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POLICY CHALLENGES FOR FOOD, ENERGY AND ENVIRONMENTAL SECURITY

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Abstract: Limited land is available globally to grow crops for food and fuel. There are direct and indirect pressures on forests and other lands to be converted from growing food for feedstock to be used for biofuel production. The balance of evidence indicates there will probably be sufficient appropriate land available to meet demands for both food and fuel, but this needs to be confirmed before global supply of biofuel is allowed to increase significantly. There is a future for a sustainable biofuels industry, but feedstock production must avoid encroaching on agricultural land that would otherwise be used for food production. And while advanced technologies offer significant potential for higher greenhouse gas (GHG) savings through biofuels, these will be offset if feedstock production uses existing agricultural land and prevents land-use change. GHG savings can be achieved by using feedstock grown mainly on marginal land or that does not use land, such as wastes and residues. To ensure that biofuels deliver net GHG benefits, governments should amend, but not abandon, their biofuel policies in recognition of the dangers from indirect effects of land-use changes. Large areas of uncertainty remain in the overall impacts and benefits of biofuels. International action is needed in order to improve data, models and controls, and to understand and to manage effects.

Keywords: Food, energy, environmental security

Introduction

Human population is projected to grow at 70 million per annum increasing by 35% to 9.1 billion by 2050 (FAO, 2009). This increased population density, coupled with changes in dietary habits in developing countries towards high quality food (e.g. more consumption of meat and milk products) and the increasing use of grains for livestock feed, is projected to cause the demand for food production to increase by 70%. The increase in production has to happen at the same time as the climate is changing and becoming less predictable, as greenhouse gas emissions from agriculture need to be cut, and as land and water resources are shrinking or deteriorating. The provision of additional agricultural land is limited, as it would have to happen mostly at the expense of forests and the natural habitats of wildlife, wild relatives of crops, and natural enemies of crop pests. Furthermore, a higher proportion of agricultural land may be used industrially to produce biofuel or fibre instead of food. Thus, we may need to grow food on even less land, with less water, using less energy, fertiliser and pesticide than we are using today. Given these limitations, sustainable production at elevated levels is urgently needed. Increasing productivity on existing land is by far the better choice.

1. Food security

The food crisis in 2007/2008 and 2010/2011 caught the world by surprise. Do we now expect a new policy paradigm from open markets to protectionism, from food security to self sufficiency, from imports to outsourcing (land acquisition) and from private to public market intervention? More recent transnational land deals are partly a consequence of the larger changing economic valuation of land and water. Higher agricultural prices generally result in higher land prices because the expected returns to land increase when profits per unit of land increase. Given that the food price crisis has increased competition for land and water resources for agriculture, it is not surprising that farmland prices have risen throughout the world in recent years.

An increasing number of countries are leasing and purchasing land abroad to sustain and secure their food production. Food-importing countries with land and water constraints but rich in capital are at the forefront of new investments in farmland abroad. Some agreements do not involve direct land acquisition, but seek to secure food supplies through contract farming and investment in rural and agricultural infrastructure, including irrigation systems and roads (*Braun and Meinzen-Dick,* 2009).

These include the acquisition of 690 000 ha of land in Sudan by South Korea, and around 320 000 ha of Pakistani land by the United Arab Emirates, as well as a pending Saudi request for 500 000 ha of Tanzanian land and Chinese attempts to secure more than one million hectares in the Philippines. A major evolution from past patterns is the transition from overseas profit oriented investments for tropical cash crops to farmland acquisition for growing basic staples, with an eye to bolstering a country's food security *(Table 1)*.

Although additional investments in agriculture in developing countries by the private and the public sector should be welcome in principle, the scale, the terms and the speed of land acquisition have provoked opposition in some target countries (the Philippines, Madagascar). Well-documented examples on these developments are scarce. The lack of transparency limits the involvement of civil society in negotiating and implementing deals and the ability of local stakeholders to respond to new challenges and opportunities.

Table 1. Transnational land acquisition, 2006-2009

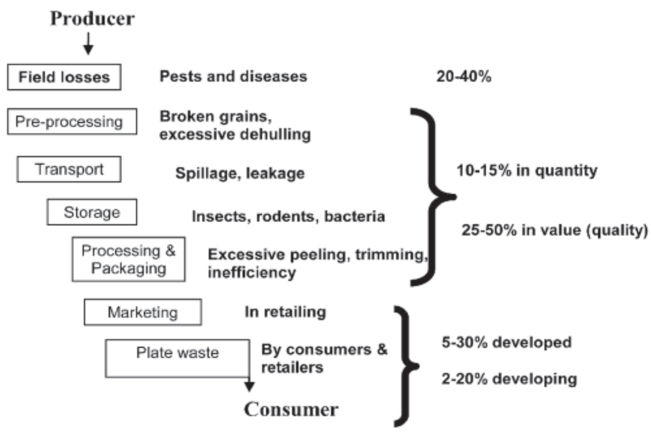
Country investor	Country	Plot size (hectares)
Bahrain	Philippines	10 000
China (with private entities)	Philippines	1 240 000
Jordan	Sudan	25 000
Libya	Ukraine	250 000
Qatar	Kenya	40 000
Saudi Arabia	Tanzania	500 000
South Korea (with private entities)	Sudan	690 000
United Arab Emirates (with private entities)	Pakistan	324 000

Source: Braun and Meinzen-Dick (2009)

The main concerns today are the declining rate of food self-sufficiency and a growing sense of the potential for disruption to domestic food supplies in an uncertain world (climate change, energy security, safety concerns over imported food, geopolitical tensions and the food price spike in 2008 and 2010). We face a future of food scarcity, with high, albeit very volatile prices both for inputs and outputs. Food scarcity is aggravated by managed trade and lack of finance and eventually also by environmental degradation. More responsibility is needed regarding food trade, and more responsibility in cutting GHG emissions. Well-functioning markets can help to reduce this risk. Domestic food supplies are not less risky than imports (energy), but it is sensible to plan for systemic risks (such as nuclear fallout, port strikes, etc.). We experience food poverty due to a lack of entitlements, not lack of food availability.

