DISCUSSION PAPER

Safeguarding and Enhancing the Ecological Foundation of Agricultural and Food Systems to Support Human Well-Being: *Bridging the Implementation Gap*

Fiona McKenzie and Ralph Ashton

February 2012

TABLE OF CONTENTS

This discussion paper has been prepared for the United Nations Environment Programme to inform discussions with key stakeholders, including at a meeting on 28 February 2012 in London hosted by The Prince's Charities' International Sustainability Unit and the World Bank. It is intended to aid discussion on the desired future for agricultural and food systems, and possible immediate and sustained action to transform our agricultural and food systems to support human well-being. It does not necessarily represent the views of UNEP. Please contact the authors with any feedback (fiona.mckenzie@sydney.edu.au).

Executive Summary

This paper reviews what we currently know about the state of agricultural and food systems, the trajectory the world is on and what we plan to do about it. It reviews the many existing definitions of 'sustainable agriculture' and the various initiatives and blueprints for steering the sector on a more sustainable course. It is evident that there exist many principles and recommendations for change. Some of the more common principles include:

- increasing productivity sustainably
- reducing resource intensity
- increasing investment
- reshaping food access and consumption patterns
- managing ecosystems within the limits of their functioning
- supporting smallholders
- innovation through science and technology
- reforming trade rules
- improving market access

The challenge is not necessarily to agree a common set of principles or even a single definition of sustainable agriculture. Given the abundance of both principles and definitions, the real challenge is to operationalise these concepts in meaningful ways – to bridge the implementation gap. How do we turn good intentions into action? What does is really mean to "reduce resource intensity" or "manage ecosystems within the limits of their functioning"? What needs to be done and who is best placed to do it – at all levels of the supply chain? What are investment priorities in the short versus the long-term? What transition pathways are necessary and possible?

If this paper can achieve one thing, we hope that it is to convey the message that it is time to move on from high-level statements. We need to make progress on bridging the implementation gap between rhetoric and action, across all levels of the supply chain and all components within global and national agricultural and food systems. If we are to change the trajectory that the world is on, then our thinking needs to move forward as well.

1. Where have we got to?

We already know a lot about the state of the agricultural sector globally, as it stands today. Many existing assessments have painted a picture of agricultural and food systems that are both rapidly changing and in rapid need of change. It is clear from these assessments that the trajectory we are currently on is unsustainable. Major trends, threats and opportunities abound. So where are we?

The demand for agricultural land continues

- Agriculture requires more land (40% of the world's terrestrial surface, water and human labour than any other industry (Kiers et al., 2008; PBL, 2009);
- Between 1985 and 2005 the world's croplands and pastures expanded by 154 million hectares (Foley et al., 2011);
- Between 1980 and 2000, more than half of new cropland came from intact rainforests and another 30 percent from disturbed forests (Gibbs, 2009);
- In the last two centuries, humans have cleared or converted 70% of the grassland, 50% of the savannah, 45% of the temperate deciduous forest, and 27% of the tropical forest biome for agriculture (Foley et al., 2011);
- Many regions of the world now face a shortage of land for additional cropland expansion (Morton et al., 2006);
- Globally, the average amount of arable land per person fell from 0.39 hectares in 1960 to 0.23 hectares in 2000 and 0.21 hectares in 2007 (Evans, 2010; FAO, 2009).

Demand for irrigated cropland is increasing

- In the past 50 years, the world's irrigated cropland area roughly doubled (Foley et al., 2011);
- The demand for irrigated land is projected to increase by 56% in Sub-Saharan Africa (from 4.5 to 7 million ha), and rainfed land by 40% (from 150 to 210 million ha) (Tweeton and Thompson, 2009; UNEP, 2009);
- Yields on irrigated croplands are, on average, 2–3 times higher than those on rainfed lands (UNEP, 2009);
- Groundwater overdraft in excess of sustainable levels exceeds 25% in China and 56% in parts of northwest India (Tweeton and Thompson, 2009).

Productivity growth is slowing down

- From 1961 to 2008, average annual growth rates of yields (output per hectare) for grains were 1.5% in developed countries and 2.1% in developing countries. Since 1985, there has been a reduction in these growth rates (Foresight, 2011);
- Up to 25% of world food production may be lost during the 21st century due to climate change, water scarcity, invasive pests and land degradation (Nellemann et al., 2009);
- Agricultural intensification has dramatically increased in recent decades, outstripping rates of agricultural expansion, and has been responsible for most of the yield increases of the past few decades (Foley et al., 2011).

