UNEP

International Resource Panel

ASSESSING GLOBAL LAND USE

Balancing Consumption With Sustainable Supply

Acknowledgements

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International Resource Panel

Summary for Policy Makers

ASSESSING GLOBAL LAND USE

Balancing Consumption With Sustainable Supply

Produced by the International Resource Panel

This document highlights key findings from the report, and should be read in conjunction with the full report. References to research and reviews on which this report is based are listed in the full report.

The full report can be downloaded at http://www.unep.org/resourcepanel/Publications. If you are reading a hardcopy, the CD-Rom can be found in the back cover. Additional copies can be ordered via email: resourcepanel@unep.org, or via post:

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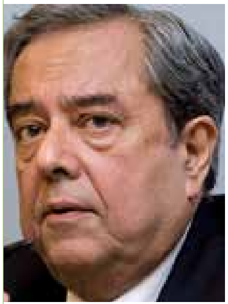
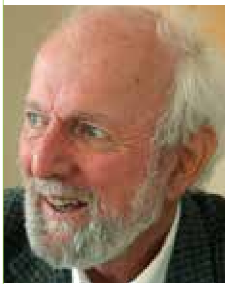
Preface



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 per cent and 37 per cent, 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 per cent 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

1. Introduction

The International Resource Panel

The International Resource Panel was established in 2007 to provide up-to-date, policy relevant and scientifically sound information on resource management. It aims to:

- Provide independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of natural resources and their environmental impacts over the full life cycle;
- Contribute to a better understanding of how to decouple economic growth from environmental degradation.

The International Resource Panel contributes to a better understanding of how to decouple economic growth from environmental degradation.

This report is part of a series of reports on a variety of resource-related topics. In particular, it builds on the land management and land use concerns raised by the first report of the International Resource Panel "Towards Sustainable Production and Use of Resources: Assessing Biofuels".

Objectives and scope of the report

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.

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 is based on an extensive review of key studies and seminal papers in the areas of agriculture, planetary boundaries and sustainable production and consumption, among others. This summary for policy makers does not include references; these are available in the full paper.

Altogether, this report is organized into four subsequent chapters. They focus on:

- Major trends related to the production of land-based products
- The drivers of cropland expansion on both the production and consumption sides
- The question of sustainability, and how a reference value indicative of a sustainable consumption level can be developed
- Policy options for improving production and reducing overconsumption, and identifying future research needs.

This report looks at the impacts of global trends 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.

A more efficient use of biomass and its substitutes is necessary and possible.

Key findings and main messages

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.

- Growing demand for food and non-food biomass will lead to an expansion of global cropland; yield growth will not be able to compensate for the expected surge in global demand.
- Reducing excessive consumption provides high untapped potentials for "saving" land, notably by reducing food waste and losses, shifting to more vegetal diets in high meat-consuming countries, and improving the fuel efficiency of transport and housing.
- Large areas with degraded soils are in need of restoration and better land use planning would help to avoid building activities on fertile land.
- Improvements are required and possible at different scales: from the sustainable management of soils on the field to the sustainable management of global land use as a whole.
- Product certification is useful for indicating best operating practices, but cannot control the global expansion of cropland. For that, countries should monitor and control the level of their global land use for supplying their consumption.
- A more efficient use of biomass and its substitutes is necessary and possible; it requires better co-operation to improve supply chains, better communication between manufacturers and consumers, enhanced international efforts toward global resource management (e.g. toward soil restoration), and a better framework for sustainable resource management at the scale of countries, regions and cities.
- In light of global efforts to increase food security, markets for food and fuel should be decoupled. This implies, for instance, reducing biofuel quotas.

2. Recent and long-term trends of global land use

Dynamics of land use change

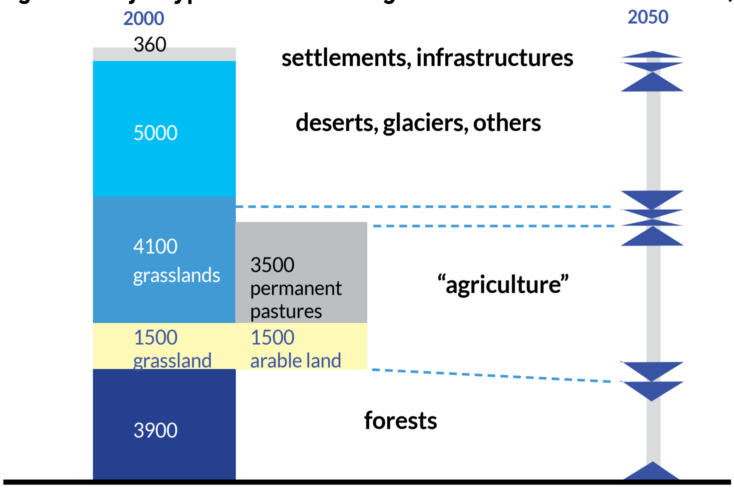
There are around 15 billion ha of land worldwide. Around 2 per cent of this area is covered by cities and infrastructures (built-up land), and this area is growing. Built-up land is expected to cover 4 to 5 per cent of the global land area in 2050. In many cases, built-up area expansion occurs at the expense of agricultural land.

Agriculture uses more than 30 per cent of the world land area, and cropland currently covers around 1.5 billion ha (or around 10 per cent of the global land area; Figure 1). Over the last 5 decades the area used for agriculture has been expanding at the expense of forests, in particular in tropical regions.

The area used for growing crops increased by around 11 per cent between 1961 and 2007, with large regional differences (decreases in Europe and North America and increases in South America, Africa and Asia). The shifts between countries and regions needs to be interpreted against the background of global trends as well as of increased international trade. These dynamics are expected to continue in the future.