If there is going to be enough food at affordable prices for the global population, we may also have to change our food habits and decrease food waste. Globally, an average of 35% of crop yields are lost to pre-harvest pests. In some developing countries pre-harvest losses can go as high as 70%. The conservation of fertile soils, the development of high-yielding varieties and the reduction of current yield losses caused by pests, pathogens, and weeds are major challenges to agricultural production Whilst technology will undoubtedly hold many of the keys to long term global food security, the development and testing of new varieties or techniques takes time. It may be 10 years or more before people see the benefits. However, there is a lot we can do today with existing knowledge. Part of the key is also to avoid waste along the whole length of the food chain. In addition to the pre-harvest losses (35% of crop yields) transport, pre-processing, storage, processing, packaging, marketing and plate waste losses are relatively high too (Figure 1). We can save also water by reducing losses in the food chain. The insects, weeds and microbial pests cause the most problems but research, education and training can play a key role in helping the world lose less after harvest along the food chain.

Helping farmers lose less of their crops will be a key factor in promoting food security, but even in the poorest countries those rural farmers aspire to more than self-sufficiency. They want to improve their livelihoods so as to buy higher quality, more nutritious food and to afford a better standard of living, healthcare and education. So we also need to build the knowledge and skills that will help them earn more for their crops. In an increasingly global food system, this is about quality as well as quantity.



Source: IWMI (2007)
Figure 1. Losses along the food chain

World population growth is the biggest challenge: 75 million more people a year, rising to 9 billion by 2050. Consequently, there is a rapidly growing demand for crop products, including feed with increasing meat consumption. Other major global trends are globalisation, urbanisation and motorisation. With production moving to the most competitive regions, food trade is becoming more liberalised but also more concentrated. Growing energy demand and climate change will also influence food production, with agriculture contributing to emissions; agriculture will also suffer or benefit from changing climates depending on climatic zones. Additional challenges are increasing market volatility, resulting from yield and end stock fluctuations and consumer sensitivity to food quality, safety and price. There is uncertainty regarding the timing and application of innovations as regards biotechnology, nanotechnology, precision farming, carbon sequestration, and information technology. These challenges are aggravated by global irresponsibility, regarding food and energy security, water and environmental sustainability.

There is good potential for new land cultivation in Latin America, Africa and Eastern Europe (Ukraine and Russia). However, new land is insufficient, and either inappropriate because of poor or polluted soils, or difficult to use for food production (due to doubtful property rights and/or poor finance and/or due to government mismanagement and lack of transportation infrastructure). Moreover, cultivated land is diminishing fast, not just because of expanding deserts, but also because much of it is being lost to urbanisation and motorisation. The addition of some 75 million people every year claims nearly 3 million hectares for housing, roads, highways and parking lots. The main reasons why world food supply is tightening are population growth and accelerated urbanisation and motorisation[1], changes in lifestyles, falling water tables and diversion of irrigated water towards the cities (The Earth Institute, 2005). All this leads to losses in soil availability, quality and use for food production.

By 2050, global food output must increase by about 70% due to higher food demand, changing diets towards high quality food, urbanisation and Motorisation. Urbanisation will double domestic and industrial water use, not to mention climate change and bioenergy production. Without water productivity gains, crop water consumption will double by 2050 *(Table 2).* The water "bubble" is unsustainable and fragile because 7 billion people at present have to share the same quantity of water as the 300 million global inhabitants of Roman times. About 80% of water for food production comes directly from rain, but an increasing part is met by irrigation (IWMI, 2007).

Table 2. Water security

Water use	***Litres of water***
Drinking water	2-5 litres per person per day
Household use	20-500 litres per person per day
Wheat	500-4 000 litres per kilo
Meat	5 000-15 000 litres per kilo
Biofuel	1 000-3 500 litres per litre
Cotton t-shirt	2 000-3 000 litres
Agriculture	3 000 litres per person per day 1 litre per calorie

Source: IWMI (2007)

Both the physical water productivity (more crop per drop) and economic water productivity (more value per drop) have to be increased by investing in rainfed agriculture and irrigation. Water productivity improvement is feasible, but farmers optimise land productivity rather than returns to water, particularly where water is subsidised. We do not know what the adequate incentives are, but farmers in the EU are fighting for a higher irrigation water subsidy without impact analysis of water productivity improvement. Promoting food trade from water rich, highly productive areas to water scarce areas contributes to global water productivity improvement.

