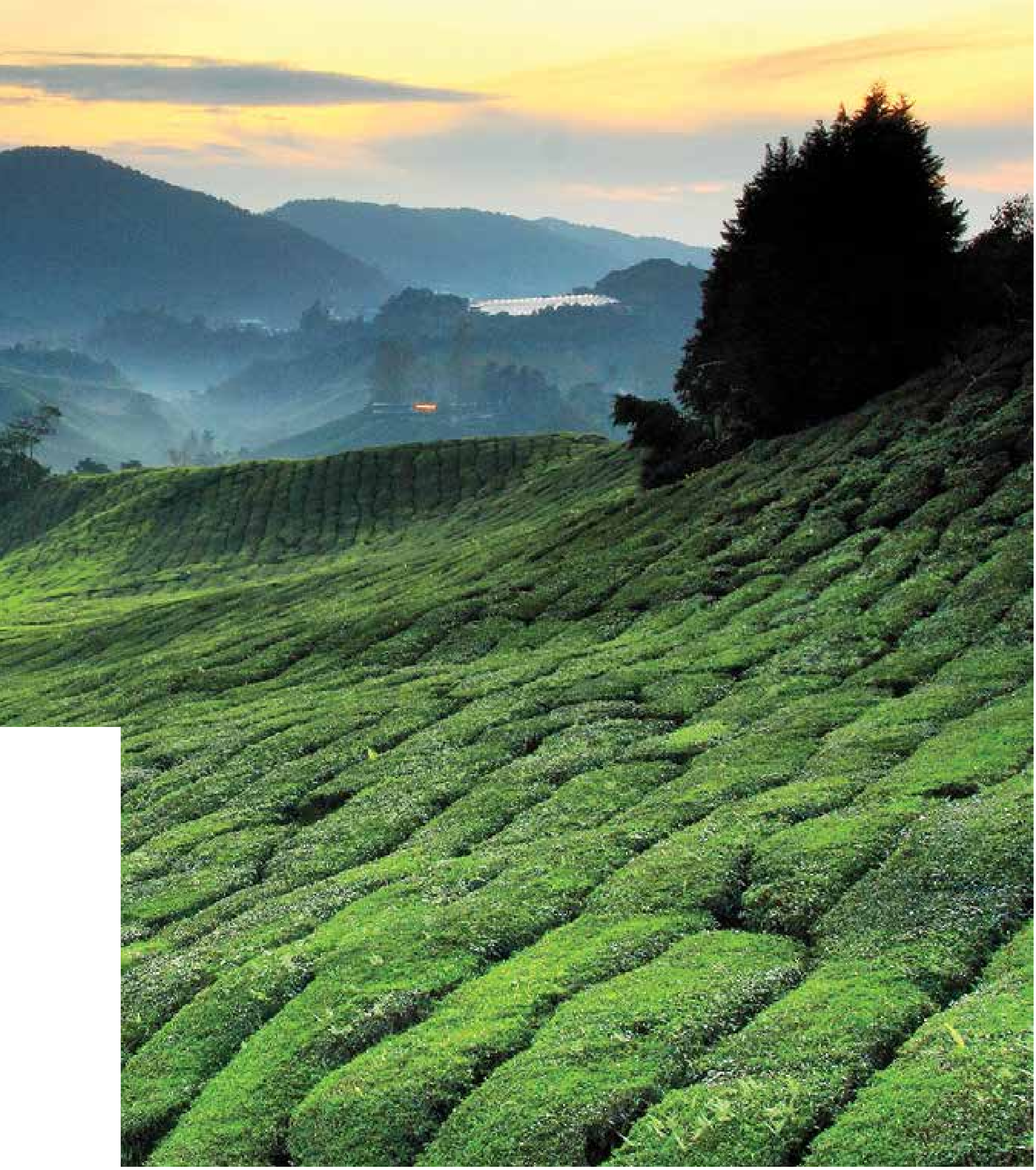
291 Mha for the mid productivity/mid consumption scenario (which the authors suppose to be the most realistic one). Assuming that the starting level in 2005 did not significantly differ from the 100 Mha estimated by Raschka and Carus (2012) for 2008, the *additional* net cropland requirement would range between 4 - 115 Mha. The wide range corresponds to the high level of uncertainty.

Compensation for built environment is based on the Electris et al. (2009) scenarios with strong political action towards "successful transition to a more equitable and environmentally resilient future" (107 Mha) versus a market driven scenario (129 Mha). The conversion value of 107 Mha also holds for the Great Transition scenario that "depicts a transition to a society that preserves natural systems, provides high levels of welfare through material sufficiency and equitable distribution, and enjoys a strong sense of local solidarity". Contrarily, in a world where "problems overwhelm the coping capacity of both markets and policy reforms" even more cropland may be converted to the built environment (the Fortress World scenario at 200 Mha).

The loss of arable land due to severe degradation, which leads to abandonment, is estimated to be around 2–5 Mha per year for the coming decades. The higher value represents the lower range value given by Scherr (1999) for estimates published for the second half of the 20th century. The lower value is the double of the yearly land use change which is expected as a consequence of shifting cultivation in Latin America only. Electris et al. (2009) in the scenario without policy intervention assumed 3.04 Mha being lost to severe degradation annually until 2050. The reader will note that the effects of non-severe soil degradation are reflected by the varying yields taken as basis for the range of the food, biofuel and biomaterial supply.

In summary, to meet the future increased demand for food supply, but also for biofuels and biomaterials, - which is growing faster than yields - **cropland** will expand. From 1530 Mha in 2005 until 2050 this ***net expansion of cropland*** will range from 123 to 495 Mha. In addition, cropland will be shifted to compensate for the expansion of built-up land and land degradation leading all in all to *gross expansion of cropland* in the range of 320 to 849 Mha.

This data has to be interpreted with caution as the estimates have not been derived from one consistent modeling approach considering all of these land use types together, and competitive effects and impacts of natural limitations via prices have not been considered.



Moreover, the influence of climate change has not yet been explicitly included in the calculations. Lobell and Field (2007) estimated that from 1981 to 2002 global warming has reduced the harvest of base crops such as wheat, maize, and barley by roughly 40 Mt or US$ 5 billion per year. This reduction was still small compared to technologically enhanced yield increases. However, the authors also assume that maize and sorghum yields will decrease in response to global warming, with an average of about 8% yield loss for each degree Celsius increase. This may indicate that the additional cropland required until 2050 may be about 10% higher than the numbers given above. Global warming will also lead to a higher frequency of extreme weather events, which might increase the variation of biomass availability between regions and years.

Altogether, the available data indicate that it is very likely that land competition will increase in the future. Without drastically increasing efficiency in the use of bio-based products the conversion of natural ecosystems into crop production seems inevitable.

CHAPTER

4

Balancing consumption with sustainable production

Balancing consumption with sustainable production

The previous chapters make it clear that without significant productivity increases, or decreases in the global per person consumption of food and non-food biomass, the world's growing population will necessarily lead to an expansion of global cropland.

In preparation for the Rio+20 Earth Summit, a number of reports were issued confirming the fact that the current 'business-as-usual' trends in consumption and production are unsustainable. For example, the "Living Planet Report 2012" estimated that "we will need the equivalent of two planets by 2030 to meet our annual demands" (WWF et al. 2012). While the results of our own analyses are somewhat more optimistic, and certainly more specific, our general conclusion is the same. Communicating our evolving understanding of limits to sustainability is challenging, particularly in light of significant uncertainty about the precise nature of these limits.

4.1 The safe operating space concept

The associated risks, although uncertain, require societal decisions on the degree of environmental change and degree of degradation which is regarded acceptable. The "safe operating space" (SOS) concept (Rockström et al 2009; see Figure 4.1) is one way of concentrating - thus simplifying - current understanding of global limits to sustainability as a starting point for understanding these limits, and as a basis for identifying potential solutions. In the following discussion, we apply the concept to further illustrate the potential constraints to sustainability under business-as-usual conditions, and to highlight the importance of aggressively seeking and adopting creative solutions that address both consumption and sustainable production issues.

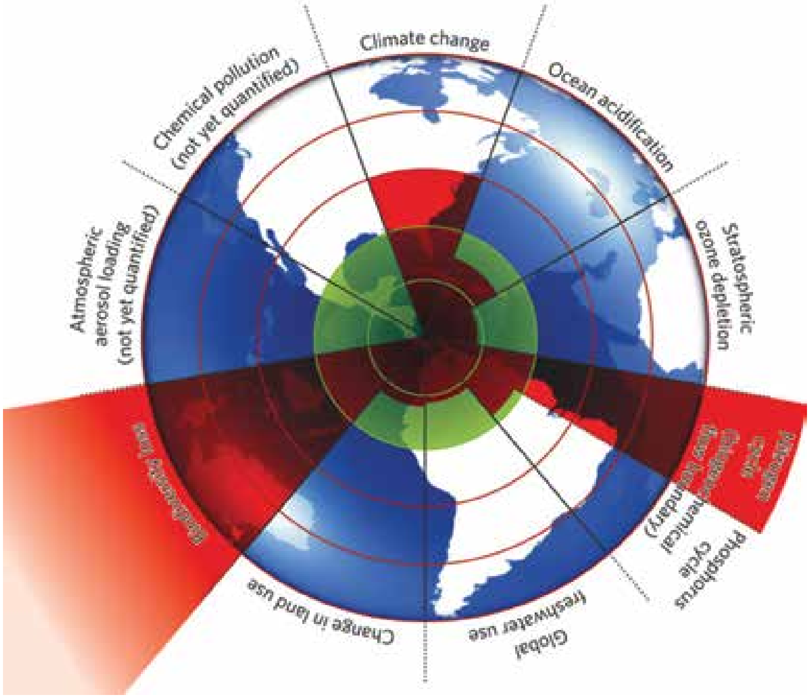
Rockström et al. (2009) defined planetary boundaries within which one may expect that humanity can operate safely. Transgressing one or more of the boundaries (which are interdependent) may be deleterious or even catastrophic due to the risk of triggering non-linear, abrupt environmental change within life-supporting systems. The authors identified nine planetary boundaries (Figure 4.1) of which seven were found to be quantifiable. Rockström and co-authors estimated that humanity has already transgressed three planetary boundaries, which are climate change, rate of biodiversity loss and changes in the global nitrogen cycle.

4.1.1 Starting point for understanding limits and identifying potential solutions

One of the strengths of the SOS concept is that it effectively highlights current over-use of the earth's resources. This indeed emphasizes the need for absolute decoupling of welfare creation from resource use, thus corroborating UNEP (2011a).

The concept is, however, just a starting point as it does not address three aspects essential for finding the ways to sustainable operation. The first aspect is that the potentials which lie in the various types of resource use within industry and society, in particular various degrees of resource use efficiency, are not considered, as the emphasis is on "negative thresholds" set by nature, while the positive 'tipping points' highlighted in the Factor X approach and other recent publications, showing how societies can become independent from those external limits, are left to subsequent discussion. The second is that, because the SOS concept has been defined at the global level, it fails to take into account local and regional differences in the impact of further resource use or permanent loss on both local and global sustainability. Finally, it does not distinguish between production and consumption, nor does it allocate global environmental impacts and resource use to producing or consuming countries, and it does not consider equity aspects.

Figure 4.1 Estimate of quantitative evolution of control variables for seven planetary boundaries from pre-industrial level to the present



Source: Rockström et al. 2009

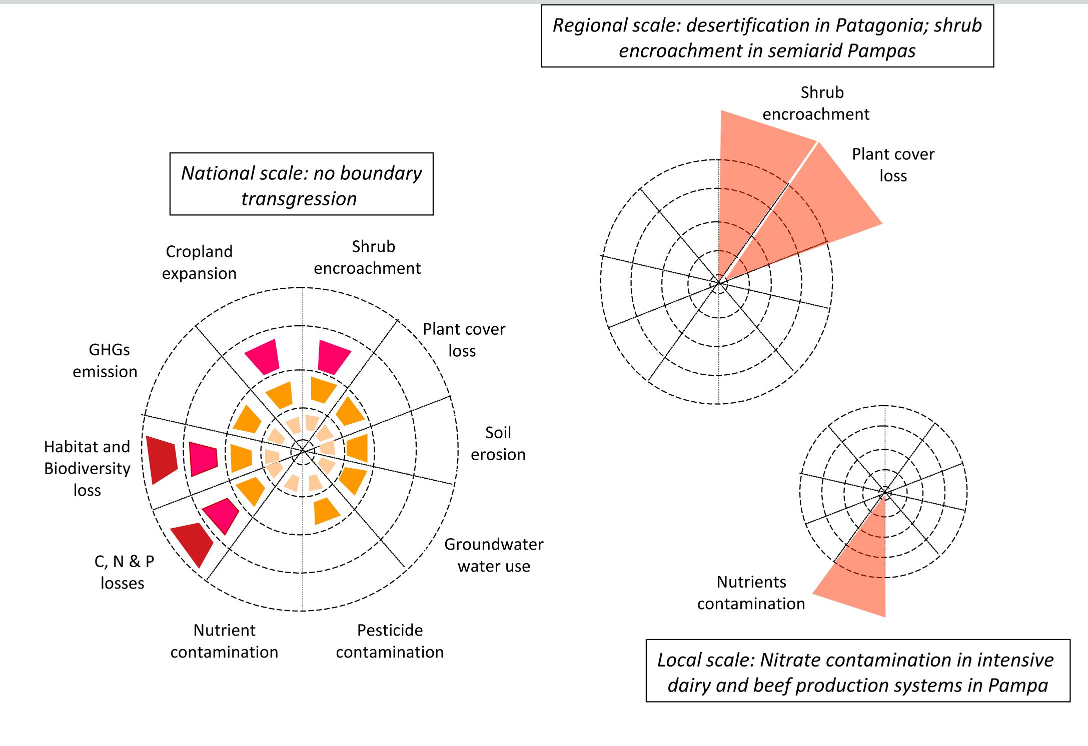
Countries differ with regard to their natural endowments and one may expect that the further development of resource extracting industries, such as mining, agriculture and forestry, will proceed in resource-rich regions with favorable conditions, also to minimize the undesirable side effects of production. As a consequence, differences between countries and regions with regard to resource extraction may even increase, and regions with rich endowments will supply regions with smaller endowments of natural resources. In contrast, consumption patterns of final products seem to converge world-wide depending on the economic performance of countries and classes. Under equity considerations, there would also be no reason why the final consumption of goods should differ among regions or countries. As the overall (final) consumption of goods, however, obviously leads to an overuse of natural resources, the question that arises is, how can countries recognize whether their consumption is within globally (or otherwise) safe limits?

The following discussion is designed to increase awareness and understanding of the magnitude of the challenges facing society, and of the extent to which the challenge must be addressed through a consideration of both consumption and production. In this chapter, we focus on what *needs **to*** be accounted for *if* consumption should become balanced with sustainable production. In Chapter 5, we briefly address some actions that *could* make a sustainable future a reality. Future reports will move farther to identify more advanced solutions.

4.1.2 The issue of scales

Operating spaces may appear to be safe at the broader scales because average values mask specific situations, and vice versa. Such a misinterpretation can become revealed when processes are scaled-down to smaller scales (Miller et al. 2004). Examples of the negative case can be detected in Argentina when the analysis scales down from the national to the regional and the local scale (Viglizzo and Frank 2006). While critical boundaries were not apparently transgressed at the national scale (Viglizzo et al. 2011), cases of irreversible shift can be detected at smaller scales in important farming areas of Argentina (Figure 4.2). Thus, even if global average values were indicating an acceptable level, this may not exclude unacceptable situations in specific regions or locations. Vice versa, if global average values are indicating a problematic level, action is needed with a world-wide effect.

Figure 4.2 Cases of critical-boundary transgression at different spatial scales in agro-ecosystems of Argentina



Source: Drawn by E. Viglizzo based on Dussart et al. 1998, Del Valle et al.1998 Herrero and Thiel 2002, Carbo et al. 2009, Araoz and Grau 2010, Viglizzo et al. 2011

The derivation of a safe operating space at the global level needs to be based on key indicators which capture essential conditions of (un)sustainability and can be applied meaningfully at various scales. If global biodiversity loss shall be halted, the conversion of natural habitats, in particular the extension of cropland, will need to be halted on the global level as well. The flows of nutrients such as nitrogen and phosphorous need to be evaluated against absorption capacities which differ widely at the regional level.

Researchers have only recently started to derive values for orientation towards a global safe operating space. Current research is not and may perhaps hardly ever be able to define unambiguous targets, as *uncertainties* and *normative assumptions* on acceptable changes of the living environment will need to be balanced. Considering the goals to halt the loss of biodiversity while securing food and fibre supply, a basic question is, which orientation targets do we set for major types of land use and how do we allocate these targets to countries and regions?

The provision of reference or target data for a globally safe operating space should, in any case, be separated from the question of how to allocate targets to countries and regions. The latter question must also distinguish between the use of biomass for production versus consumption. In this report, we will focus on the consumption side (including use in industry).

As a basis for any further assessment, the actual global land use of countries for their domestic consumption (status quo analysis) can be determined as will be shown in section 4.3. This data can be related to current global average values in order to check the degree to which the consumption of a country contributes to global land use change. And the data may be compared with the preliminary orientation values for a global safe operating space in order to indicate the direction and order of magnitude of necessary adaptations.

Safe operating space as a metaphor defines the outer road markings for keeping development on a viable track and avoid falling into gullies. How to control direction and speed and to make use of the "possibility space" is a subsequent challenge (tackled in Chapter 5). Certainly, more research is also needed considering the use of different categories of agricultural land beyond cropland, including intensively managed permanent pastures, and the determination of consolidated values for global and regional forest growth (section 5.4).

4.2 Global land use: a key indicator of global sustainability

Land use change is driven significantly by agricultural expansion and intensification (see sections 2.1 and 3.7). Defining a safe operating space for global land use means looking at how much more land use change can occur before the risk of irreversible damages becomes unacceptable. The question that arises is what extent of global cropland could delineate the safe operating space for generating long-term food security, in terms of an acceptable low risk regarding in particular

- biodiversity loss,
- release of carbon dioxide,
- disruption of water and nutrient cycles,
- loss of fertile soil.

4.2.1 Global cropland

Rockström et al. (2009) suggest that a further expansion of 400 Mha of cropland would be within the safe operating space, which is equivalent to a boundary of 15% of the global ice-free land surface (from around 12% in 2005). However, while the authors explicitly aimed at controlling transgressing the planetary boundaries caused by land use change, they did not seem to consider the expansion of settlement and infrastructure area. Recalling the Electris et al. (2009) scenarios resulting in a loss of cropland by 107 - 129 Mha being built-up in 2050 (see section 3.7) would significantly hamper the expansion potential suggested by Rockström et al. (2009). According to Seto et al. (2010), urban area alone might expand between 40 and 143 Mha from 2007 to 2050. Recent forecasts indicate a high probability that worldwide urban land will expand by 121 Mha already by 2030 (from 65.3 Mha in 2000) (Seto et al. 2012). Thus, there seems to be limited room for expanding cropland.