In many cases, built-up area expands at the expense of agricultural land, and agricultural land expands at the expense of forests, in particular in tropical regions.

Figure 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"

Over the last five decades, deforestation has occurred at a rate of around 13 Mha per year on average. Again, regional differences exist, with forest area in Europe increasing since 1990 and forest area in South America, Africa and Southeast Asia experiencing high rates of loss.

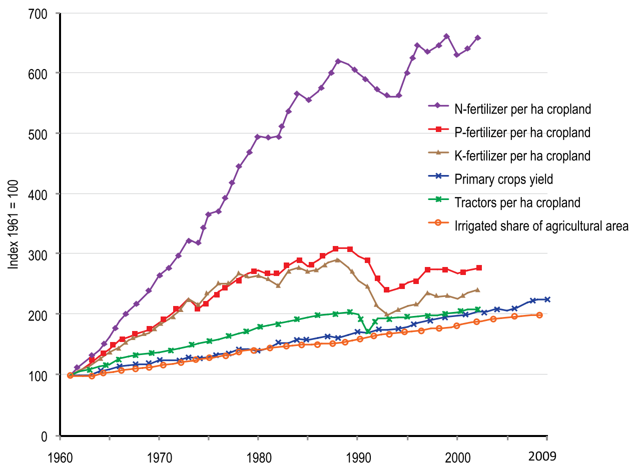
Agricultural production and environmental degradation

Technological development and innovation have contributed substantially to the tremendous increases in food production over the past 50 years. Yield gains have been significant, especially due to fertilizers (mainly nitrogen; Figure 2), machinery, irrigation, improved seeds, and pesticides. However, also negative impacts on the environment and health have increased, particularly in terms of soil erosion, eutrophication, salinization, and agrochemical contamination.

Around 23 per cent of global soils are estimated to be degraded.

Land degradation has become a serious problem. This refers to a deterioration in environmental quality and losses in the resource potential and productive capacity of the land. Around a quarter of global soils is estimated to be degraded. Nearly 40 per cent of the degraded area is thought to be "lightly" degraded, with strong potential for restoration at low cost.

Figure 2 Global trends in the intensification of crop production, 1961 – 2002/2009



Source: Drawn from FAOSTAT online database

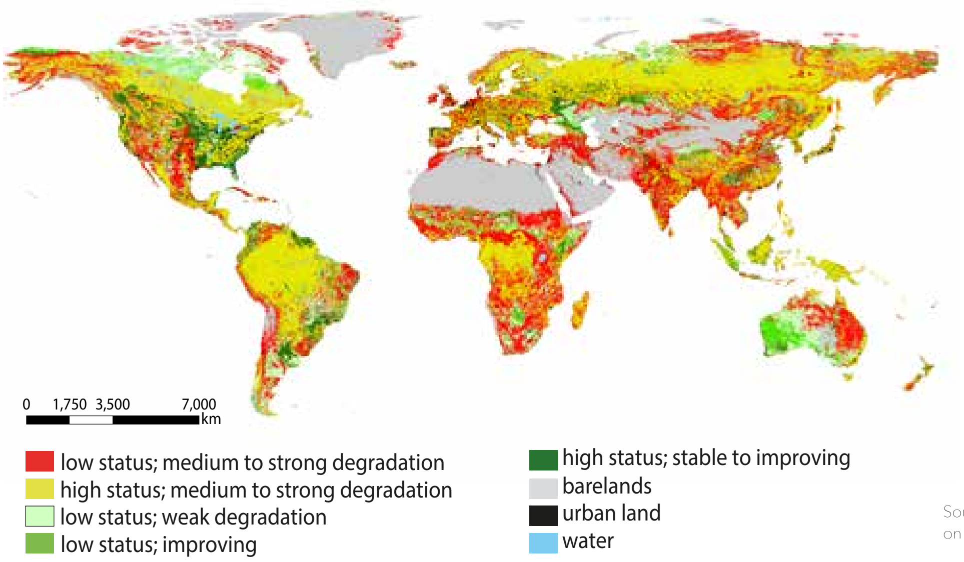
Note: This graphic was constructed after a similar Figure in Hazell and Wood (2008) which in turn was based on Cassman and Wood (2005). The main differences are: (1) fertilizer was here split into N, P and K fertilizer respectively, (2) cereal yields here were replaced by primary crops yields, (3) irrigated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

Nutrient pollution causes the eutrophication of waters and contributes to greenhouse gas emissions (N_2O). Nutrient pollution is primarily a result of large increases in the use of fertilizer, and the rate of change has been dramatic; more than half of the synthetic nitrogen fertilizer ever produced was used in just the past 25 years or less. This suggests potential environmental limits to the continued growth of agricultural yields through fertilization.

Biodiversity is especially affected by the conversion of natural habitats to agricultural land. In particular, the expansion of cropland into grasslands, savannahs and forests contributes to this loss.

Climate change is accelerated by land-use and land-cover change (LULCC). LULCC can increase the release of carbon dioxide by disturbing soils and vegetation, and the main driver of this is deforestation, in particular when followed by agriculture. It is also associated with major changes in terrestrial emissions of other GHGs, especially methane.

Figure 3 Status of land in regard to capacity of ecosystem services, degradation and direction of changes



Source: UNEP 2012b based on Nachtergaele et al. 2011

More than half of the synthetic nitrogen fertilizer ever produced was used in the past 25 years or less.

By 2005 the largest 10 seed corporations controlled 50 per cent of all commercial seed sales; the top five grain trading companies controlled 75 per cent of the market; the largest ten pesticide manufacturers supplied 84 per cent of all pesticides.