Biological and genetic diversity is under threat

- About 32% of livestock breeds are under threat of extinction within the next 20 years FAO, 2009);
- About 75% of the genetic diversity of agricultural crops has been lost since 1900 (FAO, 2009);
- Over 4000 plant and animal species are threatened with extinction by agricultural intensification (Nellemann et al., 2009);

Intensification is increasing, along with environmental impacts

- The productivity of many intensive systems cannot be maintained with current management (World Bank, 2008; Khan and Hanjra, 2009);
- Intensification has caused water degradation, increased energy use, and widespread pollution (Foley et al., 2011);
- 70% of global freshwater withdrawals are devoted to irrigation (Foley et al., 2011);
- In the past 50 years, global fertilizer use increased by 500% causing water degradation, increased energy use and widespread pollution (Foley et al., 2011);
- Industrial agriculture now uses 2-3 times more fertilisers and 1.5 time mores pesticides for the production of 1 kilogram of food than it did 40 years ago (UNCTAD, 2010);
- Between 1961 and 1999, the production of pesticides increased by 854% (Green et al., 2005);
- Current farming practices are responsible for 3-5 million cases of pesticide poisoning and over 40,000 deaths every year (UNEP, 2011a);
- Over half a million tonnes of banned, obsolete and unwanted pesticides are threatening the environment and human health (FAO, 2009);
- More than 1 billion people already live in areas experiencing land degradation and productivity decline (Nellemann et al., 2009);
- More than 20% of the global land area is thought to be degraded, with much of this area concentrated in Africa south of the equator, South-East Asia and south China (Bai et al., 2008);
- Up to 40% of global crops lands may be experiencing some degree of soil erosion or reduced fertility (Foley, 2005)
- Depleted fisheries cause US $50 billion per year in lost economic benefit (World Bank and FAO, 2009)

Sources of competition for food, fuel and fibre are changing

- Globally, only 62% of crop production is allocated to human food, versus 35% to animal feed and 3% for bioenergy, seed and other industrial products (Foley et al., 2011);
- North America and Europe devote only about 40% of their croplands to direct food production, whereas Africa and Asia allocate typically over 80% of their cropland to food crops (Foley et al., 2011);
- Cropland is being converted to other uses due to increasing urbanization, industrialization, energy demand and population growth (Nellemann et al., 2009);
- The purchase of quality agricultural land by foreign actors is increasing, particularly in Africa and Asia (Anseeuw et al., 2012). In 2009, approximately 56 million hectares worth of large-

scale farmland deals were announced (although not all announced deals proceeded) (Deininger et al., 2010).

There are many inefficiencies in the food system

- Global fertilizer use reflects 'hotspots' of low nutrient use efficiency and large volumes of excess nutrients. Nutrient excesses are especially large in China, Northern India, the USA and Western Europe. Only 10% of the world's croplands account for 32% of the global nitrogen surplus and 40% of the phosphorus surplus - where more is used than required (Foley et al., 2011);
- Developing countries lose more than 40% of food post-harvest or during processing because of storage and transport conditions. Industrialized countries have lower producer losses, but at the retail or consumer level more than 40% of food may be wasted (PBL, 2009; Foley et al., 2011)

Food and nutrition insecurity continues

- 963 million people suffer from under-nutrition. This number will increase substantially without policy interventions (Nellemann et al., 2009).
- Worldwide obesity has more than doubled since 1980. In 2008, 1.5 billion adults, 20 and older, were overweight. 65% of the world's population now live in countries where overweight and obesity kills more people than underweight (WHO, 2011).
- Many initiatives have been launched to address food insecurity over time. Selected examples include:

2000	Millennium Declaration, including the Millennium Development Goals
2001	New Partnership for African Development (NEPAD)
2002	Comprehensive Africa Agricultural Development Programme (CAADP)
2002	G8 Africa Action Plan
2002	World Summit on Sustainable Development
2006	Millennium Villages Project
2006	Alliance for a Green Revolution in Africa (AGRA)
2008	World Development Report: Agriculture for Development
2008	L'Aquila Food Security Initiative (G8 Group)
2009	Conference on Trade and Development (UNCTAD)
2009	World Food Security Summit
2010	Updated Comprehensive Framework for Action (HLTF on the Global Food Security Crisis)
2011	G20 Action Plan on Food Price Volatility and Agriculture

Climate change will magnify existing pressures

- In the next two decades, climate change is predicted to cause major crop losses in the world's poorest regions (Kiers et al., 2008).

There are alternatives

- Sustainability-related global business opportunities in natural resources (including energy, forestry, food and agriculture, water and metals) may be in the range of US$ 2-6 trillion by 2050 (TEEB, 2010);
- Global sales of organic food and drink have recently been increasing by over US$ 5 billion a year, reaching US$46 billion in 2007 (TEEB, 2010);

- The global market for eco-labelled fish products grew by over 50% between 2008 and 2009, attaining a retail value of US$ 1.5 billion (TEEB, 2010);
- Between 1974 and 2008 the area cultivated using conservation agriculture grew 35-fold from just under 3 million hectares to more than 105 million hectares (FAO, 2009);
- The market for certified agricultural products was valued at US$40billion in 2008 (2.5% of global food and beverage market) and may increase to US$210 billion by 2020 (TEEB, 2010);
- Sales of certified 'sustainable' forest products quadrupled between 2005 and 2007 (TEEB, 2010).

Trade-offs and inter-linkages cannot be ignored

- Agricultural systems are increasingly linked to other sectors and trends, including the global energy system, human induced land use change, biodiversity, water scarcity and climate change (PBL, 2009).
- Changing the way we manage land not only requires changing the way we live, but changing the way we think. Energy and food are converging in a world where energy becomes food and food can become energy. More intensive farming practices usually mean more intensive energy use. Longer supply chains, transport and distribution infrastructure, biofuels and increased water use all drive these feedback loops (TCG, 2011).

2. The changing global food system

The global food system is undergoing rapid change. Agriculture is more than farms or farmers. Increasingly, it is characterised by the wider food supply chain, where the power of key actors is in a state of transition. Massive restructuring of the agri-food industry has seen greater vertical integration, the dominance of multinational corporations and changes in both the input and retail ends of the food system.