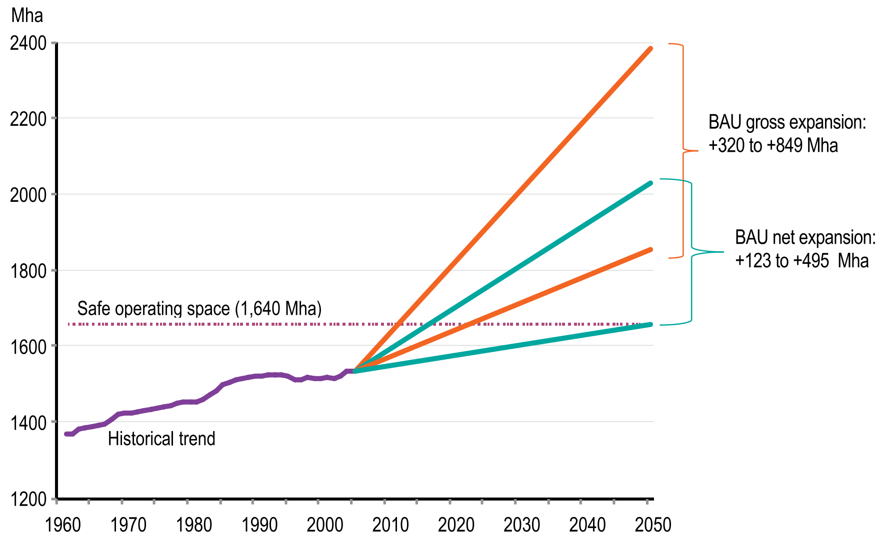
Agricultural expansion and the conversion of natural habitats are known to be key causes of the worldwide loss of biodiversity and ecosystem services (see 2.2.4). Business-as-usual might lead to a significant further expansion of cropland and pasture land as shown in Chapter 3. As a consequence, the loss of natural habitats, in particular grasslands, savannahs and forests might proceed, as is expected also in the recent UNEP (2012c) Global Environmental Outlook. Underscoring the issue of large-scale deforestation in the tropics, the Convention on Biological Diversity (2010) points out that "there is a high risk of dramatic biodiversity loss and accompanying degradation of a broad range of ecosystem services if ecosystems are pushed beyond certain thresholds or tipping points" (SCBD 2010). From an analytical perspective it would be extremely difficult to determine thresholds beyond which certain damages may be conclusively expected. Due to the complex interactions within many cause-effect networks at different scales, the uncertainties are enormous. Meanwhile, the "reality experiment" is running, and testing when and where severe and irreversible consequences will appear and turn out the errors while leaving no further trial. TEEB (2010) pointed out that in situations of uncertainty and ignorance about potential tipping points monetary valuation of biodiversity and eco-system services are "less useful" and instead policy should invoke safe minimum standards or the precautionary principle. Thus, instead of uncertain forecasting and risky testing of damage thresholds, the approach should be to control the known key drivers of global biodiversity loss at a precautionary safe level.

According to modeling of Van Vuuren and Faber (2009) "halting biodiversity loss requires agricultural land [cropland + permanent pastures], at least, to stabilize from 2020". Using that insight as a preliminary guideline and considering that also a change from permanent pastures to cropland is usually associated with losses of biodiversity as well as with carbon and nutrient release, one can conclude that a cautious global target would be to halt the expansion of global cropland into grasslands, savannahs and forests by 2020.

If the goal of halting global biodiversity loss until 2020 shall be reached, also cropland expansion, a key driver of this loss, will need to be halted. This implies that business-as-usual development could "safely" continue until 2020, at which time an additional about 100 Mha are expected for meeting future demand (net expansion) and 90 Mha are expected to be displaced (resulting in 190 Mha of gross expanion). For deriving a reference value for sustainable consumption that means the global (net) cropland area available for supplying demand could safely increase up to 1,640 Mha. This is taken as a reference value for a safe operating level of the consumption of agricultural products. Under business-as-usual conditions until 2050, the expected range of cropland expansion would overshoot the "safe operating space" in all cases (Figure 4.3)

As final consumption of food and non-food biomass and the required cropland should be used in both a safe and fair manner in the future, potential target values are expressed on a per person basis. For an interim target, a time horizon of about 15 years seems practical. Thus, the reference value of 1,640 Mha was divided by the world population expected in 2030, resulting in 0.20 ha of cropland (1,970 m^2) per person. Based on a rather conservative trend projection, this value had also been suggested by Bringezu et al. (2012) as a preliminary reference for orientation.

Figure 4.3 Expansion of global cropland under business-as-usual conditions: overshoot of safe operating space



Note: Safe operating space depicted here is a preliminary and indicative value based on a cautious global target to halt the expansion of global cropland into grasslands, savannahs and forests by 2020; in this figure it comprises only cropland used to supply food and non-food biomass (net expansion).

4.2.2 Global forests

When assessing the sustainable use of global forests two basic aspects need to be considered: (a) the extent of forest area, and (b) the quality of the forests, with regard to productivity on the one hand and biodiversity on the other hand. Plantations provide higher yields but clearly support significantly lower levels of biodiversity than native forests (Koh and Wilcove 2007; Stephens and Wagner 2007). If one wants to prevent the further loss of biodiversity contained in forests, the forest area on all continents should not be diminished and native forests should not be converted into plantations. Countries differ with regard to natural endowment with forests, and depending on geographic and cultural conditions, depend differently on forest resources (which, in contrast to food, renders it more difficult to interpret per person consumption values globally).

With regard to sustainability conditions of forestry, one may assume that wood is removed only up to the regrowth capacity of forests, i.e. the *net annual increment (NAI)*. Based on IIASA (2005), UNECE-FAO (2005) and other statistical sources Bringezu et al. (2012) estimated the global forest area for wood supply at 3.5 billion ha in 2008. As forests in the different biogeographical zones vary significantly with regard to their productivity per hectare, the net annual increment is a more relevant reference parameter for safe operating space than forest area. According to Bringezu et al (2012), the preliminary data available indicate a global NAI of 7 billion m^3/year. If around 80% of annual growth is available for use, it would mean that about 5.6 billion m^3/year could be regarded as an orientation for the safe operating space of forest harvest, given the current structure of forest types. On a per person basis, Bringezu et al. (2012) thus proposed 0.8 m^3/person as a preliminary global reference value for the sustainable use of NAI in the year 2008. Such a value can be compared with the actual consumption and the sustainable supply capacities in the various regions to gain insight on the sustainability of national timber consumption levels (see section 5.2).

Altogether, there are preliminary orientation values for approaching a safe operating space for land use at the global scale.

4.3 Monitoring global land use of countries and regions

This section will concentrate on linking the final consumption of agricultural and forestry goods in countries and regions to their global land use. The key question in this context is how much land worldwide is needed to supply the domestic consumption of countries? This can be operationalized for agricultural land and forest land.

Monitoring land use over time will allow for the quantification of land use *change* as a key driver of environmental degradation. Land use change has two dimensions which concern (1) the country's own territory (territorial) and (2) indirect land use change induced by the consumption of the economy elsewhere in the world.

Global statistics on land use are still in an early stage. *Territorial land use* and land use change are reported by so-called Annex I countries in the UNFCCC Common Reporting Format (CRF) tables 5 A-F (EU-27 countries except Cyprus, as well as the US, Japan, Canada, Russia, Australia, Switzerland, Turkey, Norway, Belarus, Croatia, Iceland, Liechtenstein, Monaco, Ukraine, New Zealand, and Kazakhstan) which – in the best case - allow to derive a land use change matrix. The categories reported are forest land, cropland, grassland, wetlands, settlements, and other land. Data is in general available from 1990 to the most recent year (currently mostly to 2008).

Indirect land use change has recently been studied for selected products such as biofuels by using various models (for review see e.g. Edwards et al. 2010). The methodological challenge lies with the uncertainty of the assumptions about the development of the consumption of the other biomass categories (not specifically modeled) and the overall land use requirements. So far, hardly any model captures all types of biomass (food, materials, energy) both on the production and the consumption side.

Before it comes to modeling of future land use, simple ex-post accounting of *actual and recent global land use* by countries needs to be improved, which allows them to compare their level of resource consumption internationally and to detect which activities and product groups are most relevant.

When total global land use for the consumption of all land use relevant products is monitored over time it will be possible to quantify country-related pressures to global land use change patterns, ideally differentiated according to key products and regions.

The SOS values (see section 4.2.1) can be taken as reference for the cropland requirements of economies in order to stay within global fair and safe shares of land use for final consumption. This needs to be distinguished from land use for production which is more bound to local and regional conditions. Monitoring global land use of countries and regions for their domestic consumption then gives an indication of how far it is away from sustainable resource use. In case of overuse of global cropland (as is the case for many rich countries) measures should be envisaged to compensate for overshoot demand (especially as future per person availability will significantly decline and production increases are uncertain). These may address on the one hand savings with regard to food consumption, biofuel targets and biomaterials demand (savings of net expansion), and on the other hand improved land use planning and investment programmes to regenerate degraded land (adding up to savings of gross expansion; see section 5.2 and table 5.4 for numbers).

4.3.1 Global land use for consumption of agricultural products

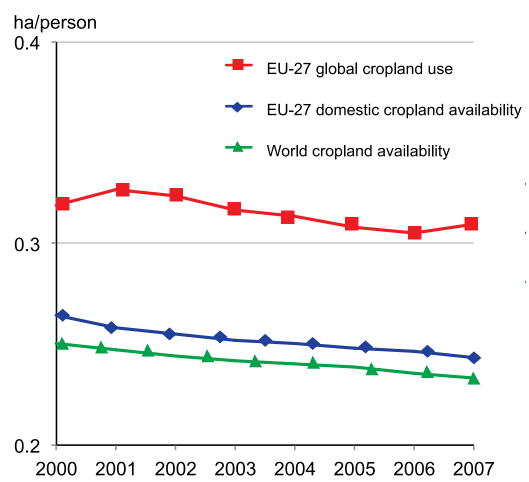
Global use of agricultural land for domestic consumption has been analyzed in several studies (Schütz 2003, Erb 2004, Bringezu and Steger 2005, Kissinger and Rees 2010, Von Witzke and Noleppa 2010). Schütz (2003) and Bringezu and Steger (2005) followed in particular the principles of economy-wide material flow accounting (ew-MFA) which allows comprehensive assessment of all materials associated with domestic consumption in a consistent framework implemented in official statistical monitoring and reporting (Eurostat 2001, OECD 2008a). Based on this framework, global land use caused by the apparent consumption of an economy is calculated using land equivalents for domestic production plus imports minus exports of all agricultural goods. Land quantities are expressed in per person terms to enable a cross-country comparison.

So far, global land use for the consumption of agricultural goods (GLU_A) has been calculated with the ew-MFA based method for Germany (Bringezu et al. 2009b), the EU and Switzerland (Zah et al. 2010). According to the authors the estimates are rather conservative. The results show that in 2007, the EU-27 required 0.45 ha per person of *global agricultural land*. This is almost one-fifth more than the domestic agricultural area within the EU (Bringezu et al. 2012).

Regarding cropland, the EU-27 required 0.31 ha per person of *cropland worldwide*, which is one-fourth more than what is available domestically (Figure 4.4). This is also one-third more than the globally available per person cropland of the world population in 2007. The EU´s consumption, thus, already uses an above-average amount of global cropland. If one accepts the suggestion that the global expansion of cropland should be halted by 2020 to stop the further loss of biodiversity a safer operating level would be around 0.20 ha per person (see section 4.2). Instead of increasing its land use abroad for supplying its own consumption, the EU would then need to work on decreasing it.

The analysis of the global agricultural land use of the EU-27 showed that – at current resource use levels and assuming further yield increases of 1% p.a. on average – neither actual levels of cropland use (AL) nor shares of acceptable cropland use (SHARE) can be reached by 2030 (Table 4.1). Data on global intensive agricultural land use in 2030 depend on rather uncertain assumptions, and should be treated with caution. They may indicate that a further intensification of permanent pastures used for European consumption abroad could reduce some pressure on global land use.

Figure 4.4 Use of global cropland by the EU-27 for the consumption of agricultural goods, 2000 - 2007



Source: Bringezu et al. 2012

Table 4.1 The EU's use of global cropland and intensive agricultural land in 2007 and 2030 compared to reference values for sustainability

	GLU_A CROPLAND (ha per person)			GLU_A INTENSIVE AGRICULTURAL LAND (ha per person)	
	2007	2030 - trend		2007	2030 - trend
(1) TRC_{EU-27} / POP_{EU-27}	0.31 [c]	(0.24) [d]		0.45 [c]	(0.35) [d]
(2) GRC / POP_g	0.23 [c]	0.21 [a]		0.43 [c]	0.39 [a]
(3) GARE / POP_g	0.20 [a]	0.20 [a]		(0.37) [b]	(0.37) [b]
AL = (1) / (2)	1.33	(1.15) [d]		1.06	(0.90) [d]
SHARE = (1) / (3)	1.55	(1.19) [d]		1.22	(0.94) [d]

Source: Bringezu et al. 2012

Notes: 2030 – trend: from Van Vuuren and Faber (2009) – trend scenario.
a. Data taken from Van Vuuren and Faber (2009) for cropland and from the Netherlands Environmental Assessment Agency, PBL for intensive grassland
b. Preliminary data derived from Van Vuuren and Faber (2009) for cropland and from the Netherlands Environmental Assessment Agency, PBL for intensive grassland
c. Calculations from this study based on FAO (for cropland) and the Netherlands Environmental Assessment Agency, PBL (for intensive grassland)
d. Data is indicative only: derived from 2007 reference by assuming 1% p.a. average yield increase with other factors (consumption levels, population, etc.) remaining constant (highly uncertain).
TRC: Total Resource Consumption; GRC: Global Resource Consumption; GARE: Global Acceptable Resource Extraction; Share of acceptable capacity (SHARE) of country i : SHAREi = TRCi/POPi

Other studies with a similar research target used somewhat modified methodologies but either lacked precise method descriptions on how to deal with processed goods or made simplistic assumptions, which are in need of further refinement. For example, Erb (2004) estimated the global land use for the domestic consumption of biomass products in Austria based on specific land use coefficients by product and country. However, neither coefficients nor information on how exactly they were derived, have been published. Kissinger and Rees (2010) calculated the global agricultural and forest land demand for U.S. domestic consumption based on a method with several simplifications, like pasture land use being estimated from the amount of livestock products consumed. Von Witzke and Noleppa (2010) traced processed goods back to their primary crops and arrived at the EU-27 global agricultural land use estimates similar to those of Bringezu et al. (2012) described above.

The reader will note that the global land use accounting presented here differs from the concept of the ecological footprint (EF) developed by Wackernagel and Rees (1996). The EF represents society's burden on the planet in *theoretical* global hectares combining actual and a larger virtual land use, which is dominated by the assumed terrestrial or maritime area required to absorb carbon dioxide emissions. The EF clearly shows that most countries are beyond their territorial carbon absorption capacities, which underpins the need for improved climate change mitigation (WWF et al. 2012). However, we think that the pressures to global warming and land use change are global issues which need *separate* monitoring and analysis for informed decision making. Thus we focus on determining a threshold for the rate of extraction of renewable resources based on *actual* land use.

Note also that similar calculations can be completed for food production per unit of soil carbon loss. Conversion of natural ecosystems to agricultural production is often associated with soil carbon emissions to the atmosphere (e.g. Bellamy et al. 2005, McNeill and Winiwarter 2004). In the case of carbon, however, these losses can often be stopped or even reversed through the adoption of management practices designed to maximize organic inputs and reduce soil disturbance, which increases the oxidation of soil organic matter (Lal 2004, UNEP 2009b).

4.3.2 Global land use for consumption of forestry products

Global forest land (GLU_F) used to grow the volume of wooden products consumed in a country within a certain year can be estimated accordingly. In a study for Switzerland, Zah et al. (2010) determined the consumed quantities of wood and products from domestic logging and imported products minus exported products, converted the data to raw wood equivalents and calculated the required domestic and foreign area using NAI values from IIASA (2005).[41] According to their results the Swiss consumption of wood products is well below the forest land available per person globally. They also developed different scenarios for the use of forest products. In all scenarios the GLU_F remained below the globally available forest land per person (Table 4.2).

41 *Area = Consumption (m3) / NAI (m3/ha), where NAI is the Net annual increment (the annual net growth of wood of standing timber stock in a country or region in one year in m3 per hectare, i.e. gross growth minus natural losses*

Table 4.2 Global Land Use Forestry (GLU_F) of Switzerland, m^2 per person

	STATUS QUO	REFERENCE		SCENARIO 1 RESOURCE SCARCITY		SCENARIO 2 CHALLENGES		SCENARIO 3 UNLIMITED GROWTH	
	2006	2015	2030	2015	2030	2015	2030	2015	2030
Biomaterials	1,146	1,322	1,412	1,130	1,266	1,686	2,617	1,521	2,032
Bioenergy	562	505	423	697	568	626	501	557	456
TOTAL	1,709	1,827	1,834	1,827	1,834	2,312	3,118	2,078	2,489
Self-supply ratio GLU_F	83%	77%	78%	77%	78%	60%	44%	68%	57%
GLU_F World	5,210	4,703	4,133	4,703	4,133	4,703	4,133	4,703	4,133
Swiss global forest use minus GLU_F World	-3,501	-2,876	-2,299	-2,876	-2,299	-2,391	-1,015	-2,625	-1,645

Source: Zah et al. 2010

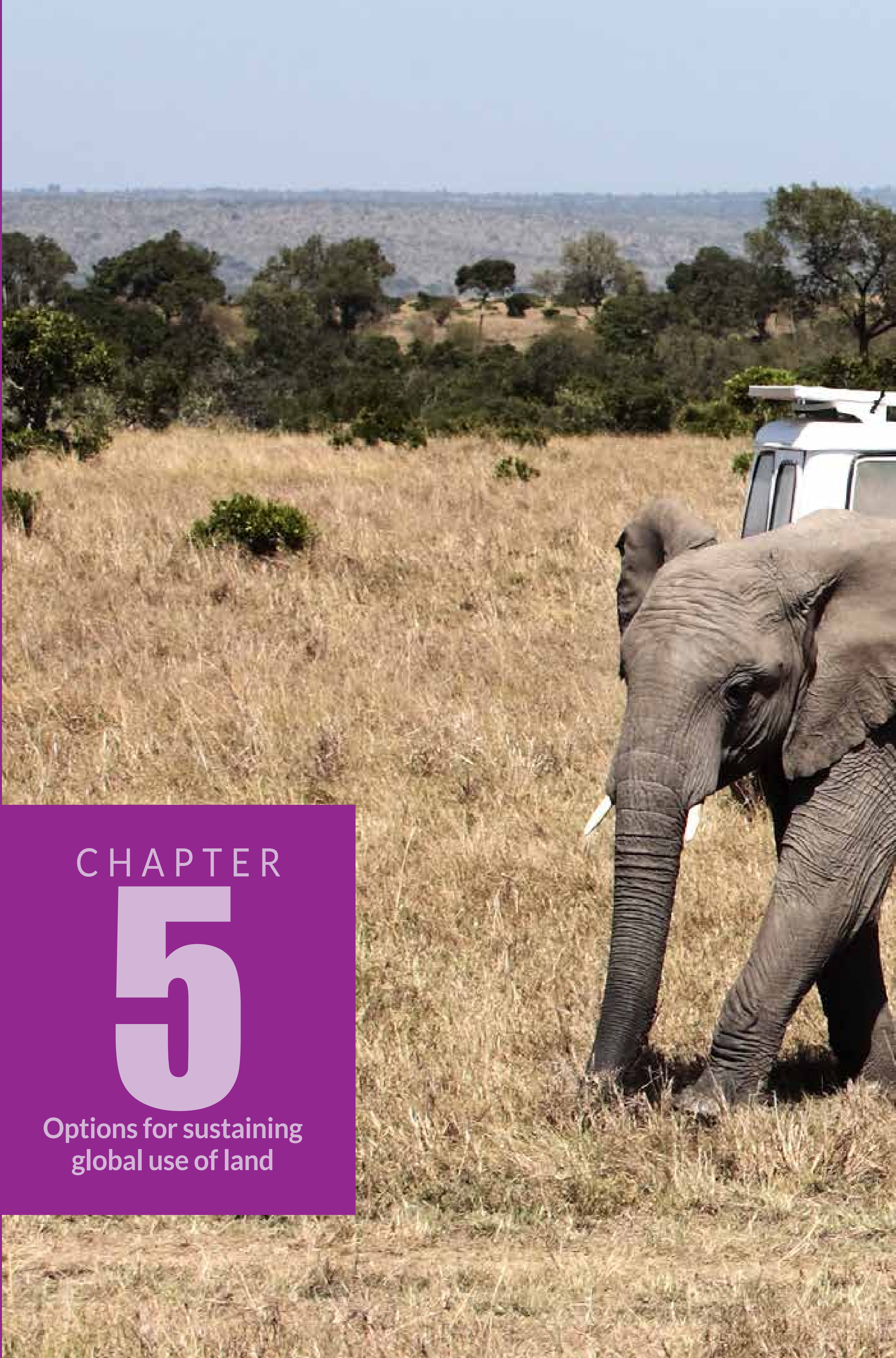
However, the provisional data on NAI indicated that Switzerland consumed forest growth capacity beyond the global average in 2006 (Table 4.3), and scenario results implied that 2nd generation biofuels based on forest primary harvest may significantly increase the imbalance.