A global agricultural industry

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

Governance in past decades supported the growth and transformation of the agricultural sector towards a global industry. While small farmers still supply a large share of food for local livelihoods, rationalization, high capital investments, privatization, and the WTO rules for agriculture products have all contributed to the dismantling of state-centered national or community based agricultural development models and their replacement with privatized agricultural systems with an industry-like structure oriented to service global markets. International agricultural trade has increased 10-fold since the 1960s. Currently around 16 per cent of world production entered international trade, with a wide variation among individual countries and commodities.

The information technology revolution has 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. By 2005 the largest 10 seed corporations controlled 50 per cent of all commercial seed sales; the top five grain trading companies controlled 75 per cent of the market; and the largest ten pesticide manufacturers supplied 84 per cent of all pesticides.

Supermarket chains have rapidly increased their share in retail food sales. In South Africa 55 per cent of all food was sold via supermarket chains in 2002, with Brazil reaching 75 per cent, while South America as a whole and East Asia (excluding China) were at just over 50 per cent and China just below 50 per cent.

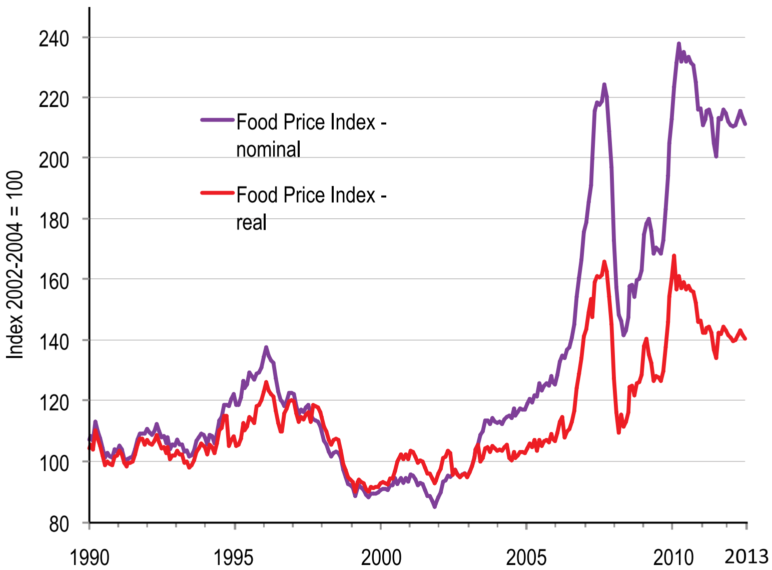
Food prices and food security

Food prices are driven by a complex combination of factors. Historically, long-term decline in prices was largely due to massive increases in agricultural productivity and output. Historical post-war peaks were largely driven by increased oil prices, leading to higher production costs for fuel and fertilizer.

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 4). The 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. If predictions of several organizations, such as the OECD or FAO, turn out to be true, the coming decades will see steadily rising prices.

Elevated food prices have dramatic impacts on the lives and livelihoods of those already undernourished or living in poverty. It creates macro vulnerabilities, particularly for countries with a high share of food imports and limited fiscal space, as well as increases in poverty. Fluctuating prices are also a core problem for stable food production. Agricultural price volatility increases the uncertainty faced by farmers and affects their investment decisions, productivity and income. On the other hand, income from the export of agricultural products may also support national economic development.

Figure 4 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

Elevated food prices have dramatic impacts on the lives and livelihoods of those already undernourished or living in poverty

Large-scale land investments

Large-scale land acquisitions, both purchased and leased, increased significantly over the last few years. Around 200 Mha are thought to have changed hands between 2000 and 2011. The average size of these land deals is large, covering around 40,000 ha (estimated for deals between October 2008 and August 2009). Around two-thirds of these acquisitions occurred in Sub-Saharan Africa.

The recent land rush is generally thought to be a result of three triggers -- the food crisis, the economic recession and biofuel targets.

The recent 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. 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.

Proponents of large-scale land investment regard it as an opportunity for 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. As large-scale land acquisitions favor industrialized, high-tech, and export-oriented agriculture, it often means a retreat for small-scale farming.

On the one hand, export income from agricultural products may support national economic development and good agricultural practices could spill-over to local farmers. On the other hand, a focus only on export markets may leave a supply gap in countries struggling to feed their population. 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.

Where and how to direct investment in agriculture is a question that needs to be answered across the globe.

The growing land acquisitions are consequences of an increasing scarcity of cropland. This report sheds further light onto the causes of this development.

3. Factors driving increased demand for cropland

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 production land available.

Constrained yield increases imply that future demand must be met with an expansion of cropland.

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. Because yield increases have been most pronounced in developed countries, little potential is seen for significantly increasing yields in those regions. There is still, however, considerable potential in certain developing countries (particularly in sub-Saharan Africa), which could be realized through improved agricultural practices. Estimates on future yields are rather uncertain, and will be influenced by a number of factors (e.g. climate change, rate of soil degradation, etc.). Constrained yield increases imply that future demand must be met with an expansion of cropland.

Population growth

The UN 2008 population prospects predict world population to increase from 6.8 billion in 2009 to around 9.2 billion in 2050. Less developed regions will contribute the most to this increase. Supplying these people with food under business-as-usual conditions will require an increase in cropland area.

Urbanization

In 2010, around half of the world population lived in cities. This share is expected to increase to almost 70 per cent in 2050. Urban population in developing countries is projected to nearly double between 2010 and 2050.

Urban growth can be characterized by e.g. urban sprawl—which often implies little planning of land transformation—and there is evidence that built-up land often expands on fertile soils and agricultural lands. For compensation, the loss of fertile soils and river plains are being accompanied by the conversion of natural vegetation to farmland at other places. In 2007, around three-quarters of the new settlement area in the EU-27 was on former agricultural land. 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.