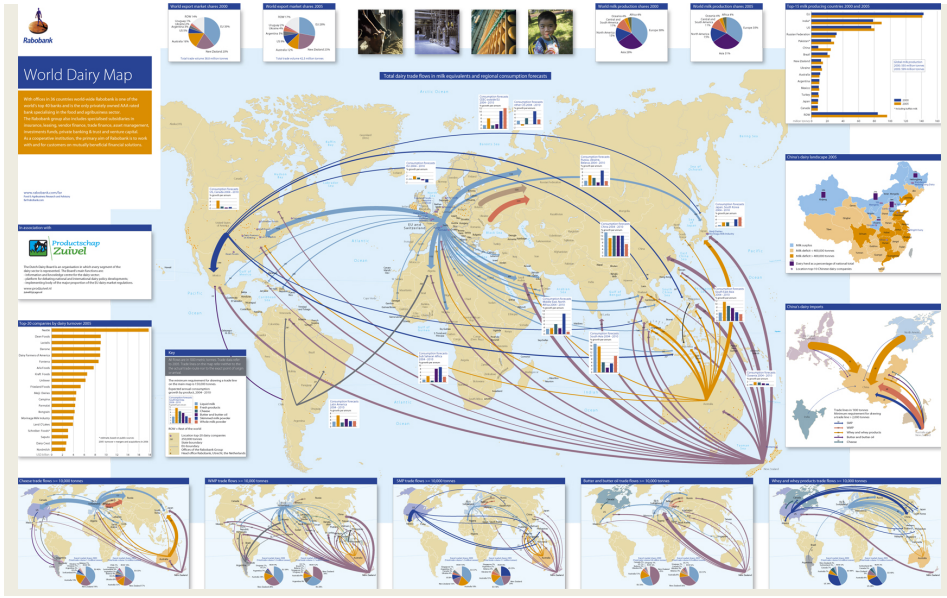
According to Nellemann et al., (2009) and UNEP (2011b), the economy of the corporate food supply chain has grown steadily over the past years. Between 2004 and 2006 total global food spending grew by 16% from US$5.5 to US$6.4 trillion.

- 50% of the commercial seed market is controlled by 4 companies
- 82% of the world pesticides business is controlled by 10 companies (including some which are also seed companies)
- 28% of the global food processing market is controlled by 10 companies
- 13% of the food retail market is controlled by 5 companies
- 30% of global food sales are through 15 supermarket companies

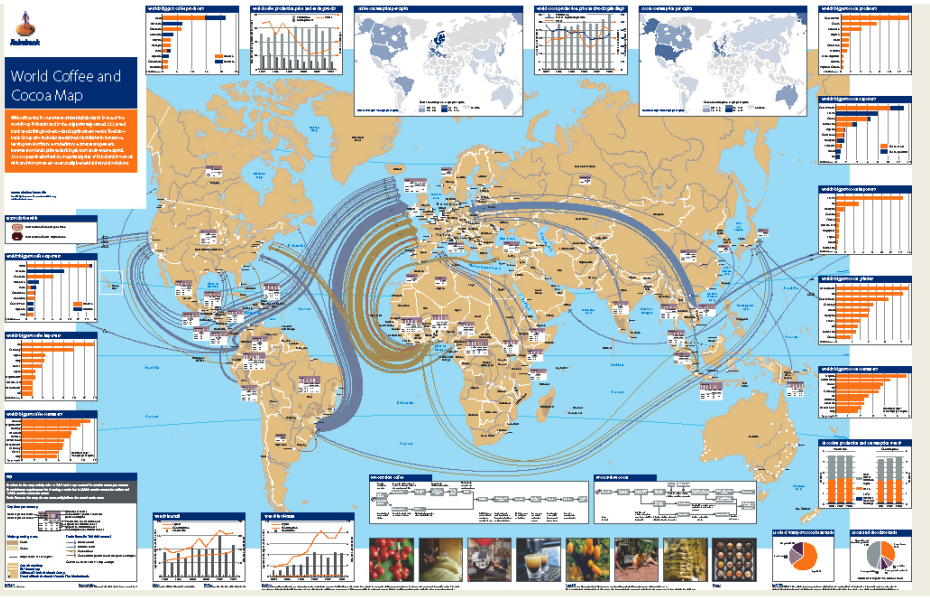
Together, approximately 50 companies could transform the global agricultural sector through their endorsement and support of green and sustainable farming practices.

The world is connected through food more than ever before. The following maps in Figure One show the global nature of key commodities such as dairy; coffee and cocoa; meat; and grains and oilseeds. These images are included not to focus on the numbers, but to show the level of geographical distribution and global connectedness.