Table 4.3 Global Land Use Forestry (GLUF) of Switzerland – Net Annual Increment (NAI) in m^3 per person

	STATUS QUO	REFERENCE		SCENARIO 1 RESOURCE SCARCITY		SCENARIO 2 CHALLENGES		SCENARIO 3 UNLIMITED GROWTH	
	2006	2015	2030	2015	2030	2015	2030	2015	2030
Biomaterials	0.54	0.66	0.77	0.61	0.78	1.20	2.33	1.06	1.75
Bioenergy	0.30	0.29	0.28	0.51	0.50	0.41	0.40	0.36	0.35
TOTAL	0.84	0.95	1.05	1.12	1.28	1.62	2.73	1.43	2.10
Self-supply ratio MFA	91%	85%	90%	93%	98%	57%	40%	64%	52%
Sustainable NAI World	0.80	0.72	0.63	0.72	0.63	0.72	0.63	0.72	0.63
Swiss timber consumption minus world timber production	0.04	0.23	0.41	0.40	0.64	0.89	2.10	0.70	1.47

Source: Zah et al. 2010

Altogether, regarding global land use, the first results indicate that due to their high consumption of products, some countries and economic regions use land-based resources beyond the level of their equitable share of a global safe operating space. With increasing trends they contribute to the growing pressure on land use change in regions with net exports of those products. Global land use accounting applies both a "life-cycle-wide" and a comprehensive systems perspective, as different types of biomass use (food, feed, fuel and materials) are considered together and related to their original land use. Nevertheless, the methods and data bases - in particular for pasture and forest land - need further refinement.



CHAPTER 5

Options for sustaining global use of land

Options for sustaining global use of land

This chapter will describe possible improvements of both production and consumption of biomass and depict effective institutional settings to make it happen.

5.1 Improving agricultural production

Sustainable land management systems are those that sustain or increase social, economic and environmental benefits while maintaining the land's long-term productive capacity. A sustainable production system is one in which "outputs do not decrease when inputs are not increased" (Monteith 1990). "Best management practices" (BMPs) are the building blocks for sustainable land management systems.

Agricultural ecosystems rely on ecosystem services provided by natural ecosystems (biodiversity, pest control, maintenance of soil structure and fertility, nutrient cycling, hydrological services), and also produce several ecosystem services, such as regulation of soil and water quality, carbon sequestration, support for biodiversity, and cultural services (Power 2010). However, agriculture can also be the source of numerous disservices, including loss of wildlife habitat and soil biodiversity, erosion, nutrient losses, greenhouse gas emissions, and pesticide contamination. Sustainability of agriculture production would be greatly enhanced through the adoption of BMPs which realize the benefits of ecosystem services and reduce disservices at different scales.

The objectives of this section are to briefly (1) identify the properties and processes affected by BMPs, and (2) identify the factors that should be considered in evaluating the impacts of BMPs on these properties and processes. The section concludes with (3): a vision for increasing the development and application BMPs across the diversity of rapidly evolving social, economic and environmental conditions throughout the world. This vision acknowledges the importance of supporting the development, adaptation and application of BMPs across the multiple continua of small to large-scale, organic to conventional and organic, non-mechanized to highly mechanized and low- to high-external input land management systems.

Properties and processes affected by BMPs, and factors affecting their impacts

The contribution of BMPs to sustainable land management systems depends on their individual and interacting effects on land and soil properties and processes. Table 5.1 lists 13 properties and processes, and lists representative BMPs that can positively affect them. The ultimate effect of each BMP depends on the social, economic and environmental context within which they are applied. Interactions among BMPs, and among different properties and processes can also result in very different effects. These effects may vary with scale (Bindraban et al. 2010) from the field or farm level through watershed, regional and global levels. Finally, several of the BMPs are in fact systems that arise from combining many different practices, i.e. agroforestry or site-specific management, and are also included under the best management concept. Chapter 6 of the IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development) report provides a more detailed discussion of several options related to sustainability (IAASTD, 2009).

Key principles

Altieri (2002) has identified a number of 'principles' of agroecology. While these principles are commonly cited to support BMPs based on small-scale, highly diverse agricultural production systems, they are relevant to the development of BMPs for a much broader range of land management systems. This relevance is illustrated by the extent to which they have been applied to the development and continued refinement of minimum tillage systems applied at large scales. These principles include:

- Recycle and re-use all available biomass (e.g. crop residues, cuttings from surrounding trees/shrubs, manures) in order to replenish and constantly restore soil nutrients;
- Grow plants by building soils, focusing in particular on soil organic matter and soil biotic activity by, for example, adding manures and promoting the growth of earthworm populations;
- Minimize losses of growth factors above and below ground by protecting the soils from direct solar radiation, strong winds and erosive water flows;
- Maximize diversity in order to increase resilience;
- Enhance beneficial biological interactions and synergies so that natural ecological processes can work to enhance rather than undermine agricultural production.

As Hillel (1991) and others point out, these and similar principles have been successfully applied to sustain civilizations for millennia.

Increasing the development and application of BMPs

Sustaining and increasing social, economic and environmental benefits while maintaining the land's long-term productive capacity at local to global scales will require the development and application of BMPs for a wide variety of current and potential future land management systems (Table 5.1). While debates continue about the relative sustainability of different classes of land management systems (e.g. organic vs. conventional, small vs. large-scale), there is a tremendous opportunity to increase sustainability through the adoption of BMPs within each of these land management systems. As Uphoff (2002) suggested, it is "more useful to consider practices and technologies along a continuum between likely-to-be- sustainable and unlikely-to-be-sustainable, rather than to categorize practices and technologies – and their proponents – into separate and opposing camps".

Table 5.1 Processes and properties affected by best management practices with multi-scale examples

PROPERTIES/ PROCESSES	SCALES OF INTERVENTION		
	FIELD/FARM	WATERSHED	REGION/GLOBAL
PHYSICAL STATE	Contour cropping, terraces, crop-livestock rotations, conservation tillage, returning of crop residues, grassland management, windbreaks	Protected areas, Agroforestry	Protected areas, Agroforestry
SOIL PROTECTION	Cover crops, conservation tillage, Intercropping, returning of crop residues, grassland management, windbreaks	Protected areas, Agroforestry, Riparian strips	Territorial Planning, Protected areas, Agroforestry
CARBON SEQUESTRATION	Crop management, cover crops, conservation tillage, returning of crop residues, intercropping, crop-livestock rotations, grassland management, fertilization, organic inputs (recycling), amendments, N fixing microorganisms	Protected areas, Agroforestry	Protected areas, Agroforestry
SOIL BIOLOGICAL ACTIVITY	Rotations, organic inputs (recycling), cover crops, PGPR, N fixing microorganisms, irrigation water management, conservation tillage, returning of crop residues, fertilization, organic inputs (recycling), amendments, N fixing microorganisms,	Protected areas	Protected areas, corridors
WATER CYCLING	Contour cropping, terraces, crop-livestock rotations, cover crops, conservation tillage, returning of crop residues, intercropping, fertilization, organic inputs (recycling), amendments, drainage systems	Riparian strips, Integrated watershed management, Protected areas	Protected areas, Agroforestry
NUTRIENT CYCLING	Fertilization, organic inputs (recycling), amendments, N fixing microorganisms, crop-livestock rotations, site-specific management, returning of crop residues, crop management	Riparian strips, Agroforestry	Territorial planning
BIODIVERSITY	Rotations, Cover crops, conservation tillage, returning of crop residues, intercropping	Corridors, Riparian strips	Protected areas, Corridors
PEST CONTROL	Balanced use of pesticides, Rotations	Corridors	Protected areas, Corridors
SOIL POLLUTION	Waste treatment, site-specific management, fertilization, organic inputs (recycling), amendments, balanced use of pesticides	Protected areas	Territorial planning
WATER POLLUTION	Waste treatment, site-specific management, fertilization, organic inputs (recycling), amendments, balanced use of pesticides	Riparian strips, Integrated watershed management	Territorial planning
AIR POLLUTION	Fertilization, organic inputs (recycling), amendments, N fixing microorganisms, Waste treatment, site-specific management	Integrated watershed management	Territorial planning
ENERGY USE	Conservation tillage, site-specific management, waste treatment, fertilization, organic inputs (recycling), irrigation	Integrated watershed management	Road and railway infrastructure, Territorial planning
SOCIAL AND WORKING CONDITIONS	Rotations, balanced use of pesticides, intercropping, irrigation, conservation tillage	Integrated watershed management, Agroforestry	Road and railway infrastructure, Territorial planning

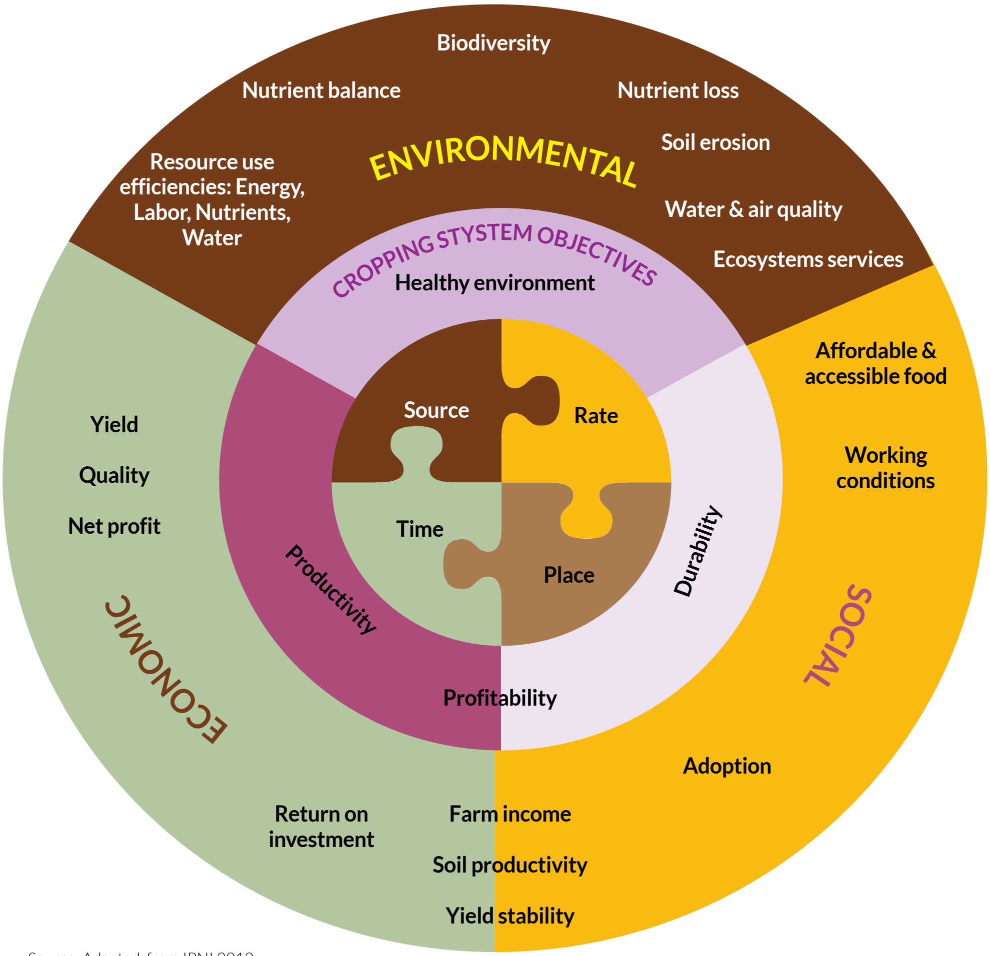
Potential yield gains (gaps between realistically attainable yields and farmer yields) in dryland agriculture and in developing countries (Lobell et al. 2009, Fischer and Edmeades 2010, Conijn et al. 2011) provide an opportunity to systematically explore the potential benefits of both applying currently available BMPs, and the need to develop new BMPs for novel combinations of social, economic and environmental conditions. Yield gap analyses carried out for major rain-fed crops in semiarid regions in Asia and Africa and rain-fed wheat in West Africa and North Africa revealed large yield gaps with farmers' yields being a factor 2 to 4 times lower than achievable yields for major rain-fed crops (Singh et al. 2009; Fisher et al. 2009), and historic trends present a growing yield gap between farmers' practices and farming systems that benefit from management advances (Wani et al. 2003, 2009). A recent article by Chen et al. (2011) shows the potential impact of integrated soil-crop system management (ISSM) for food security in maize production in China, demonstrating that ISSM would increase maize yields by improving partial factor productivity, a nutrient use efficiency indicator, by 120% and 170% compared to farmer´s practice and high yielding systems, respectively.

A FAO (2009a) panel indicates that a significant increase in food production by 2050 can be achieved if the necessary investment in research and development and policies in agricultural production are undertaken. Long-term experimentation would provide relevant data and guidance on BMP for sustainable land and soil management (Richter et al**.** 2007). There is a large need to expand the outreach and extension education efforts to ensure that research results on improved management practices are transferred and adopted rapidly by farmers. A critical point for the research and extension involved in developing and disseminating BMP is the active participation of farmers and other stakeholders. A good example has been on-farm research which facilitates the communication among farmers, agronomists, soil scientists, government staff, and other stakeholders. As indicated at the Delhi Declaration on Reactive Nitrogen Management (INI-ING 2010): "Identification, communication, and promotion of BMPs require collaboration among many stakeholders including governments, scientists, practitioners, and policy makers at global, regional and national levels".

'4R Nutrient Stewardship' (Bruulsema et al., 2008; IFA, 2009) is an example of a framework that can be used to guide the development and application BMPs across the diversity of rapidly evolving social, economic and environmental conditions throughout the world. The 4R nutrient stewardship is an innovative approach to BMPs for fertilizers and other nutrient sources (crop residues, manure, recycling products, amendments, and biological fixed N_2), which ensures that the right source is applied at the right rate, right time, and right place (Bruulsema et al**.** 2008; IFA 2009) (Figure 5.1.)

The BMPs should be based on scientific principles that are universal but locally applied. This simple concept can help farmers and the public understand how the right management practices for nutrients contribute to sustainability for agriculture. Getting practices "right" depends on important roles played by farmers, crop advisers, scientists, policymakers, consumers, and the general public. There is considerable research that has addressed the improvement of nutrient management in general and fertilizer nutrient management in particular. There is a need to improve the adoption of BMPs to achieve higher nutrient use efficiency (NUE) and improve nutrient balances. Site-specific management systems, remote sensing technologies, and crop modeling would provide for improved NUE.

Figure 5.1 The 4R Nutrient Stewardship



Source: Adapted from IPNI 2012

Fertilizer use BMPs—applying the right nutrient source at the right rate, time, and place—integrate with agronomic BMPs selected to achieve cropping system management objectives of productivity, profitability, durability, and health of the biophysical and social environment. A balanced complement of performance indicators can reflect the influence of fertilizer BMPs on the economic, social, and environmental goals for sustainable development (Bruulsema et al. 2008, IFA 2009).

Nutrient cycling is just one of the 13 properties and processes described in Table 5.1. A similar analysis could be applied to the other properties and processes. An integrated framework could be developed allowing decision-makers to optimize BMPs relative to multiple processes for diverse environmental conditions. Ideally, this integrated framework would link the properties and processes to ecosystem services, allowing for optimization of BMPs relative to these services at multiple spatial scales.

While development and quantitative application of this type of analytical framework is currently unattainable at the global scale, it can be semi-quantitatively applied at local scales through the participatory development of conceptual models supported by local and scientific knowledge. This 'bottom-up' approach is being widely and successfully applied through approaches such as 'site-specific management' (SSM). SSM is a system that deals with the implementation of BMPs for specific land, soils, and cropping system conditions. SSM can contribute to sustainability by adapting BMPs to the social, economic and environmental conditions (Dobermann et al. 2004; Shanahan et al. 2008; Gebbers and Adamchuk 2010). Local-level analyses for improved production conditions may then be complemented by analyses of consumption at regional or national level (Section 5.2).

Interim Conclusion

Development and selection of BMPs is extremely complex, requiring a detailed knowledge of existing practices, the social, cultural, institutional, economic and environmental context in which the practices are to be applied, and an understanding of potential interactions. Increasing sustainable agricultural production, and the provision of other ecosystem services depends on a continued willingness to explore all possible options, and integrating and applying both scientific and local knowledge to enhance the potential for sustainable land management. The active participation of farmers and other stakeholders is a critical point for the research and extension involved in developing and disseminating BMP.

A number of other recent reviews have highlighted the primary importance of pursuing specific sets of strategies which are broadly categorized as organic or ecological (Bedgley et al. 2007, Foresight Report on Global Food and Farming 2011, FAO 2002b, UNEP 2009b), germplasm improvement (Beddington 2010, Tester and Langridge 2010), increased fertilizer use and nutrient use efficiency (Tenkorang and Lowenberg-DeBoer 2009) or some combination (e.g. Tilman 2002, Godfray et al. 2010) to sustainably increase food production, sometimes while reducing greenhouse gas emissions per unit production. Each of these sets of strategies presents unique challenges and opportunities that must be addressed in a broader context of global resource use. These challenges and opportunities will be more explicitly addressed in future IRP reports.

5.2 Steering consumption towards sustainable supply

The key causes of our global challenges are linked to unsustainable and disproportionate consumption levels, but in high-consuming countries only a few policy instruments address excessive consumption habits and the structures that encourage them.

This section looks at arguments for including an overarching land perspective in policy approaches for managing land-based resources (section 5.2.1). It argues that both consumption-based and production-based approaches are needed (section 5.2.2) and shows that reducing demand can be achieved in a number of innovative ways (section 5.2.3). This includes aiding consumers to cut out wasteful and excessive consumption behaviors, improving efficiency across the life-cycle of agricultural commodities and increasing the efficiency with which land-based resources are used and re-used.

5.2.1 Product-specific approaches alone are insufficient

It has been widely recognized that policy instruments are needed to manage increasing competition for land and land encroachment, especially into high-value nature areas. Efforts to this end have been intensified across the globe. In the EU, for example, where 10% of final energy consumption in the transport sector has been set as a target to be met with renewables by 2020, the regulation states that 'fuel crops' must not be produced on primary forestry land, highly biodiverse biomes, peat land and other valuable areas. Minimum levels of GHG savings must be met, increasing from 35% to 50% in 2017, and methods to account for GHG emissions from indirect land use change must be developed (EU 2009).

However, such product-related stipulations alone cannot solve the problem of land use change induced by biofuel production. First, displacement effects are methodologically difficult to capture. An increasing number of analysis and debate on how to quantify and assess the direct and indirect land use change induced by biofuels has recently emerged (e.g. Searchinger et al. 2008; Ravindranath et al. 2009; Al-Riffai et al. 2010; Hiederer et al. 2010). Edwards et al. (2010) compared different models for quantifying the scale of land use change, finding that estimates depend heavily on the model and parameters chosen. For instance, estimates on total indirect land use change induced by the expected demand for biodiesel in the EU alone range from 242 to 1,928 kha per Mtoe, depending on the model used. In the US, some models (e.g. AGLINK-COSIMO and GTAP) predict that the majority of indirect land use change induced by the demand for ethanol would occur outside the US, while another model (LEITAP) projected that 90% of indirect land use change would occur within the US (at a scale of 107 to 863 kHa per Mtoe). Key assumptions leading to such wide disparities include the future development of yield increases -- which are rather uncertain (see section 3.1) -- as well as substitution effects between crops, products and regions and the non-linearity of marginal land requirements for extended croplands (Edwards et al. 2010). With the provision of ever more GHG estimates for specific types of biofuels, there is a real risk of getting lost in the details and losing sight of the big picture. More importantly, the production of biofuels will increase as long as it makes economic sense to produce them. Manufacturers will continue to source their biofuels from highly productive crop plantations in regions like South America and South East Asia, for instance Brazil and Indonesia, in order to meet legal requirements. As a consequence, the production of food and other non-food biomass will be driven elsewhere. As shown in section 5.1 for the EU, biofuels will add to the overall demand for land, which already exceeds domestic availability by around 25%. As such, the increasing demand for both food and non-food biomass can only be met by the net expansion of global arable land. Thus, the risk of indirect effects depends on the overall demand for land-based products. Globalization has made it particularly difficult and complicated for governments to maintain an overview of how much agricultural land they 'consume', as the amount of global land used by national economies needs to be accounted for. Product-specific approaches such as certification are still important, but will be only effective in the context of overall land use (Bringezu et al. 2009a).