Changing Diets

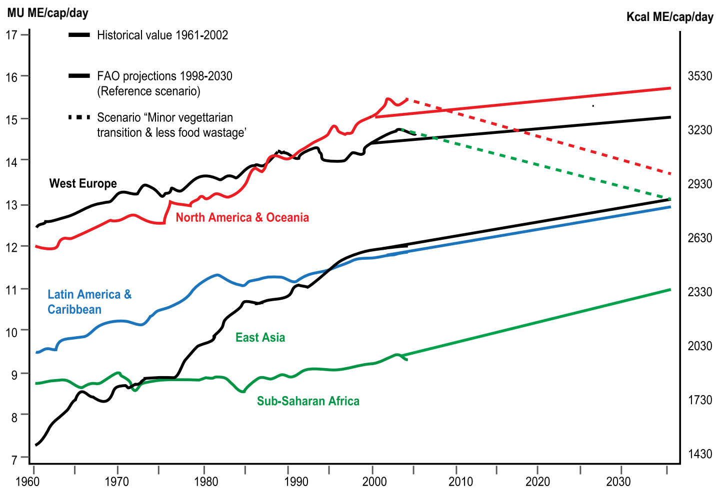
A combination of rising income and urbanization are changing diets, and increasing the demand for land. These trends are reinforced by the spreading of fast food chains, supermarkets, and the global advertisement of a Western style of (over-) consumption. Dietary change may override population growth as the major driver behind land requirements for food in the near future.

Change to more meat-based diets will result in a significant increase in the need for agricultural land, both pasture and cropland. Urbanized populations consume less basic staples and more processed food, which are also associated with higher land requirements than basic home made food for a given number of calories.

Diets in developed countries are already high in processed food and livestock products. The challenge in these countries is to reduce in particular meat consumption and excessive waste. The challenge in developing countries is to raise daily calorie intake to converge diets worldwide around levels more consistent with dietary recommendations (Figure 5).

Change to more meat-based diets will result in a significant increase in the need for agricultural land.

Figure 5 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)

Renewable energy and land use

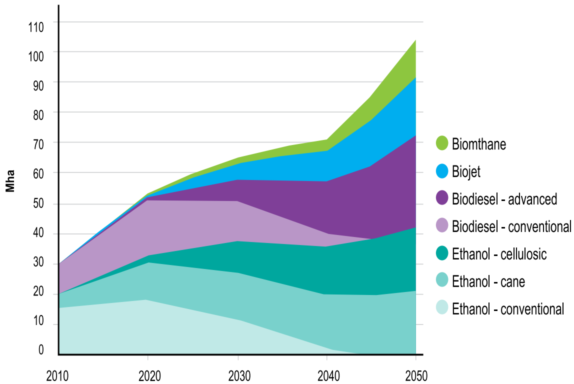
Land use demand for renewable energy projects varies with the technology. Hydropower reservoirs can cause flooding of a significant land area; solar PV and concentrated solar power require land for mounting the technologies (if not installed on roof-top or in building-integrated units); wind turbines and related access roading take up only a small portion (2-5 per cent) of the total land area used for a wind farm.

For biomass, considerable areas of land are required for dedicated energy crop production, more per unit of energy than for all other technologies. No or relatively low additional land is needed for crop and forest residues and organic wastes.

The contribution of biomass to future energy supply is uncertain.

The contribution of biomass to future energy supply is uncertain. In the Blue Map scenario of the 2008 IEA Energy Technology Perspectives around 23 per cent of primary energy by 2050 is assumed to be provided by biomass (under the condition that this would help keep global temperature rise below 2ºC). With around half of this supply assumed to arise from crop and forest residues, the amount of energy crops needed to supply the rest would require around 375 to 750 Mha of land, with 100 Mha used for biofuel production (Figure 6).

Figure 6 Land demand projected for future transport biofuel production, 2010 - 2050.



Source: IEA 2011

Note: assuming 50 per cent of biofuels will use organic wastes and residues and excluding land-use reduction for biofuel co-products; "Biojet" is advanced, synthetic aviation fuel

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 (from forests or residues) for direct combustion to cogenerate heat and electricity rather than producing liquid biofuels, because of the far greater efficiencies and lower environmental consequences.

Biomaterials

Both the US and EU regard products based on biomass as one of the most promising future markets, with a high potential for innovation. Existing products (paper, pulp, detergents, and lubricants), modern biomaterials (pharmaceuticals, industrial oils, biopolymers and fibers) and innovative, high-value added products (wood-plastic-composites, bio-based plastics, pharmaceuticals, etc.) are markets with varying degrees of growth. Estimates for the EU and the US reveal that biomass currently makes up an around 8 per cent share of the chemical industry's raw material base.

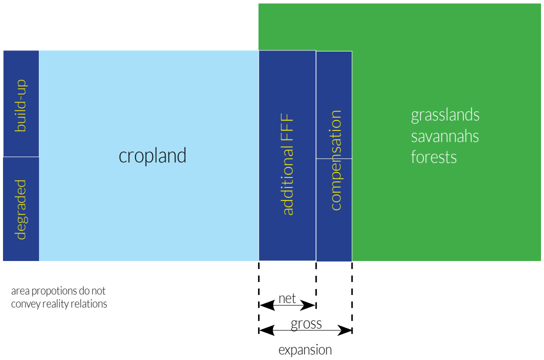
In contrast to energy plants, the use of biomass for material purposes provides a potential double dividend, as the energy content may be recovered after material use and recycling.