FIGURE ONE – Global food supply chains

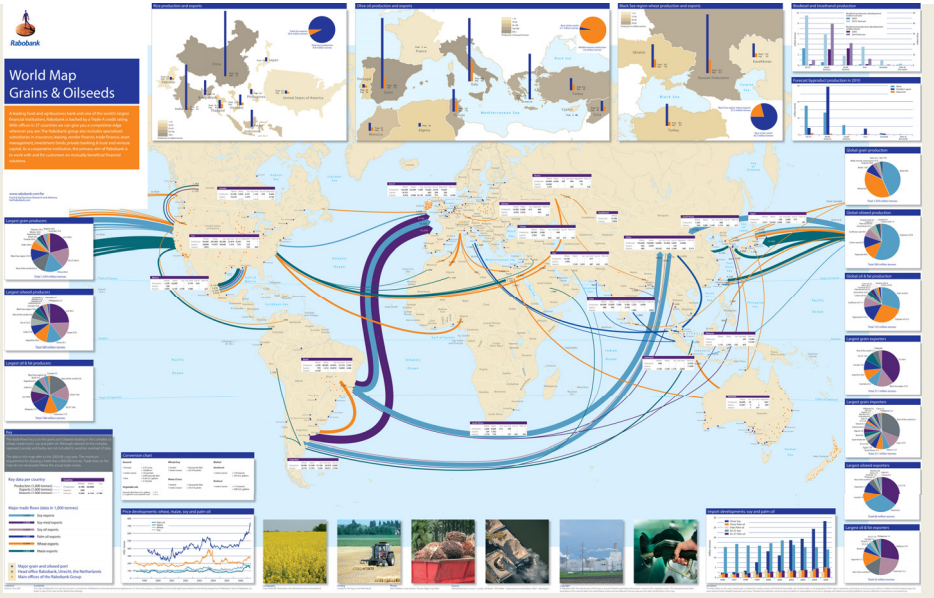


Dairy http://www.rabobank.com/content/images/DairyMap_tcm43-37597.jpg



Coffee & Cocoa http://www.rabobank.com/content/images/Coffee_tcm43-37607.jpg

Meat http://www.rabobank.com/content/images/MeatMap2006_tcm43-37599.jpg



Grain & Oilseeds http://www.rabobank.com/content/images/Map_full_tcm43-46836.jpg

Maps sourced from: Rabobank's Food & Agribusiness Research and Advisory Department http://www.rabobank.com/content/research/FoodAndAgriResearch/

3. Many definitions – many meanings?

Various umbrella terms are used to describe overlapping but different ambitions. The assumption is often made that different terms mean the same thing. However, different organisations and sectors come with their own perspectives, objectives, and skills. It is important not to gloss over these potential differences in detail, because until a deeper understanding and a more commonly-held vision is reached, any collaboration will likely be fraught and counterproductive and therefore a waste of resources. The task to identify productive and actionable common ground is crucial.

Table One below illustrates that different organisations and terms are targeting different aspects of agriculture and food security. Some are focussed on farming practices at the farm scale, others focus on rural communities, ecosystems, watersheds, the food supply chain or broader economic frameworks. The good news is that there are common areas of interest and ambition and that none of these approaches appear mutually exclusive. The challenge is to harness the different energies and efforts in a coordinated way to ensure comprehensiveness, address implementation gaps, and to deliver effective outcomes.

Likewise, within conventional and even alternative approaches to agriculture, there are many ways of doing things. Extensification and intensification can involve multiple pathways. So too can commodification, market orientation and product specialisation. Sustainable agriculture can mean organic agriculture to some people, while to others it could mean permaculture, biodynamic agriculture, low-input or agro-ecological systems and/or renewable or regenerative agriculture.

The common objective seems to be to restore, enhance and maintain the natural resource base and ecosystem processes and functions, while minimising external inputs and impacts. This addresses agriculture at the landscape and farm scale. It doesn't necessarily paint a picture of what would make broader agri-food supply chains sustainable. It also doesn't explain how the three pillars of sustainability – economic, social and environmental – are to be achieved. Does sustainable food production necessarily mean sustaining farmer's livelihoods or even farming communities? Does achieving food security for a nation necessarily result in more sustainable agricultural practices and vice versa? Are there really win-win outcomes for development on the one hand and environmental conservation on the other?

TABLE ONE – Many definitions for 'sustainable agriculture'