Not only biofuels demonstrate how in a globalized world decisions in one country may affect land use in another: around 72% of poultry and 55% of pigs were raised in global industrialized animal-production systems at the turn of the 21st century (Galloway et al. 2007). The feed for these animals is produced in other regions and then often consumed far from the point of production. Meat and dairy products account for about three-fourths of the global land used for producing food for European consumption (Bringezu and Steger 2005). In Brazil the growing demand for feed contributes to the expansion of cropland into natural ecosystems (Morton et al 2006, Wassenaar et al. 2007). A model developed by Galloway et al. (2007) suggests that primary expansion of cropland in Brazil is most sensitive to changes in soy yield and to the quantity of meat and feed demand from abroad.

One may argue that the market will 'regulate' the price and therefore production will be located in regions optimal for it. The problem, however, is that markets do not function ideally and do not take into account typically negative externalities. Therefore the consumption of agricultural goods in a country or region may lead to cropland expansion in other countries, which altogether may surpass the safe operating space for land use. Proper monitoring systems and smart regulations are needed to prevent this overexploitation. Regulations do not need to be market-inhibiting, but may rather trigger innovation across the supply chain to foster the most effective use of existing cropland resources in dynamic and evolving markets.

In a globalized world, national sovereignty has to cope with international interdependencies and principles of equity and burden sharing. Climate change and the degradation and loss of ecosystems, like forests, are regional, national and global challenges that call for regional, national and global strategies and cooperation. Responsible use should therefore become a matter to producers as well as consumers who indirectly use others' resources, in particular when that resource use may contribute to an overuse of global capacities. This is especially relevant for regions such as the EU, as a "net consumer" of global cropland. The need to monitor and control the domestic consumption of global agricultural goods grows with the increasing globalization of food, feed, biofuel and biomaterial markets.

In summary, as long as global cropland expands -- as will be the case for the coming decades to feed the growing world population -- product-specific quality standards will be insufficient for controlling indirect land use change. Product-specific measures at the micro level (e.g. biofuels certification) must be complemented by demand-specific measures at the macro level (e.g. addressing net land use) in order to prevent problem shifting.

5.2.2 Production-based approaches alone are insufficient

Even if safe operating practices were adopted on each hectare of agricultural land, the overall consumption of agricultural resources could lead to land use changes beyond globally acceptable levels. This happens when the demand for land-based products exceeds levels of sustainable supply, causing an expansion of cropland into high-value nature areas to meet this extra demand. This could be a result of distorted price signals (e.g. subsidized consumption of non-food biomass) or possibly also a rebound—i.e. consumers drive more with certified biofuels, thereby increasing demand. For these reasons, consumption-based approaches are not only necessary to adjust consumption toward sustainable levels, but may also be an effective way to trigger life-cycle wide improvements in the efficiency of food and non-food biomass use.

Box 3. Production and consumption oriented policies need to complement each other

Production-oriented targets may only address half of the picture, especially in global markets where domestic production can be usurped by imports. For instance while cattle numbers declined by 34% and consumption of domestic beef decreased by 40% between 1990 and 2004 in Germany, the consumption of products from cattle (meat, milk, dairy products) remained more or less the same (in absolute quantities as well as in calories) (FAOSTAT). The land used for animal production within Germany also remained rather constant during this time period (BMELV 2006), largely because feed production became more extensive, leading to a larger area used per animal. One reason may be that farmers were subsidized according to the amount of acreage they cultivated, considering cross compliance with environmental requirements. The reduction and extensification of domestic production was compensated by increased imports and the overall global land requirements rather increased. On the other side of the coin, consumption-targeted approaches alone may be less effective for achieving domestic environmental targets when excess production can be exported. Tukker et al. (2011) modelled the environmental impacts of a healthier diet in Europe (toward nutrition guidelines, in particular with less red meat consumption) and found that environmental impacts could be reduced by about 8%. However, modelling of secondary rebounds suggested that the European meat production sector would likely export more meat, reducing the environmental benefits of decreased consumption within Europe. While this may reduce environmental pressure in those countries exported to, Tukker et al.'s analysis suggests that policies stimulating diet changes alone are probably not enough if the goal is to reduce domestic environmental impacts of food consumption; a bundle of policies targeting consumption and production seem appropriate.

Governmental interventions deliberately targeting consumption patterns may be considered unacceptable in liberal market economies. In reality, however, governments already steer consumption significantly. For instance, tax, tariff, and subsidy policies increase the desirability of some products while making others unattractive or unavailable. Safety and performance standards shape and constrain choice for everything from food to cars (Maniates 2010). The government 'choice-edits'[42], for example by banning environmentally harmful products like CFCs and, recently in Australia and some EU countries, incandescent light bulbs. As Maniates (2010) points out, the real worry is that for decades such activities have been used to encourage a culture of consumerism that makes mass consumption appear to be both natural and the foundation of 'healthy' economies and human happiness. For this reason, the government, along with business, would have to play a major role in shifting societies away from systems of mass consumerism. A starting point could be tackling consumerism of land-based products, but far-reaching efforts for all natural resources are also needed.

It is not only government's responsibility to 'tackle' consumption. A report published by the World Business Council for Sustainable Development (WBCSD) on sustainable consumption begins with the statement: "We recognize the need for business to play a leadership role in fostering more sustainable levels and patterns of consumption, through current business processes such as innovation, marketing and communications, and by working in partnership with consumers, governments and stakeholders to define and achieve more sustainable lifestyles" (WBCSD 2008). The report emphasizes that business has a role to play, for instance by choice influencing—using marketing and awareness-raising campaigns to encourage consumers to make sustainable choices—and through choice editing—removing unsustainable products and services from the market. It also highlights that in order for consumers to be able to change behaviors and make informed purchasing decisions, they need the support of business, governments and civil society.

Relying on consumer choice alone is not an effective strategy. Research has shown, for instance, that consumer awareness of environmental problems does

42 Choice editing describes instances where governments and/or businesses influence the choices made by consumers.

not necessarily translate into consumer willingness to pay extra for environmentally friendly goods or to adopt sustainable consumption practices. Sustainable consumer choices are hindered by a number of barriers, including availability, affordability, convenience, product performance, conflicting priorities, skepticism and force of habit (WBCSD 2008). Consumers are also heavily influenced by marketing—global advertising expenditures hit $643 billion in 2008 (Assadourian 2010). They may also be confused by the multitude of product labeling systems which they are confronted with on a daily basis. For instance, the ecolabel index website[43] has compiled a database of 377 ecolabels in 211 countries and 25 sectors, with 127 of these labels dedicated to food alone.

While harmonization and transparency of labeling and certification are needed to help consumers keep track of different schemes and make informed choices, evidence on the capability of ecolabels to transform mainstream behavior is diverse. According to a Mintel survey in 2010[44], more than a third of U.S. consumers say they would be willing to pay a premium for eco-friendly products. Almost 40% of German consumers said they were influenced by the best-known eco label in Germany, "Blauer Engel" (UBA 2010). The rapidly expanding market for organic food in North America and Europe (comprising more than 90% of sales in organic food worldwide) seems to indicate that consumer choices can lead to changes in the market. The global market for organic food expanded 170% between 2002 and 2011, reaching $63 billion in global sales in 2011 and covering an estimated 37.2 Mha (FiBl and IFOAM 2013; Soil Association 2013). Nevertheless, the market share (e.g. around 4% in the US (Soil Association 2013)) and the agricultural land share (around 0.9% of agricultural land in the 162 countries surveyed[45]) is relatively small, indicating that these trends have not, yet, reached the mainstream.

43 *http://www.ecolabelindex.com/ Accessed 10 May 2011*

44 *http://www.mintel.com/press-centre/press-releases/514/are-americans-willing-to-pay-moregr-een-to-get-more-green*

45 *By the latest FiBL-IFOAM (Research Institute of Organic Agriculture and the International Federation of Organic Agriculture Movements) survey on organic agriculture worldwide (FiBl and IFOAM 2013).*

Indeed, surveys in the UK revealed that only a minority of shoppers seemed to be influenced by eco-labeling schemes (Maniates 2010, DEFRA 2008). A study analyzing promising transformations in consumer cultures in the UK concluded that the green consumer has not traditionally been the tipping point for green innovation, but rather interventions by government and business to edit out less sustainable products has been the determining factor (SDC and NCC 2006).

While price and suspicions of "green washing" may hamper labeling schemes, a more inherent problem for transformational change may be rooted to people's behavior and choice architecture. Values and emotions may influence people's choices more than facts. As regards purchasing decisions, influences such as group identity and status seeking may undermine "sustainable consumption" efforts in cultures which value materialistic wealth. As regards attitudes towards waste and waste generation, (modern) richness seems to be associated with wastefulness in several cultural settings. For instance, there is a physiological limit (when dietary requirements are fulfilled) supporting the decoupling of income growth and food consumption. However, higher amounts of food waste in high-income-regions prevent such a decoupling. Facts about global environmental challenges are unlikely to motivate the levels of public engagement needed to meet these challenges without also addressing underlining cultural values like social status and financial success (WWF 2010).

Consumption-targeted strategies may also contribute to large gains. For instance, Bringezu et al. (2009b) estimated that in Germany it would be feasible to save around 1,200 m^2 of land per person with just three demand-side measures: reducing the total fuel consumption of cars by 26-30%[46] and phasing out first generation biofuels, reducing the consumption of animal-based food products to a level recommended by the German Society for Nutrition, and reducing the share of wasted (or waste) food products in households and retail trade (Table 5.2). Such strategies will be further discussed in section 5.3.3.

46 *Rebound effects were not considered.*

Table 5.2 Estimated effect on global land use and GHG emissions of alternative scenarios for biomass use in Germany

SUPPLY SIDE	SAVINGS POTENTIAL FOR GLOBAL LAND REQUIREMENT (2030)	SAVINGS POTENTIAL FOR GHG-EQUIVALENTS
Biogas replaces biofuels	a) constant b) 100 m^2 per person	a) 15.8 – 17.9 million tonnes b) n.a.
Photovoltaic replaces biogas	100 m^2 per person	2.7 – 3.0 million tonnes
Reduced domestic animal production	+/- at constant consumption	+/- at constant consumption
DEMAND SIDE		
Emission mitigation for automobiles to 130 g CO_2/km	500 to 600 m^2 per person	29.6 million tonnes 26% diesel, 30% gasoline
Reduced domestic animal based diet according to recommendations of DGE	400 to 500 m^2 per person	n.a. (synergistic)
Reduction of wasted food in households	ca. 200 m^2 per person	n.a. (synergistic)

Source: Bringezu et al. 2009b

Notes: a) Biogas produced from biomass on land formerly used for biofuels. b) Biogas replaces the energy content of biofuels from domestic land. DGE is the German Society for Nutrition.

On the whole, when the overall use of land exceeds the threshold of a safe operating space, it becomes necessary to limit the overconsumption of land-based products, and to decouple resource consumption from further growth of wealth and well-being. If food supply were to be ranked first, measures would primarily aim to reduce consumption of non-food (biofuels and biomaterials) and related land requirements. At the same time, high potentials exist for reducing the use of land for food production. Monitoring and policies need to account for and tackle the global land use for all consumed biomass products independent from their origin in order to avoid problem shifting.

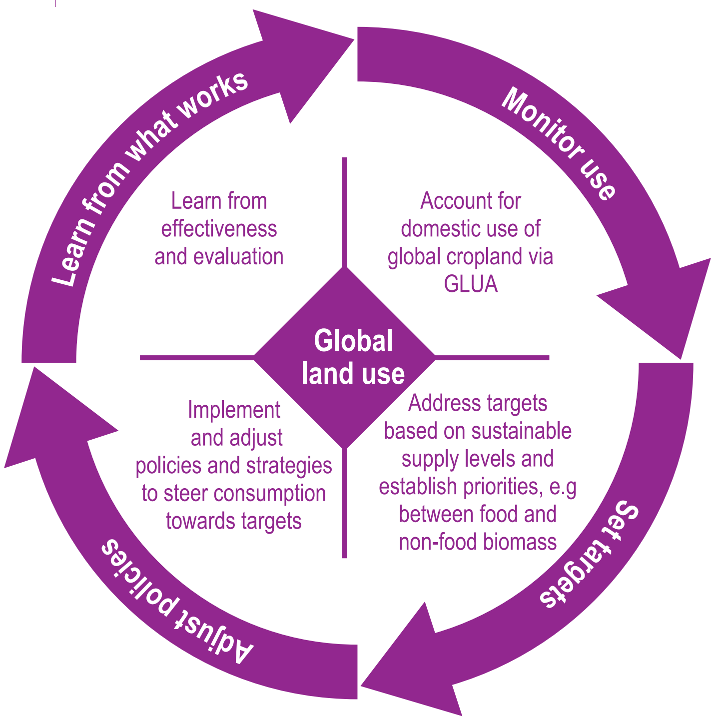
5.2.3 The transition towards sustainable consumption

The transition to sustainable levels of global land use will require a number of iterative steps, many of which have already been outlined in this paper:

1. Monitor current performance (e.g. apply global land use accounting to determine how much global land domestic economies require);
2. Set targets and define future objectives (e.g. determine a reference value based on the principles of a safe operating space to establish targets and set priorities between food and non-food biomass consumption);
3 Adjust existing and implement new strategies and policies to steer current performance towards future objectives (e.g. adjust targets, subsidies and taxes and establish a framework for efficiency);
4 Learn from effectiveness and evaluation (e.g. through impact assessments of policies to determine which strategies were particularly effective or ineffective for next time).

This section will review steps 1, 2 and 4 and especially focus on ways to steer consumption towards sustainable supply (3).

Figure 5.2 Transition cycle for managing global cropland consumption levels towards levels of sustainable use



1. Monitor current performance

Global land use accounting can be used to monitor how much global agricultural land different regions or countries require to supply their consumption (as described in 4.3.1). It provides information about the current use and a signal about the link between consumption activities and impacts inside the country and abroad. For instance, demand for feed has been one of the major drivers of deforestation in Brazil, especially in the 1990s and early 2000s (Morton et al. 2006; FAO 2006d; Boucher et al. 2011). Global land use accounting tells countries or regions how much land they require in Brazil to supply their demand for feed, and ultimately meat.

Monitoring may also enable the identification of areas of production and consumption contributing most to domestic and global land use. This should help in focusing the policies on tackling these areas first.

2. Define future targets

While knowing how much global land countries or regions require is an important first step, this amount is not very meaningful without something to compare it to. Deriving this 'reference value' is an important part of step 2.

For that purpose, the safe operating space for land use may serve as an orientation (section 4.1). This concept considers the multi-dimensions of global land use change, its various environmental and social impacts, and represents a key driver which can be linked to human activities and controlling governance.

Absolute values for a safe operating space may be divided by the world population to derive a per person reference value (e.g. 0.20 ha/person global cropland in 2030). Countries or regions may orient themselves toward this reference value as a long-term target. For instance the EU, with 0.31 ha/capita, would need to reduce its global land use. To this end, the EU, as well as other countries and regions, might consider setting priorities between food and non-food biomass consumption. First targets could focus on optimizing food supply while restricting non-food biomass consumption. If these policies were successful in reducing demand to sustainable levels, targets for the efficient use of non-food biomass could be established, for instance for reducing waste and promoting cascades or biorefineries (see below).

Over the medium term, and with a more rigorous knowledge base, this orientation value could be established as a global target reference for land use by product consumption. A possible policy tool, tradable land use certificates – akin to emission permits – might be allocated in a fair and appropriate manner between countries in a concerted international effort to achieve fair shares of global land use linked to final consumption of those countries. As it is more realistic that such an international effort, requiring testing before implementation, might take a few decades, countries or regions might implement such market-based instruments domestically first to reduce their own global cropland requirements in preparation for a cap. This would be in line with demands urged by the World Resources Forum[47].

47 *http://www.worldresourcesforum.org/declaration*

3. Adjust existing and implement new strategies and policies

Meeting resource consumption targets will require a combination of political actions across a wide span of governmental branches and departments, addressing both incremental and more structural challenges. It will mean adjusting policy targets, subsidies, and other forms of support, especially for renewable energy and materials, to coincide with levels that can be supplied sustainably.

Considerations of total consumption include both the products that reach end consumers and the resource requirements of those products, in particular land use. That means that there is an opportunity to reduce losses and optimize systems across the entire life cycle, or in other words along the extraction-production-consumption-recycling-disposal chain. This can be accomplished by improving efficiency at each of these phases or by implementing more radical changes, for instance toward greater efficiency in the use of biomass at the systems level or by altering the preferences of consumers.

Table 5.3 provides examples of measures aimed at or synergistic with a more sustainable consumption of biomass and land-based products. For details see the text.

Table 5.3 Potential measures and effects for fostering a more sustainable consumption of biomass products

	MEASURE / ACTION	EFFECT	SOURCE
Food	Reduce meat consumption by around 25% (to a minimum of 70 kg/capita) and decrease the amount of food wasted at retail and household levels by 15-20% in Europe, North America and Oceania by 2030	Save 105 Mha (or a 6% reduction) of cropland and 1,062 Mha of permanent grasslands (or a 29% reduction) compared to FAO reference scenario	Wirsenius et al. 2010b
	Achieve a healthy diet worldwide based on Harvard recommendations by 2050	Save 135 Mha of cropland and 1,360 Mha of pasture compared to business-as-usual scenario	Stehfest et al. 2009
	Implement a GHG weighted tax on animal food products in the EU of €60/tonne $CO_{2\text{-eq}}$	Save 11 Mha of permanent pastures and 4 Mha of cropland	Wirsenius et al. 2010a
	Eliminate avoidable food waste in the UK	Save 5.3 million tonnes of food waste, £12 billion, and 20 million tonnes of CO_{2eq} emissions per year	Wrap 2009
	Reduce food waste and loss to the lowest percentage achieved in any region across the food supply chain globally	Save 78 Mha of cropland and 12 Mt of fertilizer per year	Kummu al. 2012
Fuel	Abolish biofuel targets in the EU	Save 4.1 to 6.9 Mha of indirect land use change	Bowyer 2010
	Reduce fuel consumption of cars by about 30% (corresponding to the envisaged limit of 130 g CO_2 per km) and phase out 1rst-generation biofuels in Germany	Save 500 m^2/capita	Bringezu et al. 2009b
Materials	Reduce use of wood by about 40% until 2030 in Switzerland (related to the reference/BAU scenario in order to align with sustainable NAI of World; BAU will lead to an increase of wood use compared to status quo by about one quarter	Keep Swiss consumption of timber within the global NAI per person	Zah et al. 2010

Food

There is significant potential to reduce land requirements by changing diets in high consuming countries, especially related to the overconsumption of animal-based products like red meat, and by reducing food wastage—in particular after harvest and at the household levels. These land use reductions could simultaneously reduce pressure on biodiversity and reduce nutrient inputs.

Wide disparities in food consumption exist across the world; nearly 1 billion people are malnourished, making food access and availability one of the most serious challenges of the 21st century. At the same time, overconsumption of food products, especially of animal-based products with disproportionally high GHG emissions and land and water requirements, results in an over-proportionate use of agricultural land by developed countries. Animal-based food products currently supply about one-third of dietary energy in high-income populations (Powles 2009). In the U.S., for instance, average protein consumption is about twice the nutritionally recommended daily allowance (Bittman 2008). Overconsumption not only leads to enhanced environmental pressures, but also contributes to health problems like cardiovascular disease, osteoporosis, certain types of diabetes and cancer[48].