The growing use of biomaterials will require land. Although there is little literature on the potential environmental consequences of an extended biomaterials industry, cropland based biomaterials might meet similar limitations of land availability as energy crops.

Interim conclusion

This 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 7).

Figure 7 Net and gross expansion of cropland



Taking modest estimates of additional land requirements by 2050 (base year 2005) reveals that cropland would expand around 320 to 850 Mha into grasslands, savannahs and forests (gross expansion, Table 1).

Although there is little literature on the potential environmental consequences of an extended biomaterials industry, cropland based biomaterials might meet similar limitations of land availability as energy crops.

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. This means that competitive effects and impacts of natural limitations via prices have not been considered. The influence of climate change was also not explicitly included in the calculations.

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 eco-systems into crop production seems inevitable.

Taking modest estimates of additional land requirements by 2050 reveals that cropland altogether is expected to expand by around 320 to 850 Mha.

Table 1 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**	

4. Balancing consumption with sustainable production

The challenges facing society must be addressed through a consideration of both consumption and production. Comparing actual global land use of countries to a preliminary orientation value for safe operating space indicates the direction and order of magnitude of necessary adaptations.

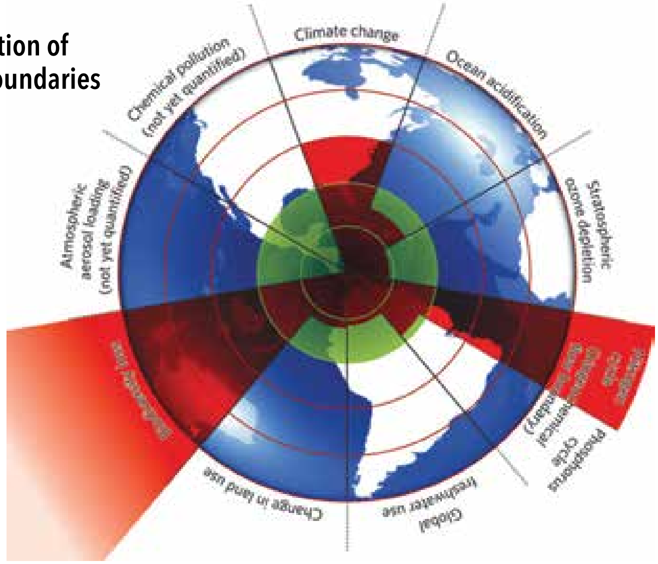
The safe operating space concept

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. In contrast, consumption patterns of final products seem to converge worldwide depending on the economic performance of countries and classes. The question that arises is, how can countries recognize whether their consumption is within globally (or otherwise) safe limits?

The "safe operating space" (SOS) concept (Figure 8) is a starting point for understanding these limits. One of the strengths of the SOS concept is that it effectively highlights current over-use of the earth's resources, and thus underlines the need for absolute decoupling of welfare creation from resource use.

One of the strengths of the SOS concept is that it effectively highlights current over-use of the earth's resources.

Figure 8 Estimate of quantitative evolution of control variables for seven planetary boundaries from pre-industrial level to the present



Source: Rockström et al. 2009

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 concept is, however, just a starting point as it does not address three aspects essential for sustainable operation:

- The potential for resource use efficiency in industry and society;
- Local and regional differences;
- Equity aspects concerning production and consumption.

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. What appears safe at broader scales can mask critical boundaries at local scales.

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. As such, safe operating space as a metaphor defines the outer road markings for keeping development on a viable track and avoiding driving off the road. How to control direction and speed and to make use of the "possibility space" is a subsequent challenge.

Global land use: a key indicator of global sustainability

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, and loss of fertile soil?

Agricultural expansion and the conversion of natural habitats are known to be key causes of the worldwide loss of biodiversity and ecosystem services. 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".

From an analytical perspective it would be extremely difficult to determine these thresholds. This is due to the complex interactions within many cause-effect networks at different scales. Meanwhile,

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.

An approach to control the known key drivers of global biodiversity loss at a precautionary safe level, instead of uncertain forecasting and risky testing of damage thresholds, may be called for.

however, the "reality experiment" is running and testing when and where severe and irreversible consequences will appear might turn out the errors while leaving no room for further trial. "The Economics of Ecosystems and Biodiversity" report 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 an approach to control the known key drivers of global biodiversity loss at a precautionary safe level, instead of uncertain forecasting and risky testing of damage thresholds, may be called for.

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.

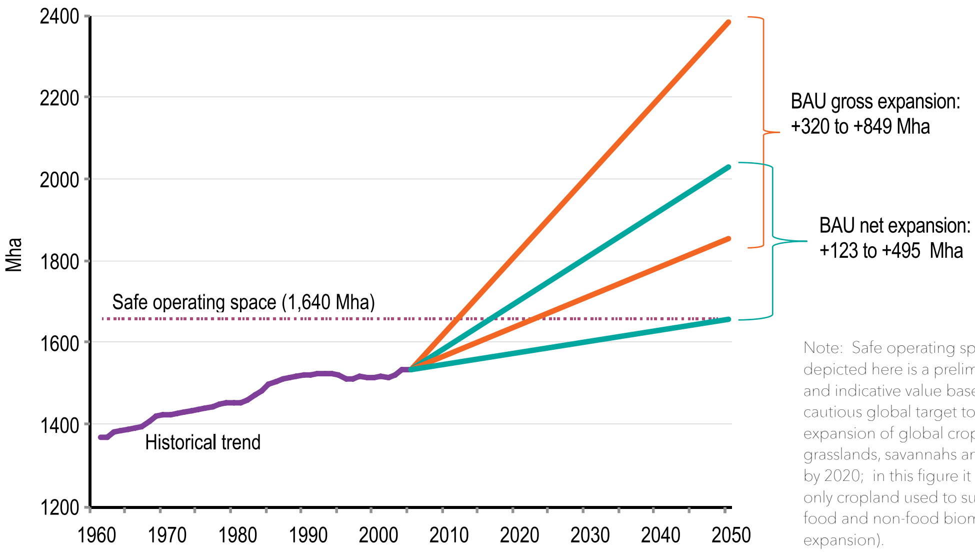
This implies that business-as-usual development could "safely" continue until 2020, at which time an additional around 100 Mha are expected for meeting future demand (net expansion) and around 90 Mha are expected to be displaced (resulting in 190 Mha of gross expansion). For deriving a reference value for sustainable consumption that means the global cropland area available for supplying demand could safely increase up to 1,640 Mha.