To meet world demand the necessary production growth will, to a large extent, have to be met by a rise in the productivity of the land already being farmed today. However, this will be difficult to accomplish as global agricultural productivity growth has been in decline since the Green Revolution of the 1960s and 1970s. Global crop yield increases have plummeted from 4% per annum in the 1960s to 1980s to 2% in the 1990s, and, to barely 1% in 2000 to 2010 (FAO, 2008). Yield increases have generally exceeded areal increases. While substantial expected yield increases in India, the USA, Russia and Ukraine are expected in the future, Europe's role and share as supplier of food to the world is diminishing. The net crop-trade position of the EU-27 can be expected to deteriorate. The EU's capacity to help fight world starvation will be reduced at a time in which food production will decline predominantly in those countries which already have record increasing food import needs.

The sharp rise in prices of basic foodstuffs created extreme difficulty for a large part of the world. Those who have been most affected by the sharply rising food prices are those who spend a larger share of their income on food. One indication of it is the remarkable amount of civil unrest and political instability that happened in 2008 and 2010 in dozens of countries (Ethiopia, Egypt, Mexico, Thailand, Tunesia, Lybia, Syria, etc.), as people were unable to afford basic nutrition. There were also some extraordinary political responses. Much of the world's system of trade in foodstuffs broke down temporarily as food exporting countries moved to limit, or in some cases completely ban exports in an attempt to provide some protection to their domestic consumers (*Krugman,* 2009).

International trade in commodities futures has expanded enormously; food and commodity prices went up very sharply in 2008, and then fell significantly. Trading commodity futures only affects the price to the extent that speculation leads to withdrawal of real supplies, which leads to hoarding. However, that was not the case with agricultural commodities, as food stocks were at record lows at that time. It is not correct that it was a speculative bubble. The rise and fall of commodity prices affected not only commodities with large futures, but those without such as iron ore or oil. Trading commodity futures only affects the price to the extent that speculation leads to withdrawal of real supplies, which leads to hoarding. However, that was not the case with agricultural commodities, as food stocks were at record lows at that time. With an economic slump, the real price of commodities always falls and *vice versa*. The great depression showed a spectacular collapse of agricultural prices. The fall in prices in 2008 was the consequences of a global recession. With the end of crisis, resource constraints plus bad policies has created a major problem for the supply of food in the world. Aside from food prices being still on an upward trend, price volatility is a clear problem. People do not eat only in the long term, they eat every day. High prices from 2008 re-occurred in 2010, which is a very serious problem, as people are very vulnerable to such high prices.

[1]An estimated 40 000 ha of land are needed for basic living space for every one million people added and 20 000 ha of land for every 1 million vehicles added.

The poor have no access to ways of diversifying risk and they have no protection against high food prices. What can be done at this point? One thing is to invest in future food production and this includes both physical and R&D. We tend to think of agriculture as being an economics one on one – market producers and consumers getting the market right. This is true only up to a point. Agricultural production and progress in production depends heavily on public goods, especially R&D. There has been much less emphasis on this research and physical infrastructure for agriculture in recent years largely because people thought these problems were solved. It looks like we have seriously underinvested and need to play catch up (*Krugman,* 2009).

With the end of recession, we are back in a world that has a growing population, growing purchasing power and a growing consumption of foods heavily reliant on cereals for their production. For example, meat uses a lot more basic agricultural production than does the consumption of grain. Water is a concern and so too is the use of potential arable land. When arable land is diverted to non-agricultural uses, it usually raises world GDP, but it also has the effect of reducing the incomes of those already at the bottom of the earning scale. We face a very serious outbreak of human suffering and political instability resulting from a increasing food price of food. There are no such mechanisms in place yet to deal with these issues.

2. Energy security

Energy prices have seen a steady decline (in constant dollars) over the last 200 years. The latest energy price hikes have not even brought us back to the price levels of some 30 years ago. The tragic reality is that political zeal has led governments to keep energy prices as low as possible, thus frustrating most attempts to increase energy productivity. Energy price elasticity is very much a long-term rather than a short-term affair, yet the investments in infrastructure that are crucial to the creation of an energy efficient society are very long term. Creating a long-term trajectory of energy prices that slowly, steadily and predictably rise in parallel with our energy productivity would give a clear signal to investors and infrastructure planners that energy efficiency and productivity are going to become ever more necessary and profitable (*Krugman,* 2009).

There is much debate about the potential contribution of agriculture to renewable energies. The problem is that with existing technology, renewable energies may be renewable, but they are mostly not green. Whether second generation biofuels can escape most of the pitfalls of the first generation is open to doubt, although admittedly they do not use the food component of plants.

Biofuels

Bioenergy covers approximately 13% of total world energy supply. Traditional unprocessed biomass accounts for most of this, but commercial bioenergy is assuming greater importance. Liquid biofuels for transport are generating the most attention and have seen a rapid expansion in production. However, quantitatively their role is only marginal; they cover 2% of total transport fuel consumption and 0.5% of total energy consumption worldwide. Large-scale production of biofuels implies large land requirements for feedstock production. Liquid biofuels can therefore be expected to displace fossil fuels for transport to only a very limited extent. Even though liquid biofuels supply only a small share of global energy needs, they still have the potential to have a significant effect on global agriculture and agricultural markets, because of the volume of feedstocks and the relative land areas needed for their production.