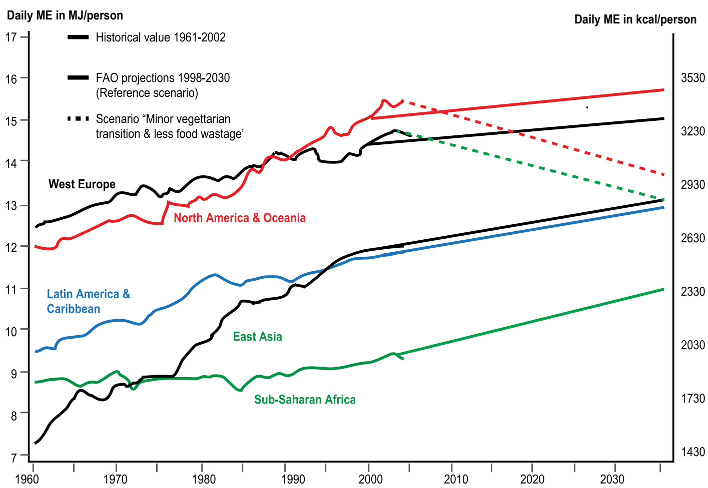
48 Harvard school of health: http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/protein-full-story/index.html

Meat-based diets are more land-intensive than plant-based diets. This is because more land is needed to produce feed for livestock than if people were to eat cereals directly (Odum and Barrett 2004). As an indicative example for Germany, Busch (2008) determined that the consumption of animal-based food per nutrition value (cal) requires a 4.8 times larger land area than the consumption of vegetal food. This makes the overconsumption of meat-based products particularly burdensome. On the other hand, ruminants can digest plants from sparse grasslands which can not be digested by humans, making it possible for both nomad and settled populations in developing countries to secure food supply with extensive grazing.

Overconsumption indicates a significant potential for reduction. For instance, just looking at Europe, North America and Oceania, Wirsenius et al. (2010b) found that around 105 Mha of cropland (or a 6% reduction) and 1,062 Mha of permanent grasslands (or a 29% reduction) could be saved by 2030 if those countries reduced their meat consumption by around 25% (to a minimum of 70 kg/capita) and decreased their food wastage by 15-20% in households and retail, which would contribute to a faster convergence of dietary consumption levels (Figure 5.3)[49].

49 Despite a higher expected consumption of vegetables, fruits and other vegetable food in those regions, the decrease in cropland area due to lower meat consumption and food wastage would still be about 10 times greater than the increase in cropland area related to the vegetables and fruits.

Figure 5.3 Dietary changes in world regions – historical and under different scenarios, 1960 - 2030



Source: Wirsenius et al. 2010b based on historical data from FAOSTAT online database and FAO projections from Bruinsma 2003

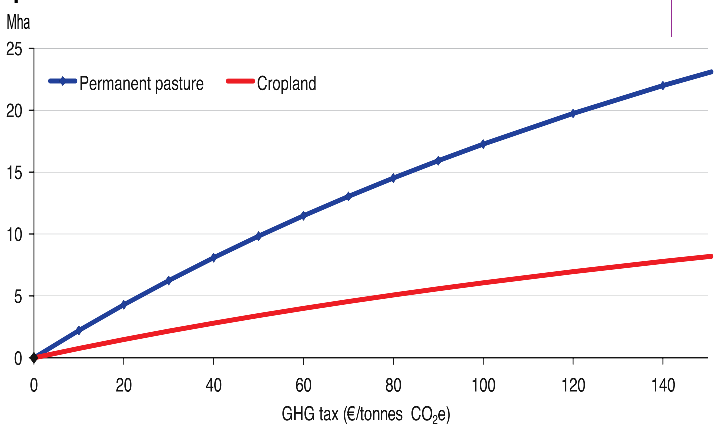
Note: Total food end-use per person for different regions. For scenario 'Minor Vegetarian Transition and Less Food Wastage', values are different from those of the 'Reference' scenario only for the regions West Europe, and North America and Oceania. ME: metabolizable energy. MJ: Megajoule (1 MJ = 239 kcal)

Stehfest et al. (2009) examined the land use saving potential of aligning worldwide meat consumption levels with the dietary recommendations of the Harvard Medical School for Public Health. This is a diet with sparing consumption of ruminant meat and pork—meaning no more than one serving per week—and 1 to 2 servings of fish, poultry and eggs per day. In 2050, worldwide consumption in the healthy diet scenario would comprise approximately 52% of the beef, 35% of the pork and 44% of the poultry/egg consumption of the global average in the reference scenario based on FAO projections (Bruinsma 2003; FAO 2006b). Meeting the requirements of a healthy diet for all world citizens would require 135 Mha less cropland and 1,360 Mha less pasture area than the reference scenario, with about 10% initial CO_2 savings.

The potential to 'save' land by reducing overconsumption appears large; the question is, how to harness and take advantage of this opportunity. Wirsenius et al. (2010a) estimated the effects of a GHG weighted tax on animal food products in the EU. They estimated that 11 Mha of permanent pastures and 4 Mha of cropland could be freed up for alternative uses by implementing a tax corresponding to €60/tonne $CO_{2\text{-eq}}$ (Figure 5.4). Such a tax would increase the price of ruminant meat by 16%, pig by 5%, poultry by 4%, milk by 9% and eggs by 5%. In total, modeling revealed that it could decrease food consumption by 1% in energy terms, with the consumption of ruminant meat decreasing by 15%. The consumption of pork and poultry would increase by 1% and 7% respectively. Because 1 tonne of beef cattle meat requires around 3 ha of cropland and 9 ha of permanent pasture, whereas pork and poultry production require less than 1 ha of cropland per tonne, the land use effects of substitution would be considerable. Moreover, for an equal amount of protein, substituting beef with pig meat decreases life cycle GHG emissions by 80%, with chicken meat by 90%, and with beans by 99%. Modeling revealed that a €60/tonne $CO_{2\text{-eq}}$ tax in the EU would also lead to a net reduction of 32 million tonnes $CO_{2\text{-eq}}$, corresponding to 7% of current GHG emissions in EU agriculture. Wirsenius et al. focused on a consumption-based tax, instead of exploring the possible effects of a production tax, because of the larger potential to cost-effectively abate agricultural emissions by lowering consumption. Monitoring emissions at the farm level -- to be able to tax production -- would be prohibitively expensive; the potential for reducing emissions through technical means is limited and biologically inherent differences in GHG emission intensity exist between different food categories. They emphasized that providing information to consumers about the environmental impacts of different types of food, together with such a carbon tax, might result in significantly lower consumption levels[50]. In future research, potential effects on the poor and on different environmental impacts should be assessed.

Choice editing also seems to be an opportunity to help consumers buy healthy or environmental-friendly products. Business may also play an important or leading role here. For instance, in the retail store Walmart consumers may only choose between certified fish species. Hannaford Supermarkets in the U.S. implemented a very successful 'guiding star' programme in which products received 1 to 3 stars depending on their health or nutritional value. The supermarket also changed product placement and shelving strategies, which are critical aspects of 'choice architecture' influencing consumer behavior (Maniates 2010).

Figure 5.4 Potential land use reductions for implementing a GHG weighted tax on animal food products in the EU



and consumer levels whereas more than 40% of food losses in developing countries happen at post harvest and processing levels (Gustavsson et al. 2011).

Per person food waste in industrialized countries is high (almost as high as total net food production in sub-Saharan Africa). Gustavsson et al. (2011) estimate that consumers in Europe and North America waste 95-115

50 See also Leip et al. 2010.

51 Kummu et al. (2012) also estimate that global food losses correspond to 28 Mt of fertilizer (or around 23% of fertilizer used annually). Their analysis is based on data from Gustavsson et al. (2011).

kg/year, compared to 6-11 kg/year wasted by consumers in sub-Saharan African and South/Southeast Asia. Monier et al. (2010) estimate that around 90 Mt (179 kg per capita) of food are wasted in the EU annually by households (42%), manufacturing (39%), food services/ catering (14%), and retail/wholesale (5%). This equates to about 170 Mt of CO_{2eq}. Studies from the UK reveal that around one-third of the food purchased is thrown out, leading to an estimated 5.3 Mt of avoidable food waste in the UK every year. This corresponds to an estimated cost of £12 billion per year, or £480 for an average household, with an impact of 20 Mt of CO_{2eq} emissions (Defra 2010; WRAP 2009). Fruit, vegetables and bakery items are the foods most commonly thrown away, and one-quarter of the avoidable food waste is disposed of in its packaging (WRAP 2008). Around 70% (or 5.8 Mt) of food waste in UK is collected by local authorities—mainly in the general bin, but also in food-waste curbside collections—while 1.8 Mt are disposed down the sewer and 0.69 Mt home composted or fed to animals. According to WRAP, anecdotal information suggests that when food-waste collections are introduced, there is a reduction in the amount of food-waste generated. This is not the only benefit of separate food-waste collections; introducing separate bins for food-waste means that this waste can be diverted from landfills and instead used for energetic purposes (see below). In several countries organic waste is no longer allowed to be deposited without prior treatment to reduce carbon content to a minimum (equal to content in incineration ash).

Without policy interventions food waste in the EU is expected to rise to about 126 Mt in 2020 (from about 89 Mt in 2006) based on anticipated EU population growth and increasing affluence (Monier et al. 2010).

While in developed countries wastage occurs mainly in wholesaling, retailing and among consumers, in developing countries most losses occur at the beginning of the food chain. For instance, poor harvesting, transport and storage, especially in hot and humid areas leads to significant losses. According to Lundqvist et al. (2008) in Africa post-harvest losses of food grains are estimated to be about 25% of the total harvest. Gustavsson et al. (2011) emphasize that losses of perishable and fresh foods (fruits and vegetables, roots and tubers) are especially high in agricultural production and postharvest handling and storage in developing countries, also as a result of warm and humid climates. There is a large potential to eliminate unnecessary losses, especially through better knowledge sharing and education in developing countries.

Kummu et al. (2012) estimate that 78 Mha of cropland could be saved in a "minimum loss scenario", or in other words, if the lowest food loss and waste percentages achieved in any region would be achieved globally. In this case, agricultural losses could be reduced by 47% (varying regionally between 25 and 59%) and consumption waste could be reduced by 86% (varying regionally between 0 and 94%). The largest reduction potentials were estimated for North America and Oceania (63%) and Europe (63%) whereas the lowest reduction potential was found for Sub-Saharan Africa (31%).

For developed regions like the EU, Westhoek et al. (2011) showed that a combination of a more healthier diet, less food waste and increased efficiency in livestock production could result in significant reductions of both land requirements and GHG emissions, mainly in the supplying regions outside the EU. Nevertheless, also at a global level, those strategies would help to mitigate the expansion of agricultural land.

The effects on natural resource use and environmental impacts of global and regional food systems will be assessed in a forthcoming report of the International Resource Panel.

Fuel

Biofuel production based on energy crops has significant environmental consequences. Bowyer (2011) calculated that meeting the EU renewable energy targets would cause between 4.1 and 6.9 Mha of indirect land use change, leading to between 80.5 and 167% more GHG emissions than would be the case if the same demand were met through fossil fuel use. This corroborates various other studies showing that first-generation biofuels can exacerbate land use pressures and should be reassessed and replaced with more effective strategies (Leopoldina 2012).

A number of strategies exist to more efficiently and effectively gain energy from biomass. There is considerable potential for using organic waste as a source of supply. Harvest residues from both the field and the forest also provide a limited potential, to the degree that their removal does not lead to nutrient depletion, destabilization of soil aggregates and continued decrease of organic matter. Stationary uses (e.g. combined heat and power, anaerobic digestion, etc.) seem to be more effective ways to generate energy and reduce GHG emissions than use in the transport sector (see Bringezu et al. 2009a).

Policy strategies promoting biogas facilities need to be well-designed to avoid increasing pressure on food crops. Germany has applied feed-in tariffs since 2004 to promote biogas plants. As a result, the number of biogas facilities multiplied, as did the area for growing maize as a biogas feedstock. In 2008, feed-in tariffs were further increased and a bonus was introduced for small-scale plants using a minimum share of 30% manure. Delzeit et al. (2010) estimated that this would still induce an increase of maize area by around 38% to cover a total area of around 2.1 Mha. Although the effects of the EU-wide 10% target would dampen this effect a bit—maize would only expand to 1.8 Mha—the area of oilseeds would increase in Germany by about 33% to cover around 2.3 Mha, mostly at the expense of set-aside land, cereals, and other green fodder. This means that food and fodder would have to be increasingly imported to meet domestic demand.

Even if second-generation biofuels overcome many of the problems associated with first-generation biofuels, land competition may remain a relevant issue. Therefore, the principles of cascading use and carbon recycling should be kept in mind. This means using the ligno-cellulose biomass as a material first, with potentially multiple phases of re-use, before finally recovering the energy content from the resulting waste at the end of its lifecycle (see also Bringezu et al. 2009a). In this way, competition with land, but also with traditional forest industries, would be reduced.

Strategies may also focus on reducing fuel demand. The National Academy of Science in the US estimated that energy efficiency improvements in buildings, transport and industry could reduce US energy demand by 30% by 2030, using technologies currently available or expected in the next decade (NAS 2010). In the EU energy efficiency has already improved by 13% between 1996 and 2007 saving 160 Mtoe (ADEME 2009). Eichhammer et al. (2009) estimated that savings of 405 Mtoe (equivalent to the entire consumption of primary energy in Romania in 2007) are possible in the EU by 2030. In developing countries, applying energy efficiency strategies in the build-up of infrastructure provides an opportunity to leapfrog development. For instance, the energy consumption in both new and existing buildings worldwide can be cut by an estimated 30 - 80 % with commercially available technologies and at a net profit during the life-span of the building (UNEP 2009a). The Expert Group on Energy Efficiency (2007) estimated that doubling global energy efficiency could reduce consumer energy bills worth US$500 billion annually by 2030.

Materials

Before embarking on a policy agenda to stimulate bio-based products and biomaterials, governments need to consider how much land they already use, give priority to food and outline how much land would be available – in proportion to world land capacities – for non-food biomass consumption. When land use requirements meet land use targets, governments may reflect on ways to effectively use the sustainability corridor for non-food biomass. Biomaterials offer in general a double dividend compared to biofuels; they can be used as a material first and also recycled several times before the residues may be used for energy recovery (e.g. Weiß et al. 2003-2004).

Waste management facilities might increasingly integrate functions of biorefineries. They may receive all organic waste, including end-of-life plastic products, to recycle organic compounds into new carbon-based materials and plastics. They may also determine which products have met their end-of-life to be recycled, using gasification to deliver syngas from some waste streams and fermentation to produce biogas from others. Ultimately, future technologies like carbon recycling, in combination with carbon capture and re-use strategies, might serve to ease land use pressure by establishing better recycling opportunities.[52]

4. Learn from effectiveness and evaluation

Adjusting policies to steer consumption toward sustainable levels is crucial. It is also critical to learn how successful different policy actions were and whether they induced any unintended side-effects. For this reason, policies may undergo ex-post evaluation[53].

52 For visions of a balanced bio-economy leading to a "bioniconomy" see Bringezu 2009.

53 Note that it is also important to put political proposals through the process of ex-ante impact assessment; see for instance the United Nations Development Programme's virtual resource on-line--http://europeandcis.undp.org/pia

It is also important that countries or regions share experiences with each other.

Interim conclusions

The challenge for policy change is enormous. A mix of strategies and measures will be necessary to reduce overconsumption of food and non-food biomass products and to improve land management. Table 5.4 summarizes the potential 'land savings' for some key measures discussed in this chapter: enhancing vegetal diets in high meat-consuming regions, reducing food waste and food losses, scaling back biofuel quotas, controlling biomaterial consumption, improving land use planning and investing in the regeneration of soils. Combined, these measures could realistically save around 160 to 320 Mha. The largest potential savings are possible by reducing the overconsumption of food and decreasing food waste. Indeed, these savings would even be high enough to compensate for the expected BAU expansion to meet growing food demand (in the low range) in 2050. If maximum savings were achieved in the areas of food, biofuels and biomaterials, and BAU expansion stayed in the low range, the cropland area needed for supplying consumption could even decrease (-36 Mha) by 2050. However, the continued displacement for built-up areas and degradation, despite saving measures, would still result in a gross expansion of at least 120 Mha. In general, implementing measures to reduce demand would result in a remaining expansion (net) of around 3 to 260 Mha in 2050 and better land use planning and soil regeneration would reduce the loss of cropland and the need for displacement by around 40 to 90 Mha. When considering the widest realistic range, the remaining gross expansion would range from around 120 to 570 Mha, or an additional 8 to 37% of global cropland area in 2050. The lower range would keep the development within the safe operating space (see section 4.2.1).

It should again be noted that these estimates are based on literature sources assessing expected land requirements of individual components, not taking systemic interactions into account. Dynamic modeling is an area in need of further research.

Table 5.4 Expansion of global cropland from 2005 to 2050 under BAU conditions and possible savings of reduced consumption and improved land management (Mha)

BUSINESS-AS-USUAL EXPANSION				POTENTIAL SAVINGS				REMAINING EXPANSION	
	Low estimate	High estimate	Sources	Measures	Low estimate	High estimate	Source	Low estimate	High estimate
Food supply	71	300	Based on Bruinsma 2009, RFA 2008, Bringezu et al. 2009a	Improving diet and reducing waste	96	135	Low: Wirsenius et al. 2010b: 6% (of 1530 Mha + 71 Mha); High: Stehfest et al. 2009	-25 (-64)	165 (204)
Biofuel supply	48	80	Based on Fischer 2009, IEA 2011	Halving biofuel targets	24	40		24	40
Biomaterial supply	4	115	Based on Colwill et al. 2011, Raschka and Carus 2012	Controlling biomaterials demand	0	57	High value halved	4	58
Net expansion	**123**	**495**		**Saving range**	**120**	**232**	**Remaining expansion:**	**3 (-36)**	**263 (302)**
Compensation for built environment	107	129	Based on Electris et al. 2009	Land use planning	11	13	10% avoidance of building on fertile cropland	96	116
Compensation for soil degradation	90	225	Based on Scherr 1999	Investment programmes to regenerate degraded soils	30	74	Restoration of 1/3 of degraded and abandoned land	60	151
Gross expansion	**320**	**849**		**Saving range**	**161**	**319**	**Remaining expansion:**	**159 (120)**	**530 (569)**

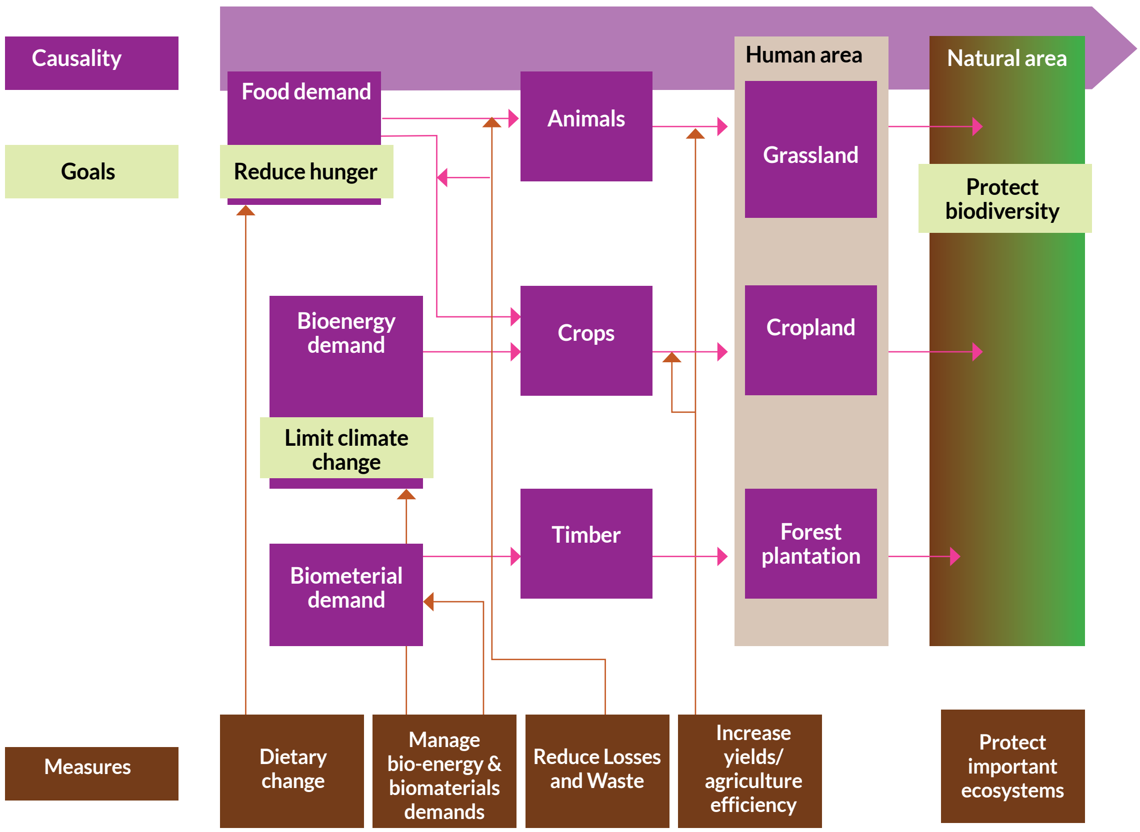
Note: numbers in parenthesis refer to the best and worse cases for food (lowest BAU expansion with maximum savings and highest BAU expansion with minimum savings). Food supply is the only "scenario" in which high and low savings can be switched as the other potential savings are dependent on the scale of BAU expansion. Cropland in 2005 covered around 1,536 Mha.