Under business-as-usual conditions until 2050, the expected range of cropland expansion would overshoot the safe operating space in all cases (Figure 9).

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. 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.

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. 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). Work is ongoing to derive a SOS value for forest harvest.

Figure 9 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).

Under business-as-usual conditions until 2050, the expected range of cropland expansion would overshoot the safe operating space in all cases.

Monitoring global land use of countries and regions for their domestic consumption gives an indication of whether they have exceeded or are within the safe operating space.

Monitoring global land use of countries and regions

The SOS values can be taken as a comparative reference for the cropland requirements of economies. Monitoring global land use of countries and regions for their domestic consumption then gives an indication of whether they have exceeded or are within sustainable resource use. The key question in this context is, how much land worldwide is needed to supply the domestic consumption of countries?

To this end, the method of global land use accounting can be applied. It follows the principles of economy-wide material flow accounting and calculates the global land use caused by the apparent consumption of an economy 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. In this way, 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.

This method has been used to calculate the global cropland requirements of the EU, finding that 0.31 ha per person were required in 2007. This is one-fourth more than what is available domestically in the EU; it is one-third more than the globally available per person cropland in 2007; and it is well over the SOS orientation value of 0.20 ha for 2030.

Altogether, 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. Nevertheless, the methods and data - in particular for pasture and forest land - need further refinement.

5. Options for sustaining global use of land

Policies to enhance supply - although necessary - might not be effective if not complemented by policies to adjust consumption toward sustainable levels.

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. "Best management practices" (BMPs) are the building blocks for sustainable land management systems.

"Best management practices" should be based on scientific principles that are universal, but locally applied.

Table 2 lists 13 properties and processes, and 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. This means that BMPs should be based on scientific principles that are universal, but locally applied. 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, this would be "more useful (…) than to categorize practices and technologies – and their proponents – into separate and opposing camps".

Potential yield gains (gaps between realistically attainable yields and farmer yields) in dryland agriculture and in developing countries 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.

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 BMPs.

Table 2 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

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.

Product-specific approaches such as certification play an important role toward informing industry and households about the "greenness" of their products. However, product-related stipulations alone cannot solve the problem of land use change induced by increased production of bio-based products such as biofuels. This is because the risk of indirect effects depends on the overall demand for land-based products. Displacement effects for biofuels alone are methodologically difficult to capture, and there is a real risk of getting lost in the details of the modeling and losing sight of the big picture.

Governmental interventions deliberately targeting consumption patterns may be considered unacceptable in liberal market economies. In reality, however, governments already steer consumption significantly. Tax, tariff, and subsidy policies increase the desirability of some products while making others unattractive. Safety and performance standards shape and constrain customer choice. 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.

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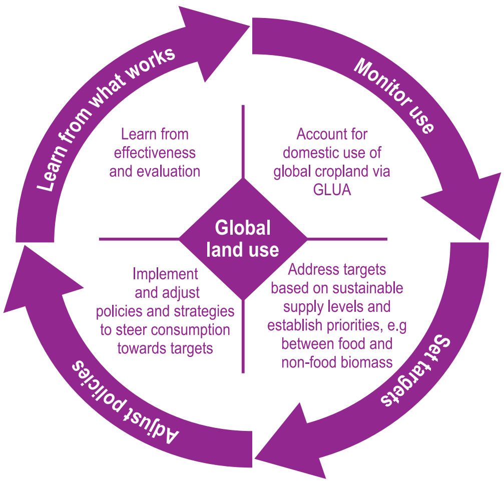
A report from the World Business Council for Sustainable Development states, "We recognize the need for business to play a leadership role in fostering more sustainable levels and patterns of consumption, through current business processes such as innovation, marketing and communications, and by working in partnership with consumers, governments and stakeholders to define and achieve more sustainable lifestyles."

Using marketing and awareness-raising campaigns to encourage consumers to make sustainable choices is certainly a step in the right direction. However, relying on consumer choice alone is not enough. Consumers are heavily influenced by marketing–global advertising expenditures almost reached around $650 billion in 2008–and customers may be confused by the multitude of product labels on the market. Globally, the ecolabel index website has identified around 130 ecolabels for food alone.

Moreover, evidence on the capability of ecolabels to transform mainstream behavior is diverse. An inherent problem for transformational change may be rooted to people's behavior and choice architecture. For this reason, reducing consumption will require political action addressing both incremental and more structural challenges.

The transition toward sustainable levels of consumption will require a far-reaching combination of bottom-up and top-down strategies across the production and consumption chain. Indeed, the transition cycle will require a number of iterative steps (Figure 10):

Figure 10 Transition cycle for managing global cropland consumption levels towards levels of sustainable use



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).

Reducing unsustainable demand can be achieved in a number of innovative ways. 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.

An inherent problem for transformational change may be rooted to people's behavior and choice architecture.

Around one-third of edible food is lost or wasted annually.