The contribution of different biofuels to reducing fossil-fuel consumption varies widely when the fossil energy used as an input in their production is also taken into account. The fossil energy balance of a biofuel depends on factors such as feedstock characteristics, production location, agricultural practices and the source of energy used for the conversion process. Different biofuels also perform very differently in terms of their contribution to reducing greenhouse gas emissions. Second-generation biofuels currently under development use lignocellulosic feedstocks such as wood, tall grasses, and forestry and crop residues. This should increase the quantitative potential for biofuel generation per hectare of land, and could also improve the fossil energy and greenhouse gas balances of biofuels. However, it is not known when such technologies will enter production on a significant commercial scale.

Liquid biofuels such as bioethanol and biodiesel compete directly with petroleum-based petrol and diesel. Because energy markets are large compared with agricultural markets, energy prices will tend to drive the prices of biofuels and their agricultural feedstocks. Biofuel feedstocks also compete with other agricultural crops for productive resources; therefore energy prices will tend to affect prices of all agricultural commodities that rely on the same resource base. For the same reason, producing biofuels from non-food crops will not necessarily eliminate competition between food and fuel. For certain technologies, the competitiveness of biofuels will depend on the relative prices of agricultural feedstocks and fossil fuels. The relationship will differ among crops, countries, locations and technologies used in biofuel production.

Biofuel development in developed countries has been promoted and supported by governments through a wide array of policy instruments; a growing number of developing countries are also beginning to introduce policies to promote biofuels. Common policy instruments include the mandated blending of biofuels with petroleum-based fuels, and subsidies. The exact contribution of expanding biofuel demand to these price increases is difficult to quantify. However, with increasing oil prices, biofuel demand will continue to exercise upward pressure on agricultural prices.

Modern bioenergy represents a new source of demand for farmers' products. At the same time, it generates increasing competition for natural resources, notably land and water, especially in the short run, although yield increases may mitigate such competition in the longer run. Competition for land becomes an issue especially when some of the crops (*e.g.* maize, oil palm and soybean), that are currently cultivated for food and feed, are redirected towards the production of biofuels, or when food-oriented agricultural land is converted to biofuel production. Biofuel policies have significant implications for international markets, trade and prices for biofuels and agricultural commodities. Current trends in biofuel production, consumption and trade, as well as the global outlook, are strongly influenced by existing policies. Policies implemented in the EU and USA, which promote biofuel production and consumption, while protecting domestic producers especially in case of ethanol production, typically exert much influence.

Trade policies *vis-à-vis* biofuels discriminate against developing country producers of biofuel feedstocks, and impede the emergence of biofuel processing and exporting sectors in developing countries. Many current biofuel policies distort biofuel and agricultural markets and influence the location and development of the global industry, such that production may not occur in the most economically or environmentally suitable locations. International policy disciplines for biofuels are needed to prevent a repeat of the kind of global policy failure that exists in the agriculture sector.

There are three traditional biofuels options: bioethanol, biodiesel and biogas. Each differs in terms of feedstock source, net energy yield per hectare and investment cost. The net energy yield per hectare with biogas can be much higher than with bioethanol production, provided the entire crop is fermented in the biogas plant. However, bioethanol would come closer to the net energy yield of biogas when cellulose is fermented to alcohol. Additionally, the investment costs are much higher for biogas than for bioethanol.

These differences explain why bioethanol is predominantly produced in countries with an abundance of agricultural areas, such as the USA or Brazil. The analysis of ethanol production from maize in the USA is totally different from that from sugarcane in Brazil due to the availability of land, energy conversion rates and technologies used. In more densely populated regions such as the EU, farmland is more expensive. Therefore, the net energy yield per unit area is more important and, thus, so is biogas production. Additionally, the population density results in more waste from food use and livestock production. The more expensive the farmland – and the more waste and manure available – the more attractive option biogas may become.

The main challenge of the biofuels industry in the coming years is how to cope with relatively low fuel prices. The longer-term outlook for fuel prices however remains bullish. The question for the biodiesel sector will be – how many companies will survive the hard times? An adjustment in production capacity seems inevitable and manufacturers which are part of conglomerates and/or are integrated in the value chain usually have better chances of survival.

The economics of first generation biofuels are location specific – as are environmental benefits. Both the USA and the EU have many of the same players supporting and resisting biofuels growth. The EU appears to be further ahead in raising issues of sustainability, including mitigating the threat to biodiversity, the effect on climate change, and concerns related to food supply. However, these issues are gaining attention on both sides of the Atlantic. The growth of biofuels and the impending evolution to second-generation biofuels present considerable challenges in terms of policy development, trade and certification of sustainability. Heretofore, these issues have been dealt with on a "local" basis; but the time has come to take a global approach as well.

Is there any market relationship between the agriculture of foodstuffs and that of energy? Is there available land? Biofuels are not the primary driver affecting worldwide food prices. However, the role of biofuels in food prices is increasing. At present, feedstock for biofuel occupies just 1-2% of global cropland. Rising population, changing diets and demand for biofuels will increase demand for cropland. The balance of evidence indicates there will be sufficient appropriate land available to meet this demand to 2020, but this must be confirmed before global supplies of biofuel increase significantly. Current policies are not entirely effective in assuring that additional production moves exclusively to suitable areas – and attempts to do so will face challenges in terms of implementation and enforcement. Governments should amend but not abandon biofuel policy in an effort to recognise these issues and ensure their policies deliver net GHG benefits.