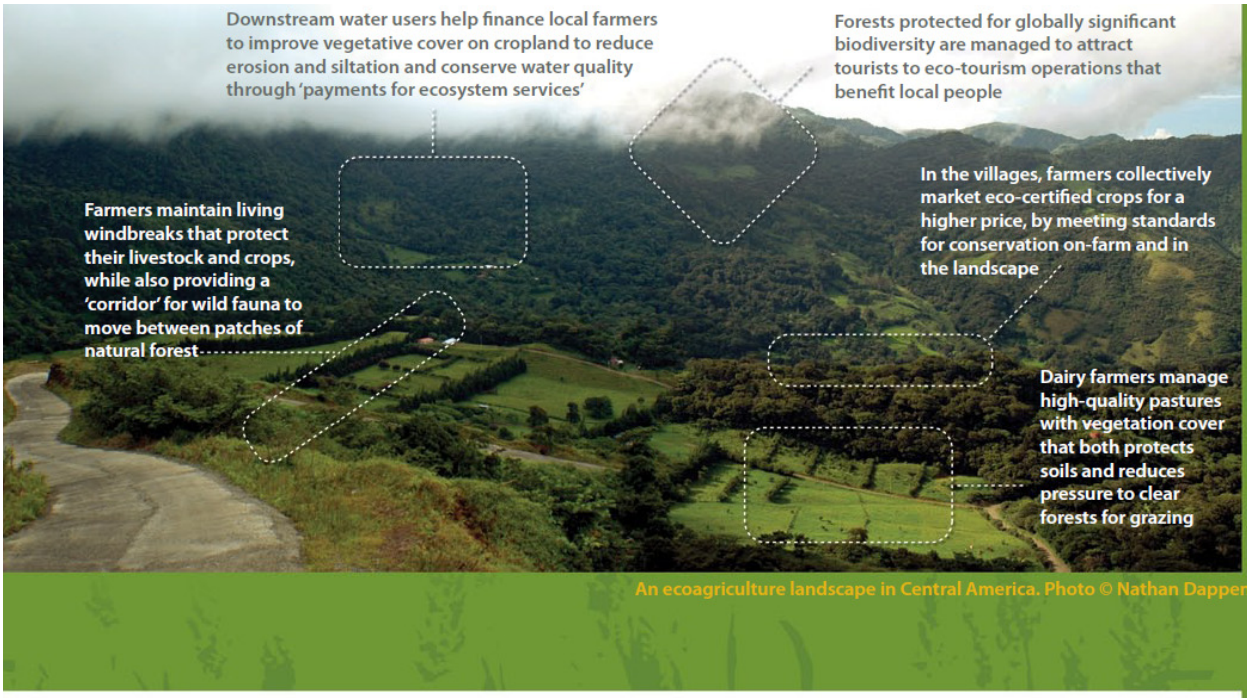
Term	Organisation	Source	Definition
Green Agriculture	UNEP	*Agriculture: Investing in Natural Capital (Towards a green economy: pathways to sustainable development and poverty eradication)* http://www.unep.org/greeneconomy/GreenEconomyReport/tabid/29846/Default.aspx	The greening of agriculture refers to the increasing use of farming practices and technologies that simultaneously: • maintain and increase farm productivity and profitability while ensuring the provision of food on a sustainable basis; • reduce negative externalities and gradually lead to positive ones; and • rebuild ecological resources (i.e. soil, water, air and biodiversity "natural capital" assets) by reducing pollution and using resources more efficiently. A diverse, locally adaptable set of agricultural techniques, practices and market branding certifications such as Good Agricultural Practices (GAP), Organic/Biodynamic Agriculture, Fair Trade, Ecological Agriculture, Conservation Agriculture and related techniques and food supply protocols exemplify the varying shades of "green" agriculture. Farming practices and technologies that are instrumental in greening agriculture include: • restoring and enhancing soil fertility through the increased use of naturally and sustainably produced nutrient inputs; diversified crop rotations; and livestock and crop integration; • reducing soil erosion and improving the efficiency of water use by applying minimum tillage and cover crop cultivation techniques; • reducing chemical pesticide and herbicide use by implementing integrated biological pest and weed management practices; and • reducing food spoilage and loss by expanding the use of post-harvest storage and processing facilities. Although organic sources of fertilizer and natural methods of pest and weed management are central elements of green agricultural practices, the highly efficient and precise use of inorganic fertilizers and pest controls may also be included in the broad spectrum of sustainable farming practices that need to be adopted to achieve global food security. This far more efficient use of inorganic agriculture inputs is particularly required in the initial phase of a long-term transition to a green agriculture paradigm.
Green Growth	OECD	Towards Green Growth (OECD, 2011) http://www.oecd.org/document/10/0,3746,en_2649_37465_47983690_1_1_1_37465,00.html	Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. To do this it must catalyse investment and innovation which will underpin sustained growth and give rise to new economic opportunities.
New Vision for Agriculture	WEF	*Realizing a New Vision for Agriculture:* *A roadmap for stakeholders* (WEF, 2010)	The three goals of the New Vision: 1. Meet nutritional demands while providing affordable choices across the food value chain: Increase agricultural production by 20% each decade and drastically reduce waste, towards the end of eliminating hunger and undernourishment; 2. Conserve or enhance the quality and quantity of natural resources and meet the challenges of changing climate: Sustainably reduce impact of agriculture on the environment; reduce resource intensity of the footprint by 20% each decade; 3. Drive rural and national economic development around the globe with well-targeted investments: Decrease

			portion of rural inhabitants living on less than $1.25/ day by 20% each decade.
EcoAgriculture	EcoAgriculture Partners	http://www.ecoagriculture.org/page.php?id=47	The term “Ecoagriculture" conveys a vision of rural communities managing their resources to jointly achieve three broad goals at a landscape scale — based on “three pillars” of ecoagriculture: 1. Enhance rural livelihoods; 2. Conserve or enhance biodiversity and ecosystem services; and 3. Develop more sustainable and productive agricultural systems. Ecoagriculture is both a conservation strategy and a rural development strategy. Ecoagriculture recognizes agricultural producers and communities as key stewards of ecosystems and biodiversity and enables them to play those roles effectively. Ecoagriculture applies an integrated ecosystem approach to agricultural landscapes to address all three pillars, drawing on diverse elements of production and conservation management systems. Meeting the goals of ecoagriculture usually requires collaboration or coordination between diverse stakeholders who are collectively responsible for managing key components of a landscape.
Ecosystem Approach	CBD (COP 5 Decision V/6)	http://www.cbd.int/decision/cop/?id=7148	Description of the ecosystem approach: 1. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. 2. An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompass the essential structure, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems. 3. This focus on structure, processes, functions and interactions is consistent with the definition of "ecosystem" provided in Article 2 of the Convention on Biological Diversity: "'Ecosystem' means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit." This definition does not specify any particular spatial unit or scale, in contrast to the Convention definition of "habitat". Thus, the term "ecosystem" does not, necessarily, correspond to the terms "biome" or "ecological zone", but can refer to any functioning unit at any scale. Indeed, the scale of analysis and action should be determined by the problem being addressed. It could, for example, be a grain of soil, a pond, a forest, a biome or the entire biosphere. 4. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Ecosystem processes are often non-linear, and the outcome of such processes often shows time-lags. The result is discontinuities, leading to surprise and uncertainty. Management must be adaptive in order to be able to respond to such uncertainties and contain elements of "learning-by-doing" or research feedback. Measures may need to be taken even when some cause-and-effect relationships are not yet fully established scientifically. 5. The ecosystem approach does not preclude other management and conservation approaches, such as biosphere reserves, protected areas, and single-species conservation programmes, as well as other