5.3 Policy options

Across a short, medium and long-term perspective effective management of natural resources will require synergistic actions across the various levels of governance. Securing sustainable supply of food and fibre, partially also fuels, while making the best use of, protecting and enhancing the natural resource base requires a policy design that fosters cross-level synergies and supports dynamic learning processes. This report focuses on governance at the national or federal level highlighting a few key issues towards sustainable land use with successful examples from across the globe.

A major message of this report is that it is possible to reach the overarching global policy goals of reducing hunger, limiting climate change and protecting biodiversity in an integrated manner (Figure 5.5). For that purpose, two major complementary strategies should be pursued in parallel: (1) improve stewardship and management of each square meter, including decisions on its optimal use (leading to increased yields or protected areas, etc.), and (2) keep the level of production and consumption within the limits of a safe operating space. Policies have already been developed with regard to the first strategy, whereas consideration of the second is still in its infancy.

Figure 5.5 Scheme of major causes of land use change, overarching policy goals and complementary measures



Source: Adapted from Van Vuuren and Faber 2009

In general, three elements are necessary for a more sustainable resource management at all levels of governance: (1) better information, (2) better (long-term) orientation, and (3) incentives for actors to take action. Involving all relevant policy sectors is important. The challenge goes beyond just agriculture and forestry; it integrates relevant ministries such as economy, infrastructure, natural resources, energy, transport, manufacturing, consumers, health and family planning, as well as climate protection and nature conservation.

A key problem arises from the linkage of food and fuel markets. Because biofuels are derived from cropland, rising petroleum prices - against the background of trends described in Chapters 2 and 3 - will inevitably also drive food prices. Without policy adjustment the distortion of markets will increasingly burden poorer people, in some regions leading to spreading hunger. Past experience shows that intolerable price increases for food may cause riots and socio-political disturbances. With international food markets becoming increasingly targeted by speculation, the rent-seeking interest on financial markets indicates the growing pressure on prices for biomass and land.

Consequently, decoupling fuel and food markets seems to be a key component of sustainable resource management. This may be achieved by avoiding a direct or indirect competition between food and fuel for cropland. In particular, countries could phase out direct and indirect subsidies for the production or consumption of first-generation biofuels. Such a measure, when enacted on a large scale, might significantly enhance global food security. This represents a straightforward measure with the potential for achieving considerable progress; many of the other challenges facing policy makers in the 21st Century will probably require a bundle of measures and more time.

5.3.1 Capacity building at the farm level

Best management practices at the farm level require consideration of a number of aspects, including integrated management of soil, water and agrobiodiversity, adequate crop choice and cultivation techniques (see also section 5.1). A perspective to secure long-term productivity of the area, also by making use of agro-ecological principles, is key. Improved know-how and monitoring is often essential. In particular, monitoring physical and economic inputs and outputs, including nutrient balances, are important instruments for improved management. In regions where farmers do not have the capacities to monitor these key parameters themselves, they may be supported by technical advisors from regional governments, cooperatives or agriculture research centers. Capacity building in developing and transition countries is a key prerequisite for improving food security, local livelihoods and environmental quality. Governments can monitor the degree to which farmers apply nutrient balances and also the outcome of such measures, such as environmental quality in rural areas (e.g. nutritional status of water bodies).

Box 4. Institutions for Capacity Building of Farmers

Programmes, institutions and projects for capacity building have been successfully established across the globe. The World Agroforestry Centre has a training unit in Nairobi[54] dedicated to capacity building and further training centers exist in various world regions, e.g. North America[55]. Projects to raise awareness and build capacity for the challenges facing agriculture caused by a changing climate have recently emerged, especially in Africa. For instance the project Strengthening local agricultural innovation systems in less favored areas of Tanzania and Malawi to adapt to the challenges and opportunities arising from climate change and variability[56] has confirmed the importance of learning plots and "networking" (Majule 2011). Organized efforts aiding farmers, especially small-holders in developing countries, to reduce losses from pests and disease have been established in 14 countries in the form of 147 "plant clinics", so far. Plant clinics are set up in local meeting places, like a market, giving local farmers the opportunity to bring a problem sample crop to get advice for treatment from "plant doctors", often locally trained experts. In Bolivia, nearly 7,000 farmers made over 9,000 visits to 9 clinics between 2000 and 2009 with overwhelmingly positive results. Based on a survey, Boa and Bentley (2009) estimated net income changes averaging $801 per hectare for farmers visiting plant clinics. Plant clinics not only aid farmers to reduce losses, but may also act as an early warning system for new diseases. A database is freely available online with diagnostic support[57]. In Central America, Campesino a Campesino (Farmer to Farmer Network) is helping peasants to implement better agricultural practices (Altieri and Toledo 2011). A recent study of Machin-Sosa et al. 2010 revealed that in less than a decade the active participation of small farmers in the process of technological innovation and dissemination through farmer-to-farmer models that focus on sharing experiences, strengthening local research and problem-solving capacities has produced a major impact (Altieri and Toledo 2011). Communication is key to the success of such programmes, which policy might support in the form of radio advertising and education.

54 *http://www.worldagroforestrycentre.org/learning/overview*

55 *http://www.centerforagroforestry.org/pubs/training/index.php*

56 *http://www.ccaa-agrictama.or.tz/*

57 *http://www.plantwise.org*

National projects may also target sustainability practices at the farm level. For instance in Paraguay the Sustainable Natural Resources Management Project, executed by the Ministry of Livestock and Agriculture, targets improved farming techniques for peasant family farming. The project transfers financial incentives to Farmers Committees, which are organized to introduce sustainable forest and land management practices such as direct harvest, green manure and crop rotation in small estates. The project has enhanced household income, reduced the risk of erosion and improved soil quality. Prior to the project, 78% of farmers harvested less than 1,000 kg/ha of corn; since project implementation in 2007, 52% of farmers are harvesting more than 2,000 kg/ha (UNEP-MercoNet 2011).

The setting up of nutrient balances at the farm, partially at the field level, has become state-of-the-art of agricultural management practice in several developed countries and regions. Monitoring of nutrient use may become even more effective when combined with economic incentives. In Finland, in order to get the basic subsidy the farmer has to follow the criteria set for maximum fertilizer rates depending on the plant and soil type and soil fertility analysis. For the specific environmental subsidy, the fertilization rate has to be based on actual nutrient balance.

Through the Sustainable Agriculture Initiative some of the world's largest agrifood companies have created an integrated platform for sharing best practices[58]. It aims to gather, develop and share knowledge on sustainable agriculture for mainstream agricultural practices. Working groups focus on developing principles and practices for sustainable agriculture as well as practical tools for farmers. Unilever has developed the "Cool Farm Tool", which is an open-access greenhouse gas calculator that should enable farmer and supply chain managers to find practical ways to reduce their agricultural carbon footprint[59].

Beyond "top-down" approaches for capacity building, it is also important to apply a richer understanding of innovation that includes indigenous, local and traditional knowledge. As De Schutter and Vanioqueren (2011) put it, "not all innovations come from experts in white coats in laboratories, and a meaningful participation of smallholders can ensure that progress is made by drawing from the experience and insight of local farmers, and by fostering the engagement by empowering the locals."

For instance, Fortmann and Ballard (2011) emphasized that combining local knowledge with "conventional science" might create better understanding of forests with better practice and policy recommendations. In a case study, local harvesters in the Pacific Northwest, USA, were heavily collaborated with and involved in a project to assess the ecological impacts and sustainability of harvesting salal (an evergreen shrub used in the floral industry and an important non-timber forest product on a commercial scale). Combining local expertise with scientific methods has helped generate sustainable management practices and informed future research. In India—as well as in other developing and developed countries—agroforestry systems may provide a decentralized strategy for sequestering carbon and co-producing food and energy. Agricultural residues and biomass generated in agroforestry systems can contribute to meeting local energy needs in India (Singh and Pandey 2011). Faminow et al. (2001) reported that in Nagaland, India, local technology based on farmer-led testing and implementation has resulted in a rapid spread of agroforestry on lands that otherwise would have been used by traditional farmers for slash and burn agriculture. Success of turning agricultural research knowledge into action on the ground appears to be especially linked to communication and capacity building of locals to innovate (Kristjanson et al. 2009).

The performance criteria for assessing agricultural projects can go beyond classical measures such as yield and labor productivity. A universal set of indicators may provide a strong basis for informed policy making, but policies directed at different levels, different types of farming systems and with different aims may also require specific indicators and present a need for future research (see section 6.4).

For instance, in Argentina, Viglizzo, et al. (2002) implemented a system at a farm level (Agro-Eco Index 2003) measuring sustainable indicators to be

58 *www.saiplatform.org*

59 *http://www.sustainable-living.unilever.com*

implemented in the major production regions (the Pampas) comprising indicators such as total energy consumption, fossil energy efficiency, nitrogen and phosphorous balances, contamination risks with N and P, relative intervention on habitat transformation, carbon stock changes in soils, and greenhouse gas balances.

5.3.2 Supporting resource management in regions and cities

At the river basin level information systems can support farmers, industry and municipalities on the dynamics of water availability, water quality and options for improvement. With 40% of the world's population living in river and lake basins that comprise two or more countries (UN Water 2008), regional approaches and cooperation are critical.

In the EU, the Water Framework Directive distinguishes between 110 river basin districts, 40 of which are transboundary. EU Member States must draw up river basin management plans, closely involving stakeholders, and meet targets for the ecological and chemical status of EU waters by 2015 (EU 2010).

In West Africa, stone barriers built alongside fields can slow water runoff during the rainy season, improving soil moisture, reducing soil erosion and replenishing water. This technique has improved both the water retention capacity of soil (5 to 10 fold) and the biomass yield (10 to 15 times) (ActionAid 2011, Diop 2001).

Helping to make innovative technologies affordable and empowering farmers may also play a large role in conserving water. In Punjab, India local rice farmers using a tensiometer have reported an average of 33% water savings in comparison to control plots. A tensiometer is a device used to measure the moisture content of soil, allowing more precise irrigation.

Nutrient management to prevent nutrient pollution across borders may become a more important political target as more information about nutrient pollution becomes available. Increasing efficiency of nutrient use on the farm is crucial (e.g. through nutrient balances, see above), but also the development of bioremediation strategies such as wetlands, riparian buffers and filter strips that limit nutrient exports from agricultural systems (IAASTD 2009).

Urban farming or gardening is becoming a new trend in bigger cities. School gardens help children learn how food is produced, a knowledge often lacking in cities.

A programme organized by FAO[60] helps cities in developing countries establish urban garden programmes. For instance, in five cities in the Democratic Republic of Congo it supported 20,000 gardeners improving their vegetable production. In Kinshasa, market gardens produce an estimated 80,000 tonnes of vegetables per year, meeting 65% of the city´s needs (FAO 2010).

One of the most influential urban and peri-urban food production programmes is Argentina's ProHuerta INTA (Instituto Nacional de Tecnología Agropecuaria). Since starting in the 1990s, the programme has helped millions of people to produce their own food, and has grown steadily over the years. Today, ProHuerta supports 500,000 urban gardens, 7,000 school gardens and 4,000 community gardens, reaching a population of over 3 million people around the country (ProHuerta INTA 2011).

In developing countries, home gardening is practiced mainly for household consumption, and production in open spaces serves mainly for market sales (FAO 2012b). The predominant produce is fresh leafy vegetables. Due to high productivity home gardens can essentially support poor local livelihoods especially where no mammal husbandry takes place. In many cities, gardening provides little more than a subsistence livelihood. But in some large cities, gardeners' incomes can place them above – even well above – the poverty line.

FAO (2012a) recommends, planning departments in African cities to map the land that is used for market gardening, and research its ownership status and production potential. Suitable areas should be zoned for horti- culture (or combined with compatible uses, such as green belts) and protected from construction. A few African cities have put this in place. The best example is Mozambique, which created "green zones" for horticulture in Maputo and other major cities in the 1980s. Although Maputo has grown exponentially since then, most of its green zones are intact, protected by Maputo City Council. More recently, Kigali has zoned 40 per cent of the city area for urban development, leaving 15,000 ha for agriculture and for wetland protection. Antananarivo's master plan protects vegetable growing areas, and Cape Town, includes horticulture in land use plans. In Mali, the government has reserved 100 ha of land in Bamako, for market gardens.

60 *Growing Greener cities; Urban and Peri-Urba Horticulture, http://www.fao.org/ag/agp/greenercities/en/projects/index.html*

While urban gardening can be valuable for supplying local livelihoods, in particular in developing countries, and reconnecting people in developed countries to the origins of their food, the potential of urban farming to fulfill the complete dietary requirements of city dwellers is limited. Available figures for cities in the U.S., Europe and developing countries show a range between 1 and 11 m^2 per person (Table 5.5). This compares with a global average area of cropland of 2300 m^2 per person (2007; FAOSTAT online database) and the worldwide cropland required for EU's consumption of 3100 m^2/person (Bringezu et al. 2012). The data clearly indicate that the space available in cities would not allow to secure supply by open field gardening[61].

61 *A different approach would be vertical farming. The pilot considerations as described by Despommier (2010) represent high-tech installations which require high-level expertise, large investments and further research; they may be expected to be tested in rich cities first, and they might not be implemented at larger scales before the issue of artificial lighting can be solved with future highly energy efficient technology.*

Table 5.5 Urban gardens in various parts of the world with area estimates

CITY	URBAN GARDEN AREA (m^2/person)	TYPE OF AREA	SOURCE
Shanghai	1.15	Green space	Yi-Zhong and Zhangen 2003
Mumbai	1.95	Open Space	Minhas 2010[62]
Lagos	2.44	Area suitable for market gardening	FAO 2012a
New York	4	Open space and roofs	Ackermann 2012
London, Elephant and Castle district	5.25	Potential area	Peduto and Satdinova 2009
Oakland	11.5	Potential area	McClintock and Cooper 2009

62 *Minhas, G. (2010). Only 1.95 sqm per person open space available in Mumbai: Concerns expressed at ORF roundtable in Mumbai. Governance Now. Available at: http://www.governancenow.com/news/regular-story/only-195-sqm-person-open-space-available-mumbai*

Nevertheless, there are numerous options to use the greening of open spaces, facades, roofs, etc. in cities for designing a beautiful living environment, contributing to cooling of hot surfaces, fostering awareness of food origins, including seasonal variations, contributing to poor peoples' nourishment, and increasing resilience capacity in the course of climate change (Dubbeling et al. 2012). As historical evidence suggests for the growth of cities, home gardening and commercial horticulture like other activities with low rent per unit of area will be driven to the periphery by economic competition. City planning will have to find a balance between more compact settlement structure with lower internal traffic and higher supply from outside, or vice versa, a wider spread structure with higher internal traffic and lower supply from outside. Because cities need some green spaces for various reasons, green belts should be foreseen which can be used for leisure parks and/or horticulture.

Manufacturers informing retailers and consumers on the sound origin of their products

The demand for products which are produced in an environmentally and socially responsible manner is growing. As a consequence, product labeling and certification is playing a more relevant role toward informing industry and households about the "greenness" of their products, including the conditions of cultivation and harvest in the fields and forests where the raw materials and final products are extracted and produced. However, labeling and certification is usually applied only in selected market segments. Moreover, it cannot control the overall demand of products and the resulting level of global resource consumption (see section 5.2).

The Forest Stewardship Council (FSC) is an independent, non-governmental and not-for-profit organization that promotes the responsible management of world forests through certification. Since its establishment in 1993 the area of certified hectares has steadily increased to reach nearly 145 Mha. Fairtrade has become one of the most visible certification labels, with sales of Fairtrade certified products growing by 15% between 2008-2009. Fairtrade International estimates that around 6 million people directly benefit from Fairtrade. Fairtrade seeks greater equity in international trade by offering better trading conditions to marginalized producers, thereby supporting small-scale farmers and workers.

5.3.3 Setting the framework for resource management by countries

Monitoring is the first step towards sustainable resource management. A wide range of issues, from reducing food waste to family planning programmes, are relevant to sustaining land use and securing food supply.

Increasing sustainable production through an understanding of resource potential

Improving land management depends on an understanding of (a) what type and level of sustainable production is *possible*, and (b) what is *realistic* (Herrick et al. 2006). What is possible depends on climate and relatively static topographic and soil properties, including slope, aspect, and soil depth, texture and mineralogy. What is realistic depends on the availability of external inputs, the availability and ability to apply local and scientific knowledge of best practices (see Section 5.1), and social, political and economic constraints to how resources are allocated and used. What is realistic across all lands depends on how efficiently resources can be allocated and applied at local to global scales. At each level, individuals and organizations can exploit unrealized potential through the application of existing knowledge, or innovations for increasing resource use efficiency. Two practical steps to unleashing the potential of the land and to maintaining its resilience include (1) improving knowledge of land potential and current status through improved inventory and monitoring and (2) land use planning.

Improving the knowledge base through better inventory and monitoring

Countries can install information systems about their land resource, the extent of major types of land use, and the inventory of the natural endowments (e.g. with regard to biodiversity, soil quality, rain fed conditions). Many countries of the world still lack land registers and detailed mapping procedures. Modern technologies such as remote sensing may help to monitor the actual land cover status (as is for instance practiced in Brazil and the EU). Of particular importance is improved information on the extent and quality of degraded soils in order to assess the options for restoration and ways to sustain productivity of soils.

Soil maps are important for a better management of soils and fertilizers. In South America, Argentina has created a map of soils systems. In North America, The USDA has created a "Web Soil Survey" with soil maps and data available for more than 95% of local counties within the United States. Europe has created a digital archive on soil maps of the world. In 2010 the European Atlas of Soil Biodiversity was published, illustrating the great diversity of life in the soils across Europe. A new initiative, the global digital soil map, is designed to increase access to soil information (Sanchez et al. 2009). The African Soil Information System (AFSIS) project is creating a pixel-scale map for Africa. Although somewhat limited by its focus on soil surface fertility, it will provide a foundation for understanding land potential. Besides monitoring of domestic land use, information on global land use to supply domestic consumption has become increasingly important. Extending existing statistics, global land use accounts can show whether a country is a net exporter or a net importer of land. Net importers may especially consider the potential implications of their dependence on land beyond their borders. Net exporters of land may reflect on their long-term targets of domestic land use, including various options to manage their natural capital. Both may consider how cooperation can be strengthened to increase the efficiency of land use across the production-consumption chain, for instance through knowledge sharing, increased transparency and accountability, and setting common goals (e.g. food first).

Box 5. Monitoring global land use for domestic consumption

The EU plans to further develop a dashboard (key set) of indicators (EC 2011a), as set out in its Roadmap for Resource Efficiency' (EC 2011b). Starting from the narrowly defined headline indicator of material productivity (GDP/DMC) the Commission aims to extend the scope to account also for indirect flows associated with foreign trade. Besides material resources, also indirect land use for agricultural and forestry products, indirect water flows and indirect GHG emissions shall be monitored regularly in the future.