An increase in the use of grains for fuel ethanol occurred, mainly due to a higher output in the USA and Europe. Net use of grains for fuel ethanol is about 6%, as ethanol yields dried distiller grains (DDGS) as by-product (F.O. Licht, 2011). The bulk of the worldwide use of grains in alcohol production comprises maize in the USA and China. The share of biodiesel in total vegoils use is around 11%. What about the impact on use of agricultural land? In Brazil, sugarcane is grown on 2.5% of the arable land and 1.5% of arable land is dedicated to ethanol production. In the USA, according to the Renewable Fuels Mandate, 136 billion litres of biofuels will be needed by 2022 requiring feedstock production on up to 15% of total arable land (own calculation). In the EU, by 2020 the 10% of biofuel impact on land use means that 15% of EU-27 total arable land will be used for biofuel feedstock production (EC, 2009).

The development and evolution of trade rules regarding biofuels is becoming a pivotal issue in both the EU and the USA. Europe is questioning biofuel production on agricultural lands. While the USA has more land, it does appear that substantial farmland could be made available in new EU Member States. Otherwise, biofuels will need to be supplied by countries outside the EU. The existence of a global market of food and biofuel requires the development of expertise in building agribusiness systems that are increasingly transnational and sustainable. This global biofuel market will involve more production, compulsory legislation and the standardisation and certification of the ethanol itself. Market structure has been influenced by policy, so strengthening the market is essential. Stakeholders focus on their local markets first (the concept of "home grown" is attractive) and international investment in biofuels has been limited. Oil prices are largely demand driven, but global recession has led to significant price falls. Investments in alternative energy sources are risky in this environment without policy measures that ensure against major drops in oil prices. Policy is a key to promote sustainable biofuel trade. At present, uncertain classification, a wide range of government measures (tax incentives, tariffs, subsidies), and a web of varying technical and environmental standards do not facilitate trade.

It should be possible to establish a genuinely sustainable biofuels industry, provided that robust, comprehensive and mandatory sustainability standards are developed and implemented. The risks of indirect effects can be significantly reduced by ensuring that the production of feedstock for second-generation biofuels takes place mainly on idle and marginal land – and by encouraging technologies that take best and appropriate advantage of wastes and residues. Sustainable production is being increasingly regarded as a prerequisite for market access. Sustainability certification has three main dimensions: environmental, economic and social. A schematic for certification must overcome the difficulty inherent in measuring and verifying what, in many cases, are aspirations or principles. Certification requires an institutional environment with requirements that can be effectively and consistently implemented, and an organisational environment that supports reliable monitoring and evaluation.

The main initiative for certification of biofuels has come from national governments, private companies, non-governmental organisations and international organisations. Most are in the early stages, while other may come into force in the near term. There is considerable variance in terms of the principles they include and the procedures and organisational processes involved. And most are based on existing systems for the agriculture, forestry or energy sectors. This certification system must cover all biomass (regardless of the end use) and all relevant bioenergy – and it must take a global approach as biomass and bioenergy sources become internationally traded commodities. Systems that focus simply on national or EU-wide implementation, for example, will not help solve major sustainability issues. Additionally, the system must take a holistic approach or risk forfeiting all relevance. For example, if the relatively small quantities of palm oil used for biodiesel production are produced in a sustainable manner, but the large volumes consumed in the food sector are not, all the effort expended would be invalidated. As certification criteria are considered, each country should prioritise the areas of law, production and products, communications, distribution and logistics, and human resources. Higher targets for biofuels in the marketplace should be implemented carefully to ensure these fuels are demonstrably sustainable. Any criterion related to competition, or demanding more than just a reporting obligation, could potentially lead to an infringement of the World Trade Organization (WTO) rules.

Long-term strategy is needed to incorporate biofuels into the energy supply chain. Fixed mandates can amplify price volatility by drawing down stocks. Inflexibility caused by mandates should be addressed: variable mandates would contribute to protect consumers from shocks to food supplies or changes in biofuels mandates and from shocks that increase petroleum prices. A switch to second generation feedstocks is a relatively inflexible commitment: diversion to food is expensive. Biofuels production may increase even in the absence of mandates at oil prices above USD100/barrel. Removing trade distortions and investing in R&D of advanced biofuels will contribute to reducing reliance on fossil fuels without jeopardising food security. However, improved regulation, functioning and transparency of food and fuel policy is needed.

3. Environmental security

Biodiversity losses have accelerated, most notably in the tropics. The depletion of fisheries and fish stocks has continued, and in some cases has accelerated. China's growing appetite for mineral and energy resources in Africa and elsewhere is cause for concern, and India, Brazil, South Africa, Angola and others are all aiming to fuel their high growth rates with accelerating resource extraction, and there is no end in sight to this trend.

In terms of climate change and the overall ecological situation, the picture is even grimmer. By adopting the right policy mix, we can decouple wealth creation from energy and material consumption just as we decoupled wealth creation from the total number of hours of human labour. That was the great achievement of the industrial revolution, and labour productivity has risen at least twentyfold in the course of mankind's last 150 years of industrialisation. Resource productivity should become the core of our next industrial revolution. Technologically speaking, this should not be more difficult than the rise in labour productivity.

We now start to recognise that the (over)exploitation of our entire ecosystem and the depletion of natural resources (the reserve/production ratio of oil reserves is rapidly declining) must carry a price which must be paid today to compensate future generations for the loss (or costs of substitution) they will be faced with tomorrow. Moreover, world population growth by 30% during the next 40 years, causing new scarcities (*e.g.* water) and pollution (*e.g.* CO_2 emission rights), is reinforcing this issue. Corporations in energy-intensive sectors need to start taking future CO_2 prices into account in their investment decisions and public disclosure policies now. Because the scarcity of emission rights has been recognised, an active market has been created in the EU and CO_2 emission rights now have a price; more regional cap and trade markets for CO_2 have been (in the USA), or are in the process of being created.