			approaches carried out under existing national policy and legislative frameworks, but could, rather, integrate all these approaches and other methodologies to deal with complex situations. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. Indeed, there are many ways in which ecosystem approaches may be used as the framework for delivering the objectives of the Convention in practice.
Climate Smart Agriculture	World Bank	http://climatechange.worldbank.org/content/climatesmart-agriculture-and-world-bank-facts	The World Bank believes climate-smart agriculture (CSA) is a "triple win" for agriculture, the climate and food security. Climate-smart farming techniques would increase farm productivity and incomes, and make agriculture more resilient to climate change, while also contributing to mitigation. CSA includes proven practical techniques, such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agro-forestry, improved grazing, and improved water management. CSA also includes innovative practices such as better weather forecasting, drought- and flood-tolerant crops and risk insurance.
	FAO	*"Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation* (FAO, 2010)	Agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals.
Ever-green revolution	UN High-level Panel on Global Sustainability	*Resilient People, Resilient Planet: A future worth choosing.* (UN HLP on Global Sustainability, 2012).	An "ever-green revolution" for the twenty-first century that aims to at least double productivity while drastically reducing resource use and avoiding further loss of biodiversity, topsoil loss and water depletion and contamination, including through the scaling-up of investment in agricultural research and development, to ensure that cutting-edge research is rapidly moved from laboratory to field.
Greening the Economy with Agriculture (GEA)	FAO	*Greening the Economy with Agriculture: Concept Note* (FAO, 2011) http://www.uncsd2012.org/rio20/index.php?page=view&type=400&nr=86&menu=45	Greening the economy with agriculture refers to increasing food security (in terms of availability, access, stability and utilization) while using less natural resources, through improved efficiencies throughout the food value chain. This can be achieved by applying an ecosystem approach to agriculture, forestry, fisheries management in a manner that addresses the multiplicity of societal needs and desires, without jeopardizing the options for future generations to benefit from a full range of goods and services provided by terrestrial and marine ecosystems. Therefore, GEA strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to agriculture, forestry, fisheries and food chains within ecologically meaningful boundaries.

Having a vision that can be imagined and illustrated through examples and case studies can be an important communication tool. What do we want the world to look like? What would success look like if widespread sustainable agriculture can be realised? Two visions that have been made tangible through visual representation are the following from EcoAgriculture Partners and *Scientific American.*