In developing countries, monitoring material flows is starting to become more common. For instance in Latin America, material flow accounts exist for Chile, Colombia, Ecuador, Peru and Mexico (UNEP-MercoNet 2011). UNIDO has launched a programme on "Green Industry for a Low-Carbon Future" in order to support green industrial growth in the developing world, where pilot studies on comparative and quantitative assessment of resource consumption and resource efficiency have been performed for Asian countries (Giljum et al. 2010) and in selected emerging economies (Giljum et al. 2011). Land use and the environmental impact of agriculture and livestock production are key issues in Latin America, especially because of the structural change in the region since the 2000s, which is increasing the role of primary goods in exports and making external market growth largely dependent on natural resources. For this reason, improving environmental statistics, especially toward accurate measurement of external costs of environmental degradation, is crucial for both informed policy making and motivating a more efficient use of natural resources in productive sectors (UNEP-MercoNet 2011). Information on national and regional nutrients balances and international trade can also be provided. A "virtual soils balance" (Pengue 2009a and 2009b), similar to "virtual water" (Hoeckstra 2003), could help to better understand the flows in a global context within a life-cycle perspective.

Land use planning

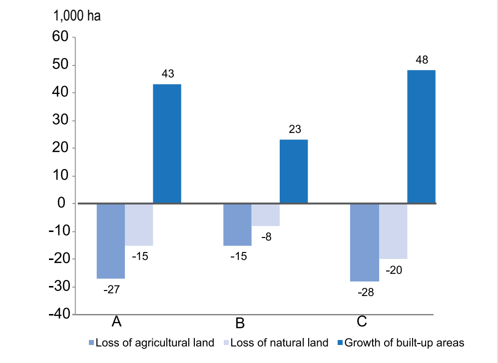
Land use planning may be one of the most relevant policy actions for agriculture and livestock on the "production side", especially introducing territorial development in developing countries (UNEP-MercoNet 2011). Implementation of land use plans can be supported through a variety of mechanisms, including education, government incentives, and regulations. In the U.S., land use planning tends to be enforced through regulation in urban areas. In rural areas, it is more flexibly supported through incentives that encourage, for example, wetland conservation and the use of best management practices on highly erodible lands.

Land use planning can also be used to define high priority areas for nature conservation. This helps to prevent the loss of high-value nature areas due to expanding agriculture and livestock production, if properly enforced. For instance, both agro-ecological zoning and economic-ecological zoning in Brazil help to prevent deforestation in the Amazon. While domestic land use planning is a traditional and valuable instrument on the production side, the effectiveness of such programmes depends on demand for agricultural products. If demand is not mitigated towards levels of sustainable supply, conservation areas will become more and more subject to conversion and/or illegal harvesting activities. Without consideration of demand, land use planning policies (like set-aside areas) may also induce imports, raising the risk of problem shifting. Assessing the intensification of agriculture and its related land demands in 161 countries, Rudel et al. (2009) found that countries which enacted conservation set-aside policies increased their per person cereal imports by 42% between 1990 and 2004 compared to a 3.5% increase in countries which did not enact set-aside policies.

Box 6. Land use scenarios for the Madrid region

Three land use scenarios identified for the region of Madrid describe alternative development paths that form the basis for decisions facing the city planners in delivering a more sustainable Madrid (Figure 5.6). The alternatives include urban regional development paths based on the idea of competitiveness and free market forces (business-as-usual and scattered scenarios), contrasting with a development path where competitiveness has been assumed in a more environmentally and socially sustainable way through integrated planning and engagement with stakeholders (compact development scenario)

Figure 5.6 Land use changes under different scenarios for the Madrid region, 2000-2020



Source: EEA 2006b based on MOLAND. Graph design reworked and numbers subject to rounding.

Programmes for economy-wide sustainable resource management

Anticipating growing global constraints and opportunities for their economies, a few countries have started *programmes for economy-wide sustainable resource management*. The intention of such programmes is to integrate supply security (for food and raw materials) with climate and resource conservation while fostering economic competitiveness. Such programmes may be regarded as cornerstones of national sustainability programmes. A key strategy is the increase of resource productivity, i.e. the enhanced decoupling of resource use and economic growth. The implementation of such programmes may focus on the increase of material and energy efficiency in industries, transport and households supported by a bundle of instruments. Whereas these programmes just recently started in a few developed countries, they correspond to the global long-term trend of economies becoming more and more efficient in the use of natural resources. This corresponds to an increasing independence from resource supply and is a tendency which is likely to become important for developing countries as well.

In Germany, a Resource Efficiency Programme (ProgRess) was adopted by the government. It stresses the importance of analyzing material flows in order to identify potentials for improving resource efficiency across the life-cycle of raw materials and products as well as to identify the potential for recycling (BMU 2011). The EU Roadmap to a Resource-Efficient Europe considers biomass and mineral use for all purposes; it builds a bridge between economy and ecology and aims at the development of comprehensive indicators to account for domestic and foreign resource use (materials, land). It kicks-off the discussion about targets for long-term orientation (with a vision for 2050) in the policy sphere and intends to minimize problem shifting (between regions, different pressures, or over time). In Finland the Natural Resources report submitted to Parliament by the Finnish Government (2011) sets the natural resources vision for 2050. According to this vision natural resources should be utilized within limitations defined by biocapacity and the need to ensure sustainability and safeguard biodiversity and ecosystem services. Finland must strive to further decouple natural resource use from economic growth and greenhouse gas emissions.

In the forthcoming debate on these programmes, if countries such as those of the European Union with net consumption beyond the global average for cropland or with significant nutrient imbalances wish to lower their global footprint, they may revisit instruments which foster consumption of land based products, e.g. redefine biofuel quotas towards maximum values instead of minimum values.

Energy policies will need to be harmonized with resource policies. A major concern is that energy policies are at times formed with limited understanding of the system perspectives, including land and water. For example, the 70 Mt CO_2 emission reductions estimated to occur as a result of the EU biofuels target could be dwarfed by the 270 Mt CO_2 that has been calculated to come from the related land use change (Croezen et al. 2010; IEEP 2011).

Options for bioenergy project deployment may be linked to improvement of agricultural management and rural development. Locally increased crop productivity could offset increases in the land area required for biomass production (however, the demand for food continues to grow globally and overall effects of yield improvements are uncertain; see Section 3.1). There can be both positive and negative social consequences of bioenergy projects at the local level (e.g. SRREN 2011a).

In practice this is challenging and the results uncertain. If marginal land can be made to produce crops cost efficiently, then why not grow food crops? However, there are several non-food crops with special properties such as drought tolerance or resistance to salinity, heavy metals etc. that might grow where food crops will not. If they can be realized in practice, the global potential of these options could be significant (Cai et al. 2011) such as perennial low-input cropping systems that have been claimed could be grown even on degraded land (Wicke 2011). However, in order to grow commercial yields also sturdy plants like Jatropha will need adequate fertilization and irrigation (De Fraiture and Berndes 2009). Since marginal lands tend to be in more remote areas, bringing the harvested energy carriers to the location of the energy demand can be a logistical and economic problem. Once large-scale energy cropping is proved viable, commercial enterprises tend to move in and the small-scale farmers are disenfranchised. In any case, if marginal land is brought into cultivation this will expand total cropland.

Box 7. Sustainable Biomass Action Programmes

Policies need to effectively address the driving forces of resource consumption. Because products grown on agricultural land are diverse, policies addressing land consumption may also be spread among many divisions and departments. One way to harmonize and integrate renewable energy and biomaterials policies could be the development of sustainable biomass action programmes – embedded in economy-wide sustainable resource management schemes.

Sustainable biomass action programmes could undertake a number of responsibilities; primarily focused on activating, implementing and co-ordinating the steps of the transition cycle for sustainable land use. This would involve a) monitoring domestic and global land use for national consumption; b) proposing binding land use targets, facilitating stakeholder conferences on biomass prioritization, and collaborating on international efforts to establish a land use target; c) advising policy on effective strategies for steering consumption; d) evaluating policy effectiveness.

Use of economic instruments to trigger sustainable supply and demand

In many world regions with an ample supply of food, agriculture is heavily subsidized. One side-effect is "international dumping" of overproduction, causing exports to squeeze local markets in developing countries. Instead, subsidies could be used, for a limited period, to trigger food production in regions with scarce food supply and to combine this with the fostering of best operating practices. As suggested by Garrity et al. (2010) an optimal solution could be a "subsidy to sustainability" approach: an exit strategy from pure fertilizer subsidy schemes that would link directly to investments on the farm to provide long-term nutrient supply, enhance soil health for sustained yields and improve efficiency in fertilizer use.

In Malawi, after a drought in 2004-2005 leaving many starving, the government launched a programme to subsidize fertilizer and maize seeds; this subsidization programme helped Malawi to nearly double corn harvest within two years. In 2007 Malawi launched an Agroforestry Food Security Programme to promote the uptake of nitrogen-fixing trees that now involves at least 200,000 families. This may foster a gradual shift of investments from fertilizer subsidies to sustainable on-farm fertility regeneration (Garrity et al. 2010). An agro-ecology systems approach is important to keep in mind for such initiatives (see section 5.1) to avoid unintended side effects (e.g. some exotic nitrogen-fixing trees species could lead to invasive species problems).

Economic instruments may also be used to incentivize a more sustainable management in forestry. For instance, a stumpage fee for each tree cut - instead of licensing the cut of a certain area – may be used to support selective cutting instead of clear-cutting. Per tree stumpage fees have been used for instance for valuable hardwoods in North America and Europe (FAO 2001). In other regions, like in the remote forests of the Congo Basin, logging is very selective for commercially high-value species, but many trees are destroyed to get access to and extract those species. Increasing the tax rate on high value species and lowering the tax rate on others may promote a more balanced harvest of species. Designing and implementing fiscal incentives together with regulatory instruments may heighten the effectiveness of such approaches (Karsenty 2010).

Ample experiences with raising the price of natural resources exist with water. Managing water prices to promote a more efficient water use can be found across the globe. For instance in the Paraiba do Sul River Watershed in South-East Brazil gradual price increases of water use started in 2003. Raised prices not only provided a progressive increase of income that could be invested into the watershed, but also triggered water conservation—water extraction was reduced by 16% and consumption by 29% between 2006 and 2008—and motivated companies to invest in water re-use technologies and processes (UNEP-MercoNet 2011). Further instruments toward conserving water are described in the forthcoming IRP report on water.

Financial incentives tied to sustainability criteria may promote best management practices. For instance an agriculture goods exportation tax in Argentina is currently applied to all exports such as soybean, maize, wheat, and sunflower and to all farmers. A policy option would be to differentiate between large and small farmers, sustainable and unsustainable farming, farmers who carry out soil management practices and farmers who do not, etc. The tax could be reduced, or even null, for farms which manage their soil resource in a sustainable way by following territorial planning legislation, avoiding soil erosion through conservation tillage and soil protection structures. The EU couples at least part of its agricultural subsidies to the compliance with environmental performance criteria, especially agri-environment measures. These are payments to farmers who subscribe on a voluntary basis to environmental commitments for preserving the environment and maintaining the countryside; between 2007 and 2013 EU expenditure on agri-environment measures amounted to nearly 20 billion Euro, or 22% of the expenditure for rural development. Although there has been much criticism of agro-environment schemes, there are also some cases of success, which can be learned from. Including stakeholders in the design of targeted schemes with careful management advice can yield substantial benefits for farmland biodiversity, and the potential to combine agri-environment schemes with the provision of ecological services might be a good way forward (Whittingham 2011).

Microfinance and microcredit integrating sustainability criteria might present a key alternative strategy for many developing countries, with benefits for small-scale agricultural systems in particular.

Improved targeting of public investments

In order to enhance food security and living conditions in rural areas, de Schutter and Vanioqueren (2011) strongly call for better targeting of public investments. The authors emphasize that the efforts should focus on the needs of smallholders. Investments are necessary in many rural regions of the world - in particular those where yields have been staggering over decades and in the hunger regions of Africa and South Asia. Investments may be directed to support, for example, extension services that can teach farmers - often women - about agroecological practices; improved storage facilities, rural infrastructure (roads, electricity, and ICT) for access to local markets; credit and insurance against weather-related risks; agricultural research and development; education; and the establishment and management of farmers´

organizations and cooperatives. De Schutter and Vanioqueren argue that public investment can be significantly more sustainable than the provision of private goods, such as fertilizers or pesticides that farmers can only afford so long as they are subsidized, a circumstance also criticized by World Bank economists (Byerlee et al. 2009, World Bank 2008b).

Switching public resources from subsidies for private goods to expenditures on public goods may be an effective instrument for promoting higher per person income in agriculture. Lopez and Galinato (2007) distinguished government subsidies for private goods (e.g. commodity-specific or focalized expenditures like irrigation) from expenditures on public goods (e.g. technology generation and transfer, soil conservation, infrastructure, information services, etc.) in 15 Latin American countries from 1985-2001. Modeling indicated that, within a fixed natural agricultural budget, a reallocation of 10% of spending to supplying public goods would increase agricultural per person income by 5%; reducing the proportion of subsidies in total public expenditures from 50% to 40% would, all other factors held constant, lead to a reduction of agricultural land area of more than 2%. In other words, governments may be able to improve the economic performance of their agricultural sectors without even changing overall expenditures, by redirecting a greater share of those expenditures to social services and public goods instead of private goods (Hunt et al. 2006).

Increasing legal safety for land users

Land tenure and ownership are important prerequisites for motivating people to invest in maintaining and improving their land and soil resources.

Box 8. Land tenure requires enabling and controlling institutions

Decollectivization and land titling in Vietnam have generated powerful incentives to invest in agriculture, however not all development has been positive. On the one hand, more secure property rights have motivated farmers to adopt agroforesty and other anti-erosion measures. Productivity has increased significantly, and poverty has been reduced. On the other hand, privatization has endangered "the commons" and put fragile lands at risk, for example in cases where land reform allocates rural wetlands to households who then convert them to farmland or aquaculture. Lessons from land tenure reform in Vietnam stress the importance of combining tenure security with interlinked components such as agricultural product markets, as well as the important role of local governance towards supporting and enabling tenure reforms or hindering them (Kirk and Do Anh Tuan 2009).

In light of the growing trend of large-scale land acquisition (see section 2.5), clarifying and respecting land and people rights have become especially important for both local land users and investors. This is happening all over the world in developed (Condon 2011) and developing countries. Before large-scale land investment occurs, proper consultation and participation with local land users seems critical, both to establish existing rights to land that may be based on indigenous agreements and not modern law and, if desirable, to work out the details of the land acquisition in a transparent and engaging environment under consideration of national law and international agreements. When larger areas are going to be sold to foreign investors some key requirements in the contracts may help to provide a sufficient benefit for local communities. Ensuring that those key requirements for locals are met requires monitoring, regulatory enforcement capacities and making sure that locals have a voice to express cases of abuse. However, legal ownership alone may not suffice to protect small holders from powerful buyers; thus countries may foresee guidelines and effective protection measures. The FAO "Voluntary Guidelines for the Governance of Tenure of Land, Fisheries and Forests" (see Section 2.5) may be used to support governments in developing guidelines, laws and effective protection measures for establishing land tenure and promoting responsible investment.

Reducing food waste

One-third of agricultural production is wasted worldwide (Gustavsson et al. 2011). A lot of natural resources, land, nutrients (e.g. from fertilizer), and energy could be saved by reducing food loss. If global food losses and waste were halved by 2025, almost one billion more people could be fed (Kummu et al. 2012). National and regional governments can design programmes to detect and minimize post harvest losses and wastage of food along the manufacturing, transport, retail and household chain. Altogether efficiency from the field to the fork can be drastically improved.

High levels of food loss at the production and harvest stage, especially in developing countries, may be countered by investing in infrastructure, encouraging the build-up of storage facilities and encouraging co-operatives that can produce at economies-of-scale necessary for gaining credit or advanced payment for crops to discourage farmers in need of cash from harvesting too early (Gustavsson et al. 2011). Better packaging in developing countries may also enable improved food safety and quality to reduce loss (FAO 2011c).

Food banks, a practice born in the United States, and adopted by several countries, centrally collect and distribute food donations to people in need. These food donations often consist of excess food which may be past the expiration date and which would otherwise have been thrown out, for example by supermarkets. Food Bank Networks[63] may not only minimize food waste, but may also be an essential tool for enabling food-access for the poorest people, especially in major cities.

At the household level considerably more food is wasted in industrialized countries than in developing countries; consumers in Europe and North America waste around 10-15 times more food as consumers in Sub-Saharan Africa and South/Southeast Asia (Gustavsson et al. 2011). One reason may be that consumers in "rich" countries can afford to waste food. In this case, education and food waste prevention campaigns, such as WRAP[64] in the UK and the global "Think.Eat.Save"[65] campaign of the Save Food Initiative[66], may be useful policy options.

63 *http://feedingamerica.org/*

64 *http://www.wrap.org.uk/*

65 *http://www.thinkeatsave.org*

66 *http://www.fao.org/save-food/en/*

Making use of agricultural residues and fostering material flow cascades

In general, instead of targeting consumption based on energy crops with biofuel quotas, energy recovery from organic waste and biomass residues should be promoted while considering also the long-term strategy to recycle the carbon content of waste (Bringezu 2009). Incentives might be re-directed toward co-generation or multi-generation technologies processing waste into recycled materials and useful energy (electricity, heat).

Programmes that foster a greater use of residues, after taking into account soil fertility needs, and re-use of biomass may also reduce pressure on land resources.

One use of crop residues in smallholder agricultural systems is as livestock feed. In China, national beef production doubled in just 3 years after implementing the "Animal Production based on Crop Residues" Program (FAO 2002a). India is the largest milk producer worldwide, based primarily on smallholder production using residues (FAO 2006b). The System wide Livestock Programme[67] is building capacity for food-feed systems that increase the nutritional value for both people and animals, and exploring trade-offs between soil fertility and fuels. For instance in West Africa, IITA (2010) assessed different cereal-legume-livestock systems and identified opportunities for improving the productivity of these systems by auditing nutrient flows and calculating nutrient balances at the farm and village-levels. Worldwide, crop residues in current integrated crop-livestock systems may account for as much as 60% of ruminant fodder. The development of second-generation biofuels is raising competition for residues, thereby affecting the biomass availability for animals. This is especially the case in places such as China and India, which lack alternative domestic feed resources and face rising demand (Dixon et al. 2010).

Biochar may be an emerging strategy for using residues to co-generate a fuel (like syngas) and "biochar" (a fine-grained, highly-porous charcoal). Biochar is thought to have water and nutrient retention capacities that increase the fertility of soils and store carbon under ground, thereby helping to mitigate carbon in the atmosphere. Experiments testing its feasibility and sustainability are ongoing (see Box 9).