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.

Overconsumption indicates a significant potential for reduction. For instance, just looking at Europe, North America and Oceania, Wirsenius et al. (2010b) found that around 100 Mha of cropland could be saved by 2030 if those countries reduced their meat consumption by around 25 per cent (to a minimum of 70 kg/person) and decreased their food wastage by 15-20 per cent at the household and retail levels. 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. Meeting the requirements of a healthy diet for all world citizens would require around 135 Mha less cropland than the reference scenario, with about 10 per cent initial CO_2 savings.

Another good opportunity to lower food consumption is to **reduce food wastage.** Around one-third of edible food is lost or wasted annually. Kummu et al. (2012) estimate that annual losses across the food supply chain correspond to around 200 Mha of cropland. According to Gustavsson et al. (2011), around 40 per cent of food losses in industrialized countries occur at retail and consumer levels whereas more than 40 per cent of food losses in developing countries happens at post harvest and processing levels.

First-generation biofuels can exacerbate land use pressures. 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. 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. Strategies may also focus on reducing fuel demand. In 2010 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 per cent by 2030, using technologies currently available or expected in the next decade.

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. Nevertheless, before embarking on a policy agenda to stimulate bio-based products and biomaterials, better information on their land requirements is needed.

Interim conclusion

Table 3 summarizes the potential 'land savings' for a mix of strategies and measures to reduce overconsumption of food and non-food biomass products and to improve land management. Combined, these measures could realistically save around 160 to 320 Mha by 2050. If maximum savings were achieved in the areas of food, biofuels and biomaterials, and BAU expansion stayed in the low range, the net cropland area needed for supplying consumption could even decrease 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. Considering the widest realistic range, the remaining gross expansion would require 120 to 570 Mha, or an additional 8 to 37 per cent of global cropland area in 2050. The lower range would keep the development within the safe operating space (e.g. Figure 11 for net expansion). 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.

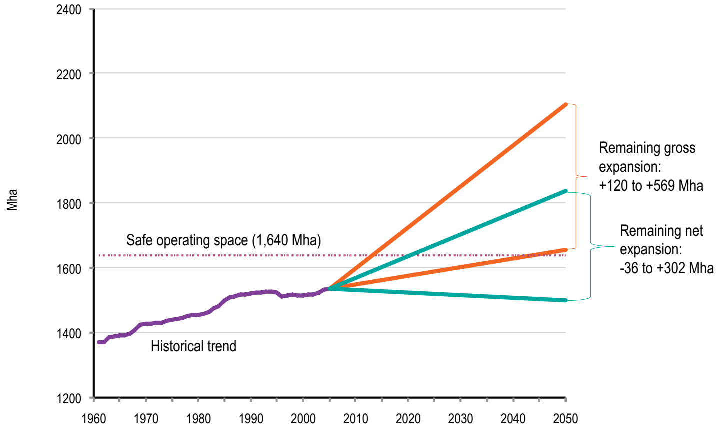
A mix of strategies and measures to reduce overconsumption of food and non-food biomass products and to improve land management could save around 160 to 320 Mha by 2050.

Table 3 Expansion of global cropland from 2005 to 2050 under business-as-usual 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 + 71Mha); 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.

Figure 11 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 3 are combined to show maximum realistic ranges for remaining net and gross expansion.

Policy options

Securing sustainable supply of food and fiber, 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.

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.

Decoupling fuel and food markets seems to be a key component of sustainable resource management. With widespread use of biofuels, rising petroleum prices will inevitably also drive food prices because biofuels are derived from cropland. Past experiences show that intolerable price increases for food may lead to spreading hunger, cause riots and socio-political disturbances. Decoupling can 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. This includes the reduction of biofuel quotas.

Three elements are necessary for a more sustainable resource management at all levels of governance: better information, better long-term orientation, and incentives for actors to take action.

Of particular importance is improved information on the extent and quality of degraded soils in order to assess the options for restoration.

Capacity building in developing and transition countries is a key prerequisite for improving food security, local livelihoods and environmental quality. Programmes, institutions and projects have been successfully established across the globe. For example, organized efforts aiding farmers, especially small-holders, to reduce losses from pests and disease have been established in the form of "plant clinics" in many developing countries. Through the "Sustainable Agriculture Initiative" some of the world's largest agrifood companies have created an integrated platform for sharing best practices.

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. This will also improve dissemination of new ideas. 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 for slash and burn agriculture.

Urban farming or gardening is becoming a new trend in bigger cities. A programme organized by the FAO (Growing Greener Cities) helps cities in developing countries to establish urban garden programmes. While urban gardening can be valuable for supplying local livelihoods and reconnecting people 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 US, Europe and developing countries show a range between 1 and 11 m^2 of urban garden space per person. This compares with the global average area of cropland of 2,300 m^2 per person and the worldwide cropland required for EU's consumption of 3,100 m^2 per person.

The framework for resource management needs to be established at the level of countries. A wide range of issues, from improving environmental statistics to family planning programmes, are relevant to sustaining land use and securing food supply.

Improving information systems, especially on land resources, are crucial. 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. Of particular importance is improved information on the extent and quality of degraded soils in order to assess the options for restoration. Integration of material flow accounts with economic statistics allows monitoring global land use for domestic production and consumption activities. This informs policy on the degree of food security, dependence on imports or exports, and the sustainability of both supply and consumption.

Land use planning can be used to channel the expansion of urban areas in order to conserve productive green belts with fertile soils for the provision of food and recreation areas. It can also be used to define high priority areas for nature conservation, helping 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.