The EU has taken the political lead in addressing global warming, setting up the European Trading System (ETS) for CO_2 emissions. The USA has given clear commitments to mitigating global warming, and China too has become very serious about tackling pollution, climate change and energy efficiency. Renewable energy sources now constitute a dynamic growth sector, and the Convention on Biological Diversity (CBD) is enjoying increasing visibility in the signatory states which means nearly all countries around the world except the USA.

The foundations for a new wave of growth based on the technologies for a low carbon economy is of great importance. The investments would drive growth over the next two or three decades, ensuring it becomes sustainable. Providing a strong, stable carbon price is the single policy action that is likely to have the biggest effect in improving economic efficiency and tackling the climate crisis. Lord Stern calculated that governments should spend at least 20% of their stimulus on green measures to achieve the emission targets (*Stern,* 2006).

The environmental resource scarcity issues also still look entirely real. Depending on the extent of climate changes, many agricultural patterns may become disrupted, and the poorest countries are the ones most vulnerable in the face of this. In the long term, environmental security is the mirror image of food security, because there is no food without substantial clean water resources, productive soils, and appropriate climate. In turn, failure to tackle environmental degradation jeopardises the future of agriculture and the countryside. Climate change puts all businesses and society at cumulative, long-term risk. The failure of agriculture alone would lead to widespread hunger in developing countries and mass migration of people (half a billion according to the UN), mostly to developed countries.

The search for more environmentally friendly agricultural inputs and practices must continue. Scientists are working to improve the efficiency of photosynthesis, carbon capture, nitrogen fixation and many other cellular processes that boost biomass yields. It may also become possible to plant crops in soils lost to salinisation, and develop genetically modified plants that can grow in marginal or otherwise unusable farmland.

Mankind is directly influenced by the loss of biodiversity. With the extinction of species we lose possibly crucial opportunities and solutions to problems of our society. Biodiversity provides us directly with essentials like clean water and air, fertile soil, and protects us from floods and avalanches. These aspects can all be economically valued. It is a difficult and complex task, but through this valuation it becomes clear how important they are for human well being and economic development *(Table 3).*

Many people are unaware of the speed at which we are using up our natural resources, and that we are producing waste far faster than it can be recycled. It is important to clarify the items of public goods and services with arguments whether or not market failures are linked to the provision of services. Market failure is a crucially important justification for taking measures to protect our landscapes. Corrections in market failures could also be achieved through investments and the provision of payments to reward land managers who provide public goods and services (EC, 2008).

It is important to demonstrate the economic value of ecosystem goods and services. We not only need to know costs, but also to be assured of the benefits. There is increasing consensus about the importance of incorporating these "ecosystem services" into resource management decisions, but quantifying the levels and values of these services has proven difficult.

Our research has revealed a disappointingly small set of attempts to measure and value these services (Amstrong-Brown *et al*. 2009). Chronologically the first is the quantification of global ecosystem services by Constanza *et al. (*1997). Estimates were extracted from the literature of values based on willingness to pay for a hectare's worth of

Table 3. Scenario of the future: 2050

Actual	2000	2010	2050	Difference	Difference	Difference
Area	**million km²**	**million km²**	**million km²**	**2000 to 2010**	**2010 to 2050**	**2000 to 2050**
Natural areas	65.5	62.8	58.0	-4%	-8%	-11%
Bare natural	3.3	3.1	3.0	-6%	-4%	-9%
Forest managed	4.2	4.4	7.0	5%	62%	70%
Extensive agriculture	5.0	4.5	3.0	-9%	-33%	-39%
Intensive agriculture	11.0	12.9	15.8	17%	23%	44%
Woody biofuels	0.1	0.1	0.5	35%	437%	626%
Cultivated grazing	19.1	20.3	20.8	6%	2%	9%
Artificial surfaces	0.2	0.2	0.2	0%	0%	0%
World Total	108.4	108.4	108.4	0%	0%	0%

Source: Braat et al. (2008), Cost of Policy Inaction, OECD, COPI.

each of the services. These were all expressed in 1994 USD per hectare and there was some attempt to adjust these values across regions by purchasing power. The results were that central estimate of the total value of annual global flows of ecosystem services in the mid 1990s was USD 33 trillion (*i.e.* 10^{12}) and the range was thought to be USD 16-54 trillion. To put this figure into some kind of context, their central estimate was 1.8 times bigger than global Gross Domestic Product (GDP) at that time. We should take the figures only as the roughest of approximations – indeed the authors warn of the huge uncertainties involved in making calculations of this kind.

The "Stern Review" parallels "The Economics of Ecosystems and Biodiversity (TEEB) study into the economics of climate change (Stern, 2006). Climate change could have very serious impacts on growth and development. The costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly. The review estimates that if we do not act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year. Key to understanding the conclusions is that as forests decline, nature stops providing services which it used to provide essentially for free. So the human economy either has to provide them instead, perhaps through building reservoirs, building facilities to sequester carbon dioxide, or farming foods that were once naturally available.