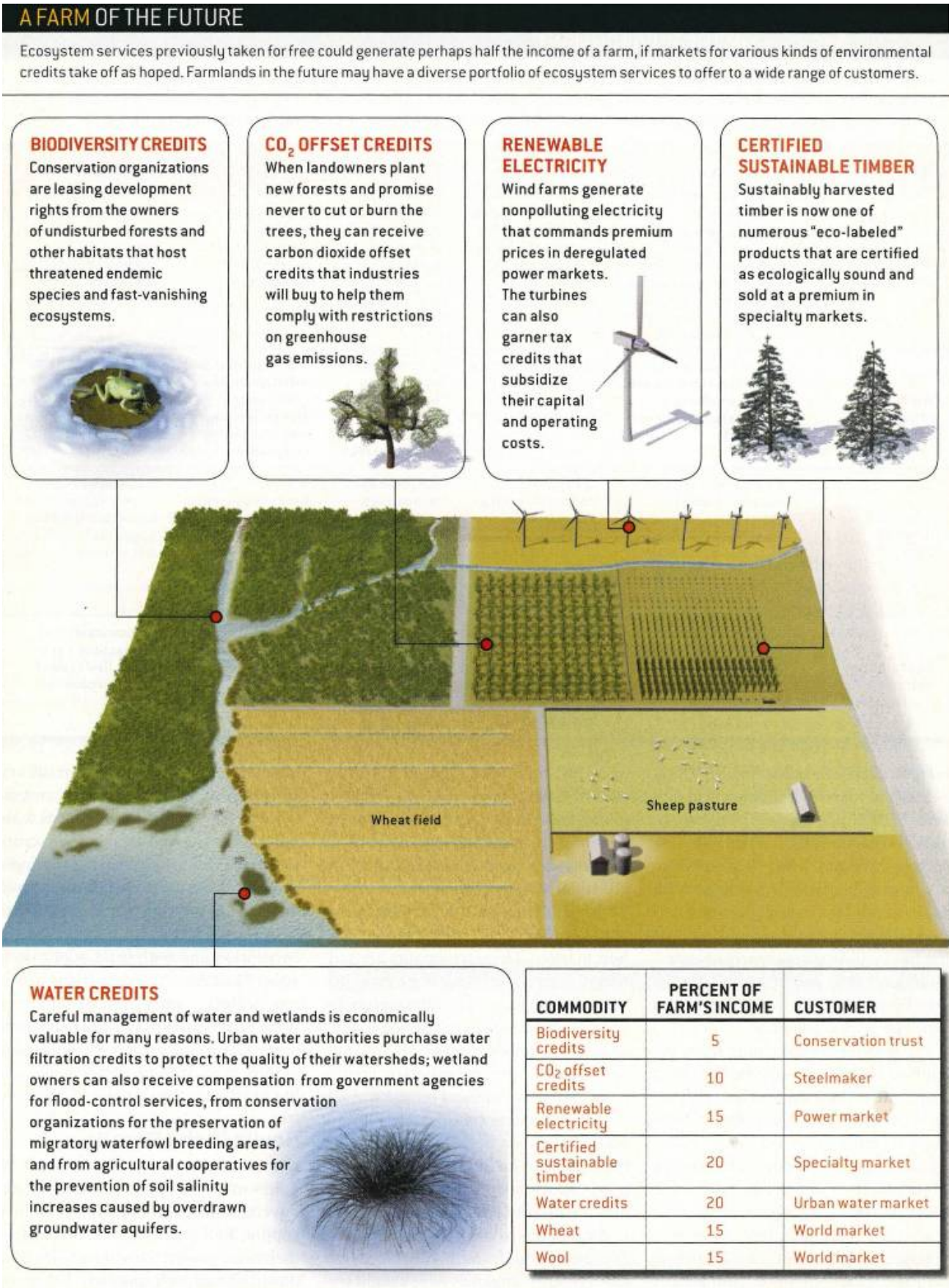
FIGURE TWO - Visions of 'ecoagricultural landscapes' (Source: EcoAgriculture Partners, 2007)



An ecoagriculture landscape in Central America. Photo © Nathan Dapper

An ecoagriculture landscape in East Africa. Photo © Louise Buc

FIGURE THREE - Vision of 'A Farm of the Future' (Source: Wayt Gibbs, 2005)



COMMODITY	PERCENT OF FARM'S INCOME	CUSTOMER
Biodiversity credits	5	Conservation trust
CO_2 offset credits	10	Steelmaker
Renewable electricity	15	Power market
Certified sustainable timber	20	Specialty market
Water credits	20	Urban water market
Wheat	15	World market
Wool	15	World market

4. Where are we heading?

These different definitions and visions for various aspects of agriculture and food security exist in stark contrast with the current state of the sector. We cannot predict the future, but projections and scenarios can help us understand the trajectory that the world is on. There have been at least 30 different major long-term model-based simulations of global food supply and demand over the second half of the 20th century (Foresight, 2011). Key models of outlined in Table Two below. A model is only as good as the data and assumptions that go into it. Most land use studies build scenarios based on factors such as economic development, technological change, population growth and food demand. Truly integrated simulation models – those that address the dynamics of both the natural and human components of the system and their interactions – are still relatively rare, and those that do this at the global scale are even rarer (Costanza et al., 2007). However, there are some common trends for our future, at least in the short term (see for example IAASTD, 2008; Trumper et al, 2009). They include:

- higher population
- higher food demand
- increased cropland
- increased global trade in food and agricultural commodities
- regions with food deficits
- biodiversity loss
- crop yield declines
- water scarcity
- increased urbanization
- intensification of agricultural production
- increased bioenergy production
- decline in employment in agriculture
- decline in investment in traditional agricultural disciplines
- decline in regulating (eg. climate regulation, pollination, water purification) and supporting (eg. soil formation, nutrient cycling, primary production) ecosystem services

Specific examples include the OECD-FAO's Agricultural Outlook 2011-2020 (2011) which found:

- Due to constraints in available land area, agricultural production will expand into less developed areas and into marginal lands with lower fertility and higher risk of adverse weather events;
- From 2010-2020, global agricultural production is projected to grow at 1.7% annually, on average, compared to 2.6% in the previous decade;
- Per capita food consumption will expand most rapidly in Eastern Europe, Asia and Latin America where incomes are rising and population growth is slowing. Vegetable oils, sugar, meat and dairy products should experience the highest increases in demand;
- By 2020, an estimated 13% of global coarse grain production, 15% of vegetable oil production and 30% of sugar cane production will be used for biofuel production;
- Trade is expected to grow by 2% per year, which is slower than over the previous decade, with only modest production increases by traditional exporters and higher domestic