Programmes for economy-wide sustainable resource management may be regarded as cornerstones of national sustainability programmes. Due to the diverse nature of products grown on agricultural land, policies addressing direct and indirect land use are often spread among different divisions and departments. One way to harmonize and integrate food, renewable energy and biomaterials policies could be the development of sustainable biomass action programmes – embedded in economy-wide sustainable resource management schemes.

Economic instruments can also be used to trigger sustainable supply and demand. One example is a "subsidy to sustainability" approach, which links subsidies to certain performance criteria. It may, for instance, link directly to investments on the farm to provide long-term nutrient supply, enhance soil health and improve efficiency in fertilizer use. Cases of targeted management of water prices to promote a more efficient water use can be found across the globe.

Improved targeting of public investments especially focused on the needs of smallholders would enhance food security and living conditions in rural areas. 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.

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

Family planning programmes that slow down population growth may have a more pronounced impact on future food security than efforts to enhance crop yields.

Guidelines for the Governance of Tenure of Land, Fisheries and Forests" may be used to support governments in developing guidelines, laws and effective protection measures for establishing land tenure and promoting responsible investment.

Reducing food loss at the production and harvest stage, especially in developing countries, may be achieved by investing in infrastructure, encouraging the build-up of storage facilities and better financing of co-operatives (to prevent farmers in need of cash from harvesting too early). Education and food waste prevention campaigns, such as WRAP in the UK and the global "Think.Eat.Save" campaign of the Save Food Initiative, may be useful policy options for reducing food waste in developed countries.

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. Incentives might be re-directed toward co-generation or multi-generation technologies processing waste into recycled materials and useful energy (electricity, heat).

Programmes promoting a healthy and balanced diet in high-consuming countries, especially as regards meat products, may help to reduce obesity and land pressure. At the national scale, one of the first places this may be evident is in programmes promoting a more healthy diet in schools. This may be combined with social aspects. In Brazil, for instance, 30 per cent of the food served in its national school-feeding programme should stem from family farms.

Family planning programmes that slow down population growth may have a more pronounced impact on future food security than efforts to enhance crop yields. Around 25 per cent 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. Case studies have shown that programmes integrated into existing health agencies were associated with higher levels of success.

BOX 1 HOW TO FINANCE THESE PROGRAMMES?

It is estimated that consumption-based subsidies for fossil fuels reached US$ 312 billion in 2009. 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 countries. Reducing and partly redirecting these subsidies could not only combine climate and resource conservation efforts, but also might reduce public debts and contribute to the stabilization of financial markets. Leveraging synergies between agriculture, food security and climate change may also present an opportunity for gaining funding. Experiences in on-going land-based carbon finance projects reveal that agricultural investment can leverage five times its value in carbon revenues. Payments for ecosystem services may also play an increasing role. 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 per cent, providing a good opportunity for public and private investment.

International institutions can help to increase knowledge and improve the data basis for decision makers. For example, the German Scientific Council for Global Environmental Change suggested to establish a Global Commission on Sustainable Land Use. Within the UN system, the activities to implement the three Rio conventions - on Biodiversity, Climate Change and Desertification - could join forces, with sustainable land use as one common underlying element. The Global Soil Partnership for Food Security and Climate Change Mitigation and Adaptation, as proposed by the FAO, could support actions both on the supply and the demand side of agricultural products. Pilot projects such as the Land 2050 initiative of the Terrestrial Carbon Group could also help to promote the search for solutions.

All in all, policies are needed - and available - which not only treat the symptoms of unsustainable land use (soil degradation, deforestation, growing world hunger, etc.) but also the underlying causes leading to those unsustainable practices.

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Further research is needed on options to make use of the safe operating space concept, exploring its use at different spatial scales and developing methodologically sound ways to consider societal acceptance of uncertainty.

Research needs

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. Specifically, research is needed to:

Improving land management for agricultural production to further develop integrated models of food production, especially to increase biomass yields while maintaining soil health, fostering biodiversity, and minimizing nutrient losses. Quantitative analysis of agroecological and alternative farming practices and the options and preconditions for their scale-up are needed, as well as the development of easy to handle indicators and tools for monitoring and support of best operating practices.

Improve monitoring and assessment of transboundary land use and related impacts, especially as regards:

- Monitoring and assessment of degraded land, its potential for restoration and improvement of productivity;
- Methods and monitoring systems for measuring global resource use associated with domestic activities;
- Options to make use of the safe operating space concept, exploring its use at different spatial scales and developing methodologically sound ways to consider societal acceptance of uncertainty.

Develop key technologies and institutions for more efficient and renewable resource use. For example, setting up inventories of food waste and analysis of effective preventative measures.

Support policy preparation and evaluation to better address the interlinkages 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 the evaluation of policy effectiveness and the analysis of those instruments which foster efficient and renewable resource use under different development conditions.

Abbreviations and acronyms

APEC	Asia-Pacific Economic Cooperation
BAU	Business-as-usual
BMP	Best management practice
CO_2	Carbon dioxide
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
G20	Group of Twenty Finance Ministers and Central Bank Governors
GHG	Greenhouse gas
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Developmnent
IEA	International Energy Agency
K	Potassium
LULCC	Land-use and land-cover change
N	Nitrogen
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
P	Phosphorus
SCOPE	Scientific Committee on Problems of the Environment
SOS	Safe Operating Space
UK	United Kingdom
UN	United Nations
US	United States
WTO	World Trade Organization

Units

°C	Degrees Celsius
ha	Hectare
kg	Kilogram
m^2	Square meter
Mha	Million hectares

THIS BOOKLET summarizes the report "Assessing Global Land Use: Balancing Consumption with Sustainable Supply". The report was produced by the Land and Soils Working Group of the International Resource Panel. 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.

Global cropland is expanding and 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.

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