The World Wildlife Fund's "Living Planet" Report demonstrates that mankind is living way beyond the capacity of the environment to supply us with services and to absorb our waste (WWF, 2008). They express this using the concepts of ecological footprints and biocapacity, each expressed per hectare per person[2]. Humanity's footprint first exceeded global biocapacity in 1980 and the overshoot has been increasing ever since. In 2005 they calculated the global footprint on average across the world was 2.7 global hectares (gha) per person[3] compared to a biocapacity they calculated as 2.1 gha per person; a difference of 30%. That is, each person on earth is on average consuming 30% more resources and waste absorption capacity than the world can provide. We are therefore destroying the earth's capacity and compromising future generations.

The study on TEEB is fundamentally about the struggle to find the value of nature. There are about 100 000 terrestrial protected areas on Earth, covering 11% of the land mass of our planet. These protected areas provide ecosystem services and biodiversity benefits to people valued at USD 4.4 trillion to USD 5.2 trillion (*i.e.* million millions) per annum. As a comparison, that is more than the revenues of the global car manufacturing sector, steel sector and IT services sector combined! Calculations show that the global economy is losing more money from the disappearance of forests than through the recent banking crisis, as forest decline could be costing about 7% of global GDP. It puts the annual cost of forest loss at between USD 2 trillion and USD 5 trillion. The figure comes from adding the value of the various services that forests perform, such as providing clean water and absorbing carbon dioxide. But the cost falls disproportionately on the poor because a greater part of their livelihood depends directly on the forest, especially in tropical regions. The greatest cost to western nations would initially come through losing a natural absorber of the most important greenhouse gas (EC, 2008).

The study shows that diversity is crucial for survival and the importance of biodiversity for economic development. It might be possible to substitute some of the ecosystem services by human-made technologies, but the study results clearly show that it is often cheaper to invest in the conservation of biodiversity than to invest in new technologies to substitute the services nature provides for us. Therefore, it is essential for the safeguarding of our natural resources to jointly create a co-ordination of economic interests. We need to give the ecosystem services of biodiversity a market value to create incentives for developing countries to conserve their biodiversity.

Market-based instruments are helpful for giving the peoples of the world a chance to secure the natural resources and secure their livelihood simultaneously. In this context the inclusion of the private sector into the process of conservation and sustainable use of biodiversity has high priority. The goals of conservation and sustainability will only be achieved if the main drivers of ecosystem and biodiversity loss are actually addressed through appropriate intervention and response based on credible valuations. Businesses have to accept biodiversity as the indispensable resource which it is and have to treat this resource with respect and care.

The Global Canopy Programme's report concludes*:* "If we lose forests, we lose the fight against climate change". International demand has driven the intensive agriculture, logging and ranching which have lead to deforestation. Standing forest was not included in the original Kyoto protocols and stands outside the carbon markets. The inclusion of standing forests in internationally regulated carbon markets could provide cash incentives to halt this disastrous process. Marketing these ecosystem services could provide the added value forests need and help dampen the effects of industrial emissions. Those countries wise enough to have kept their forests could find themselves the owners of a new billion-dollar industry (Parker *et al.*, 2008).

Currently, there are two paradigms for generating ecosystem service assessments that are meant to influence

[2] The Ecological Footprint "measures the amount of biologically productive land and water area required to produce the resources an individual, population or activity consumes and to absorb the waste it generates, given prevailing technology and resource management" (WWF, 2008).

[3] A global hectare is a hectare with a global average ability to produce resources and absorb wastes.

policy decisions. Under the first paradigm, researchers use broad-scale assessments of multiple services to extrapolate a few estimates of values, based on habitat types, to entire regions or the entire planet (Costanza *et al.*, 1997). This "benefits transfer" approach incorrectly assumes that every hectare of a given habitat type is of equal value – regardless of its quality, rarity, spatial configuration, size, proximity to population centres, or the prevailing social practices and values. Furthermore, this approach does not allow for analyses of service provision and changes in value under new conditions. By contrast, under the second paradigm for generating policy-relevant ecosystem service assessments, researchers carefully model the production of a single service in a small area with an "ecological production function" – how provision of that service depends on local ecological variables (Kaiser and Roumasset, 2002). These methods lack both the scope (number of services) and scale (geographic and temporal) to be relevant for most policy questions (Nelson *et al.*, 2009).

Spatially explicit values of services across landscapes that might inform land-use and management decisions are still lacking. Quantifying ecosystem services in a spatially explicit manner, and analysing tradeoffs between them, can help to make natural resource decisions more effective, efficient, and defensible (Nelson *et al.*, 2009). Both the costs and the benefits of biodiversity-enhancing land-use measures are subject to spatial variation, and the criterion of cost-effectiveness calls for spatially heterogeneous compensation payments (Drechsler and Waetzold, 2005). Cost-effectiveness may also be achieved by paying compensation for results rather than measures. We have to ensure that all possibilities for creating markets to provide environmental services are fully exploited to minimise the public costs (and the extent of government bureaucracy etc).

Creating markets for environmental services could encourage the adoption of farming practices that provide cleaner air and water, and other conservation benefits. Products expected to generate the greatest net returns are the ones generally selected for production. Since environmental services generally do not have markets, they have little or no value when the farmer makes land-use or production decisions. As a result, environmental services are under-provided by farmers. The biggest reason that markets for environmental services do not develop naturally is that the services themselves have characteristics that defy ownership. Once they are produced, people can "consume" them without paying a price. Most consumers are unwilling to pay for a good that they can obtain for free, so markets cannot develop. Can anything be done other than relying on government programmes to provide publicly funded investments in environmental services?