67 *http://vslp.org/*

Box 9. Carbon sequestration via biomass

IPCC models have shown that to achieve 450 ppm stabilization levels, negative annual CO_2 emissions will be needed towards the end of this century. In effect, CO_2 will have to be removed from the atmosphere. There are several options:

a Reduction of deforestation, desertification and erosion of land would enhance net carbon sinks, representing a significant option for “biogenic” carbon sequestration which might be less costly (and risky) than carbon dioxide capture and storage (CCS), and could be developed in combination with increasing soil carbon levels;

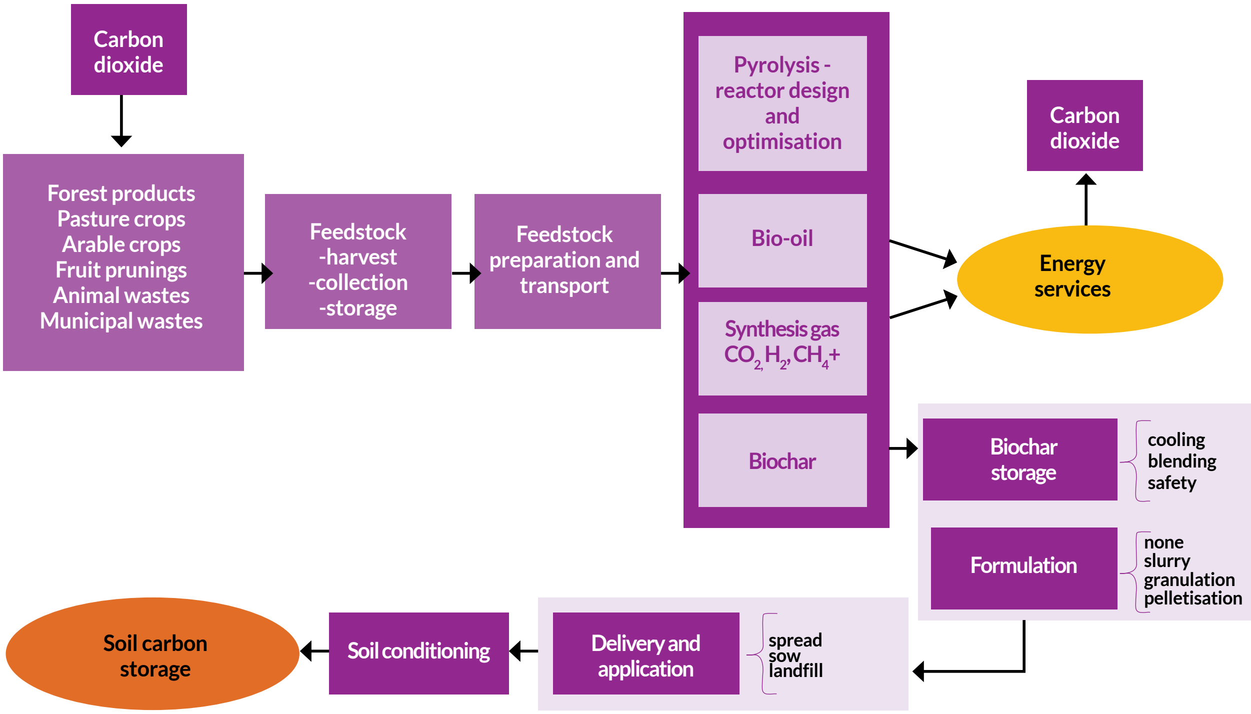
b Linking biomass production and use for energy with CCS technologies: The use of biomass for energy provides the opportunity for reducing atmospheric concentration levels of CO_2, for example, by co-firing woody biomass in a coal-fired plant with CCS. When the land harvested for the biomass is replanted, then additional CO_2 would be absorbed prior to the next harvest, making more carbon ready for sequestering. Capacities for CO_2 storage, however, seem limited and would not suffice for fossil fuel emissions. Mitigation by substituting coal with wood seems more efficient;

c Increasing the levels of carbon in the soils: Biochar (a material similar to charcoal) can be produced from the controlled pyrolysis of biomass, with any gases and bio-oils co-produced used for energy purposes, both to drive the exothermic process as well as to provide useful energy services (Figure 5.7). The subsequent incorporation of biochar into the soil to increase the soil carbon content for long periods of time holds good potential (Woolf et al. 2010). Much research is underway (including at Massey University, New Zealand[68]) to identify the characteristics of various biochars produced from different sustainable feedstocks, including sewage sludge, prunings from fruit trees, plantation forest residues, poultry litter (Chan et al. 2008) etc., all with limited value. Felling indigenous forests is not acceptable since the carbon emissions from deforestation and land use change would more than offset the carbon later sequestered in the soil. Matching various biochar properties with different soil types to maximize the carbon uptake is not yet understood, nor is the potential to enhance crop productivity by improving the soil water holding capacity, recycling of nutrients, stability of biochar in soils, etc. (NSW 2011). In addition, ascertaining the technologies and financial drivers (such as a carbon price) that would be needed to encourage landowners to undertake such a laborious and dirty soil-conditioning process is work-in-progress;

d Carbon sequestration and use (CCU): instead of depositing sequestered carbon in limited caverns or uncertain layers in the earth´s crust it can be used as base material in the form of polymers for various purposes in durable goods (buildings, infrastructures, vehicles, etc.); the technologies for such carbon recycling and storage are available to a large extent, although the use of carbon based polymers (such as carbon fibres) for a growing number of applications still needs to be explored (Bringezu 2009).

68 See www.biochar.co.nz/; www.vti.bund.de/no_cache/en/startseite/institutes/agricultural-climate-research/research-projects/hydrothermal-carbonisation.html; www.bayceer.uni-bayreuth.de/biochar/index.php?lang=en, and www.biochar.org.uk among others for details of research on biochar production and soil analyses.

Figure 5.7 Biochar production and process, supply chain utilization



Source: Compiled for this report by R. Sims and J. Jones, Massey University

Programmes for a more healthy diet in high-consuming countries.

In cases of food overconsumption, promoting a healthy and balanced diet, especially as regards meat products, may help to reduce obesity and land pressure (see also FAO 2012b).

At the national scale, one of the first places this may be evident is in programmes promoting a more healthy diet in schools, for instance by removing vending machines for candy and sugary drinks. In the United States the "Healthy, Hunger-Free Kids Act" of 2010 requires the USDA to establish national nutrition standards for all food sold and served in school at any time during the school day[69]. Efforts are also being made toward promoting locally grown food in schools. In Brazil, 30% of the food served in its national school-feeding programme should stem from family farms (De Schutter 2010). In Finland, a governmental policy programme on the promotion of health sets targets for healthy diets, including the increasing use of vegetables. The Environment Passport for institutional kitchens was developed in Finland in 2011 as part of the campaign promoting Finnish food culture and has been widely adopted already in schools and canteens. It focuses strongly on environmentally friendly diets[70].

Family planning programmes

An effective policy to control human fertility and thus growth of the world population may have a more pronounced impact on future food security than efforts to enhance crop yields. Mitigation of birth rates requires improved education, in particular of

69 http://www.schoolnutrition.org/content.aspx?id=2402

70 http://www.ymparistopassi.fi/doc/Ympristopassi-E.pdf

women. Thus health and education policies can pursue synergistic aims.

Case studies of Family Planning Programmes in 23 developing countries over the period 1970-1995 have revealed positive programme effects, even after controlling for socio-economic conditions. Fertility rates declined in the selected countries from an average of 6.3 births per woman in 1960-65 to an average of 3.1 by 1995 to 2000. While there is not a best programme suited for all — culture and socio-economic situations differ and may require different approaches — many of the programmes that were integrated into existing health agencies were associated with higher levels of success (World Bank 2007). Research from J. Casterline (2011) supports the success of family planning; he estimates that around 44% of the fertility decline in 50 low-income countries between 1975 and 2008 was the result of preventing unwanted births. However, Casterline argues that there is a need to expand programmes, especially in sub-Saharan Africa and South Asia. Around 25% of women in Africa have unmet needs for family planning, meaning that they report not wanting children in the near future, but are not using contraception. In Asia and Latin America rates are around 17-18% (Grabmeier 2011).

Box 10. How to finance these programmes?

It is estimated that consumption-based subsidies for fossil fuels reached $312 billion in 2009[71] (IEA et al. 2010); the Global Subsidies Initiative[72] estimates that around $100 billion are paid to producers worldwide.

In 2009, the G20 agreed to phase out inefficient fossil-fuel subsidies over the medium term, followed by a similar agreement made by the APEC (Asia-Pacific Economic Cooperation) countries. The aim is to particularly cut out subsidies that encourage wasteful consumption. Reducing and partly redirecting these subsidies could not only combine climate and resource conservation, but also might reduce public debts and contribute to the stabilization of financial markets. Triggering innovation towards higher material and energy efficiency and renewable supply, it will reward those industries and regions embarking on this way by increased competitiveness. The IEA, OECD and World Bank Roadmap for phasing-out fossil fuels may help policy makers to implement changes and reallocate savings in a way that could offset potential negative social impacts for the poor (IEA et al. 2010). Indeed, removing and partly redirecting subsidies toward alternative strategies may contribute to food security and improved living conditions in developing and developed countries, enhancing social stability.

Leveraging synergies between agriculture, food security and climate change may also present an opportunity for gaining funding (FAO 2009b). For instance, with a carbon price of $\$20/tCO^2eq$, the IPCC (2007a) estimates that implementation of agricultural mitigation actions from the four main terrestrial categories could generate annual revenues of roughly US$ 30 billion. Experiences in on-going land-based carbon finance projects reveal that agricultural investment can leverage five times its value in carbon revenues (World Bank 2009); there is an opportunity for carbon finance to provide incentives to leverage US$ 150 billion worth of climate smart agricultural investments in developing countries (FAO 2009b).

Besides carbon revenues, payments for ecosystem services may also play an increasing role. UNEP (2010b) reports that appropriate restoration compared to loss of ecosystem services may provide a benefit/cost ratio in the order of 3 -75 and an internal rate of return of 7 to 79 %, providing a good opportunity for public and private investment.

Implementing programmes for a green economy can make use of incentives that value the multi-functional uses of agricultural land and have proven to be effective in improving the after tax revenues for farmers that practice sustainable land management. The OECD countries have developed a wide range of policy measures to address environmental issues in agriculture, which include economic instruments (payments, taxes and charges, market creation, e.g., tradable permits), community-based measures, regulatory measures, and advisory and institutional

71 *In 2008, due to price surges in fossil fuel prices, consumption subsidies are estimated at $558 billion.*

72 *http://www.globalsubsidies.org*

measures (research and development, technical assistance and environmental labeling). Payments for environmental services (PES) can further incentivize efforts to green the agriculture sector. Public policies can reallocate agriculture subsidies and help defray the initial transition costs associated with the adoption of more environmentally friendly agriculture practices. Such incentives could be funded by corresponding reductions of agriculture related subsidies that reduce the costs of agricultural inputs, enabling their excessive use, and so far promote commodity crop support practices that focus on short-term gains rather than sustainable yields (UNEP 2011b). Efforts to further green agricultural subsidies are emerging. For example, the proposal for the new Common Agriculture Policy (CAP) in the EU proposes that 30% of subsidies between 2014 and 2020 should be made conditional upon compliance with mandatory greening measures (e.g. crop diversification, maintaining permanent pastures and grasslands and creating ecologically-focused areas)[73].

5.3.4 Supporting global resource management by international institutions

International institutions can help to increase knowledge and improve the data basis for decision makers. The quality and accuracy of global data on soils quality and land use is poor. Although adequate national and regional databases in several parts of the world exist (USDA, EU, Mercosur), integration of this information to support global analysis is only partial. As a consequence, analyses of global development issues, including climate change, food production and biodiversity, give limited consideration to land and soil information. Hence research efforts on global issues could strive to incorporate soil information, while soil scientists may better target their information to the user needs.

The ISRIC – World Soil Information[74] acts as a coordinating institute for collecting, storing, processing and disseminating global soil and terrain information for research and development of sustainable land use. These activities can be taken only in global consortia and networks including the Global Soil Partnership[75], the GlobalSoilMap.net consortium[76], the IUSS[77] and regional soil networks, while the Global Earth Observation System of Systems[78] serves as a platform to communicate developments in world soil information to policy circles and the general audience.

The annual value of global agricultural production is estimated to be around US$ 2.4 trillion[79]. A fund that invests just 1% of this value (e.g. US$ 24 billion) to restore the degraded soils of the planet is a more attractive alternative to the potentially riskier and more costly venture of finding an additional several hundred Mha of arable land in an increasingly densely populated and ecologically endangered world. The Earth Institute of Columbia University has estimated that globally the protection of topsoil on cropland and the restoration of rangelands would cost about US$24 billion and US$9 billion, respectively (Brown 2011)[80].

In 2011, as food prices reached a record high, also the G20 made price fluctuations a top priority issue. Discussions are ongoing[81]. In order to mitigate price fluctuations, Brown (2011) has suggested the establishment of a World Food Bank (WFB). The WFB would guarantee a minimum and a ceiling price. It would buy when prices are low, and sell when prices increase. Nevertheless, such an institution would not be able to mitigate the average price level from growing due to increasing scarcity. This would require an effective decrease in essential drivers of that scarcity.

The German Scientific Council for Global Environmental Change (WBGU 2010) suggested to establish a Global Commission on Sustainable Land Use in order to step up priority for the matter on the international agenda. The tasks should comprise in particular the review of the scientific state-of-the-art, bundling the information on goals and initiatives for climate friendly nutrition, the development of minimum standards for products made from biomass, and the assessment of options for a global land management.

Further institutional improvement at the international level should not be confined to land and soil but comprise the sustainable management of all major

73 http://www.europarl.europa.eu/sides/getDoc.do?type=IMPRESS&reference=20110526FCS2031-3&language=EN

74 http://www.isric.org/

75 http://www.fao.org/nr/water/landandwater_gsp.html

76 http://www.globalsoilmap.net/

77 http://www.iuss.org/

78 http://www.earthobservations.org/

79 Refers to the gross production value in current million US$ for the year 2010 from the FAOSTAT online database (http://faostat3.fao.org/),

80 Although with reference to older studies in the 1980s

81 See e.g. http://www.economonitor.com/blog/2011/06/can-food-prices-be-stabilized/

natural resources. For that purpose, an international convention on sustainable resource management and the establishment of an international agency for sustainable resource management could be viable options (Bringezu and Bleischwitz 2009).

Within the UN system, the activities to implement the three Rio conventions - on Biodiversity, Climate Change and Desertification - could join forces. Sustainable land use is one common underlying element to these conventions. The secretariats may consider together with UNEP appropriate actions to improve the monitoring of global land use by countries, to foster more efficient production and use of biomass in order to halt the loss of biodiversity, mitigate climate change and reverse desertification by land degradation.

Next steps could be facilitated through cooperation of pilot countries. The Global Soil Partnership (GSP) for Food Security and Climate Change Mitigation and Adaptation, as proposed by the FAO[82], could make use of the findings of this report and support actions both on the supply and the demand side of agricultural products. Pilot projects such as the Land 2050 initiative[83] of the Terrestrial Carbon Group could also help to promote the search for solutions by proactive governments willing to embed their country´s development in the sound use of global resources. Also regional activities with global perspectives like the EU action against soil degradation and desertification[84] might be helpful in joining forces for improvement of monitoring and management capacities.

All in all, governments in countries of different development status have a number of options to improve the management and use of land and soil resources. None of the issues presented in this report are new. Quite the contrary, there is a plethora of literature and debate dedicated to single issues. Before that background, the report tried to provide an overview. Looking for one solution to one problem is no longer good enough. It is a complex, interconnected world, where trade-offs and synergies across environmental media, sectors, countries and time must be considered. Policies are needed which not only treat the symptoms of unsustainable land use (soil degradation, deforestation, growing world hunger, etc.) but also the underlying causes (socio-economic systems based on growing consumption, population growth, etc.). To this end, overview and systematic knowledge on strategic options for sustainable resource use is crucial.

5.4 Research needs

Improving land management for agricultural production

Research is needed to further develop integrated models of food production, especially to increase biomass yields while maintaining soil health, foster biodiversity, and minimize nutrient losses for various biogeographical zones. This includes site-specific management practices for efficient resource and input use, breeding climate change robust crops, and the more widespread use of agro-forestry systems. Moreover, research is needed in particular on:

- Quantitative analysis of agroecological and alternative farming practices; notably on the potential of agroecological approaches, and elements thereof, in conventional farming and the options and preconditions to scale-up agroecological farming;
- Further material and substance flow analysis of life-cycle-wide resource requirements, macro and micronutrients in different production systems (e.g. intensive vs. extensive livestock production), consumption, recycling and waste management systems with regard to the implications for land management at different scales;
- Exploration of resource-efficient ways to enhance urban, periurban and vertical farming. The latter may be an option in particular in megacities, but will require a co-development with resource-efficient renewable energy technologies and efficient water and wastewater management;
- Analysis and assessment of the most appropriate land tenure models for agricultural and forestry land across the world to ensure optimum food, fibre or timber production while ensuring the sustainable use of resources.
- Analysis of the effectiveness and efficiency of institutions for education and training of farmers, and of making use of their traditional knowledge;

82 http://www.fao.org/landandwater/docs/GSP_Background_Paper.pdf

83 http://www.terrestrialcarbon.org/site/DefaultSite/filesystem/documents/Global Conferece on AFSCC Hague Ashton Speech 101102.pdf

84 http://www.europa-eu-un.org/articles/en/article_11400_en.htm

- Development of easy to handle indicators and tools for monitoring and support of best operating practice in developing countries, for farmers, cooperatives, customer groups and finance institutions.

Monitoring and assessing global land use of countries and regions

While data on domestic land use is becoming more spatially explicit and related to sustainable land management potentials, the information on transboundary land use and related impacts is still in its infancy and needs to be enhanced significantly. In particular, research and development is required with regard to the:

- Monitoring and assessment of degraded land, its potential for restoration and improvement of productivity, considering climate change, restoration costs and benefits, in particular for food supply and environmental quality;
- Further development of methods and monitoring systems for measuring global resource use (land, water, materials) associated with domestic activities in production and consumption (considering trade also of processed goods and intensity of land management);
- Further research on the options to make use of the safe operating space concept, supporting the pursuit of goals in UN conventions, exploring its use at different spatial scales, revisiting and further developing the preliminary reference values while improving the knowledge base, and exploring methodologically sound ways to consider societal acceptance of uncertainty.

Developing key technologies and institutions for more efficient and renewable resource use

Making the use of resources more efficient is the key challenge. Technical innovations might be necessary, while technological solutions might not be sufficient. New institutions help to support the search for and application of resource-efficient technologies. Research is needed in particular for the:

- Analysis of the various options to foster material, energy and water efficiency in industries and households;
- Evaluation of monitoring tools, economic incentives, and institutions of know-how transfer such as efficiency agencies;
- Set up of inventories of food waste and analysis of effective preventive measures;
- Analysis and further development of options for enhanced material flow cascades of biogenic waste;
- Exploring possibilities for carbon recycling, converting biogenic waste from households and industry into feed-stocks for base materials.

Supporting policy preparation and evaluation

Sectoral analysis and policy design should be supplemented by and further developed towards more comprehensive and effective approaches. Future research and policy will need to better address the interlinkage of biomass, minerals, land, water and energy resources, the complementarity of production and consumption, and the interrelations between regions and economies. This requires in particular:

- Comprehensive modeling of land use scenarios (food, material, energy use of biomass);
- Assessment of national and regional policies with regard to impacts on global resource use;
- Analysis of the effectiveness of various policy instruments – legal, economic as well as informative – in the implementation of BMPs;
- Policy effectiveness evaluation and the analysis of those instruments which foster efficient and renewable resource use under different development conditions;
- Analysis of consumer choice behaviour and incentives to foster a healthy and resource sound diet.

In general, research is challenged to support the transition towards a more sustainable use of global resources at various levels. For that purpose, not only more systematic knowledge on problems and perspectives is required, but also know-how on the possibilities to involve actors and get decision makers and people engaged and moving in a promising direction. Global society has the chance to co-develop attractive, positively defined visions of possible and sustainable futures.

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About the UNEP Division of Technology, Industry and Economics

DTIE plays a leading role in three of the six UNEP strategic priorities:**climate change, harmful substances and hazardous waste, resource efficiency.**

DTIE is also actively contributing to the Green Economy Initiative launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for **fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund** and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

The Office of the Director, located in Paris, coordinates activities through:

- **The International Environmental Technology Centre** - IETC (Osaka), promotes the collection and dissemination of knowledge on Environmentally Sound Technologies with a focus on waste management. The broad objective is to enhance the understanding of converting waste into a resource and thus reduce impacts on human health and the environment (land, water and air).
- **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- **Chemicals** (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.

For more information, www.unep.org/dtie

Global land use plays a central role in determining our food, material and energy supply. Many countries have started to support the use of biomass for biofuels and biomaterials, and, at the same time, are becoming concerned about the increasing consequences of land competition, such as rising food prices, land use change, and land use intensification. Cropland expansion at the cost of tropical forests and savannahs induces severe changes in the living environment with uncertain repercussions.

A central question is, thus, to what extent can global cropland expand to serve the growing demand for food and non-food biomass, while keeping the consequences of land use change, such as losses of biodiversity, at a tolerable level?

This report explores how the management of land-based biomass production and consumption can be developed towards a higher degree of sustainability across different scales: from the sustainable management of soils on the field to the sustainable management of global land use as a whole.

Specifically, this report looks at the impacts of global trends—population growth, urbanization, and changes in diets and consumption behaviors—on global land use dynamics, considering the consequences for biodiversity, the supply of food, fibers and fuel, and the long-lasting implications for resource security.

It is intended to support the international discussion and to provide decision makers in national and regional governments and NGOs with an overview of key challenges and possible options related to sustainable land use.

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