Governments play a central role in creating markets for environmental services, as has been done for markets in water quality trading, carbon trading and wetland damage mitigation. These markets would not exist without government programmes that require regulated business firms (such as industrial plants and land developers) to meet strict environmental standards. In essence, legally binding caps on emissions (water and carbon), or mandatory replacement of lost biodiversity (wetland damage mitigation) create the demand needed to support a market for environmental services. So-called cap and trade programmes create a tradable good related to an environmental service (Ribaudo *et al.*, 2008).

Mandatory reduction pledges can be experienced in all developed nations apart from the USA. The same is true for project-level reductions in developing countries. Mandatory cap-and-trade programmes have been introduced in north eastern USA and EU. The USA and Australian governments announced that they will also institute a mandatory cap and trade programme to create financial incentives to limit energy use or reduce emissions.

In the case of water quality, it is necessary to establish caps on total pollutant discharges from regulated firms in some watersheds, and issue discharge allowances to each firm specifying how much pollution the firm can legally discharge. In markets for greenhouse gases, carbon credits are exchanged. Contracts also include renewable energy credits and voluntary carbon credits.

No-net-loss requirements for new housing and commercial development require that damaged/lost wetland services be replaced, creating demand for mitigation credits, which are produced by creating new wetlands. In all of these cases, the managing or regulatory entity defines the tradable good and enforces the transactions.

Simply creating demand for an environmental service does not guarantee that a market for services from agricultural sources will actually develop. A number of impediments affect agricultural producers' ability to participate in markets for environmental services. Purchasers may be unwilling to enter into a contract with a farmer who cannot guarantee delivery of the agreed-upon quantity of pollution abatement, wetlands services, or other environmental service. Some markets prevent uncertain services from being sold. For example, the Chicago Climate Exchange does not certify credits from soil types for which scientific evidence is lacking on the soil's ability to sequester carbon. Transaction costs can also undermine the development of markets for environmental services (Ribaudo *et al.*, 2008).

If markets are to become important tools for generating resources for conservation on farms, government or other organisations may have to help emerging markets overcome uncertainty and transaction costs. Government can reduce uncertainty by setting standards for environmental services and can play a major role in reducing uncertainty by funding research on the level of environmental services from different conservation practices. For example, the government can develop an online Nitrogen Trading Tool to help farmers determine how many potential nitrogen credits they can generate on their farms for sale in a water quality trading programme.

While markets have many desirable properties, they are limited in what they can accomplish, even with government assistance. Public good characteristics that defy ownership discourage markets for environmental services from developing – and prevent the full value of environmental services from being reflected in prices The prices of credits in water, carbon, and wetland markets also may not reflect their full social value, only their value to the regulated community. A national cap-and-trade programme could establish a national market for carbon credits. Others, such as water quality trading or wetland damage/loss mitigation, may be limited to a few specific geographic areas.

Enthusiasm can be observed for green public procurement, linked to certification/labelling, and supported by due information on embedded water/carbon/biodiversity or simply guidance to help public procurers buy less biodiversity harmful goods/commodities. It is a useful stepping stone towards due biodiversity reflective procurement in public sector establishments in due course (schools, hospitals).

"Ecosystems" markets will change the present, economics-only value-paradigm, with winners and losers. As an example, countries and companies with significant carbon-sink potential will benefit. On the other hand, applying the "polluter pays" principle, CO_2 emitters must pay a price for continuing to be able to do so. The concept of limiting (capping), auctioning and trading emission/ access/user rights must be further developed beyond CO_2, in scope (*e.g.* water) and scale (worldwide). On the basis of valuing our ecosystems and regulating the access thereto, a market will be created for payment for ecosystem-access entitlements and for ecosystem services. We really need to upgrade our performance metrics. The same is true with respect to human/social capital: also here the metrics, the value of education, culture, social cohesion, etc. should be established and more prominently included in investment/ development decisions.

4. Conclusion

Limited land is available globally to grow crops for food and fuel. There are direct and indirect pressures on forests and other lands to be converted from growing food for feedstock to be used for biofuel production. The balance of evidence indicates there will probably be sufficient appropriate land available to meet demands for both food and fuel, but this needs to be confirmed before global supply of biofuel is allowed to increase significantly. There is a future for a sustainable biofuels industry, but feedstock production must avoid encroaching on agricultural land that would otherwise be used for food production. And while advanced technologies offer significant potential for higher greenhouse gas (GHG) savings through biofuels, these will be offset if feedstock production uses existing agricultural land and prevents land-use change. GHG savings can be achieved by using feedstock grown mainly on marginal land or that does not use land, such as wastes and residues (although this may compete with other uses of these materials). To ensure that biofuels deliver net GHG benefits, governments should amend, but not abandon, their biofuel policies in recognition of the dangers from indirect effects of land-use changes. Large areas of uncertainty remain in the overall impacts and benefits of biofuels. International action is needed in order to improve data, models and controls, and to understand and to manage effects. These challenges are aggravated by global irresponsibility, regarding water and environmental sustainability. Finally, there is the challenge of who will pay for agricultural public services provided by land managers that the market does not pay for, such as rural landscape maintenance, environmental protection, biodiversity and animal welfare.

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