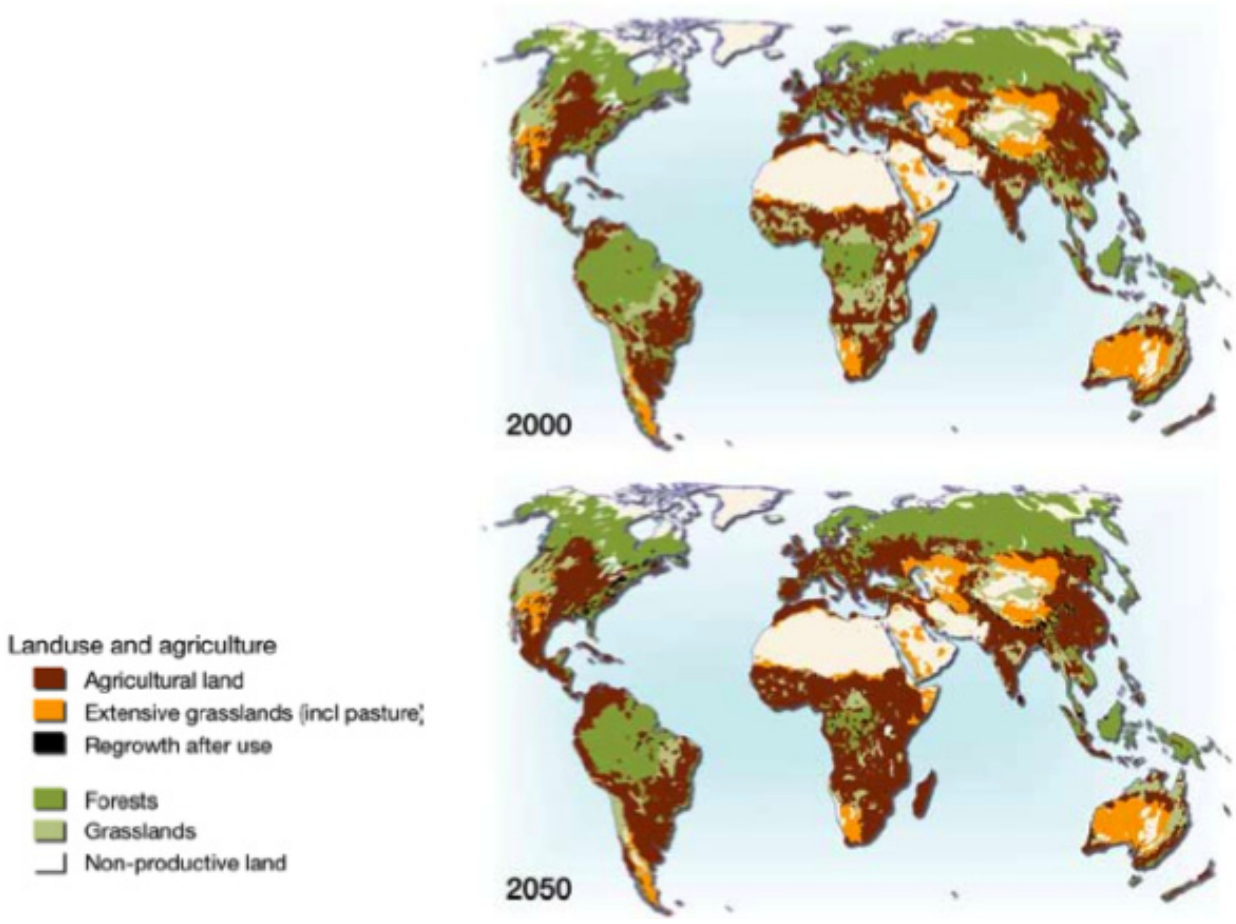
production by importers. The fastest growth will come primarily from emerging exporters in Eastern Europe, Central Asia and Latin American countries.

TABLE TWO - A selection of existing global models

Tool	Desciption
GLOBIO - Mapping human impacts on the biosphere	The GLOBIO model is a tool to assess past, present and future human impact on biodiversity. As a policy tool, it is regularly applied in global, regional and national assessments.
GTEM (Global Trade and Environment Model)	GTEM is a dynamic multi region, multi sector, general equilibrium model of the world economy. It was developed specifically to address policy issues with long term global dimensions, and was derived from the GTAP model.
GUMBO (The Global Unified Metamodel of the Biosphere)	GUMBOs goal was to simulate the integrated Earth system and assess the dynamics and values of ecosystems services. GUMBO was apparently the first model to include the dynamic feedbacks among human technology, economic production and welfare, and ecosystem goods and services within the dynamic Earth system.
IFs (International Futures simulator)	International Futures (IFs) is a world model or computer simulation of long-term global development. It is a menu-driven modelling system that facilitates exploration of alternative scenarios or 'if–then' statements about the future. It represents global demographics, economics, food systems, energy systems, selected environmental systems, and elements of sociopolitical change in 10 global regions.
IMAGE	IMAGE is an advanced integrated assessment model. It is a spatially explicit global land-use model that simulates energy and industry related activities simultaneously with land-use activities for the same set of drivers
IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade)	The IMPACT model is designed to examine alternative futures for global food supply, demand, trade, prices and food security. This is the widely used IFPRI model.
TARGETS (Tools to Assess Regional and Global Environmental and health Targets for Sustainability)	TARGET consists of five submodels: population and health, energy, land, food and water and has generated insights into the accelerating influence of the human race. TARGETS is a direct descendent of IMAGE. TARGETS is not used to develop scenarios, but utopias or worlds dominated by a particular world view or perspective.
World 3	*The Limits to Growth* was based on the results of modelling by World3, developed at MIT. The model examined the interactions of five subsystems of the global economic system: population, food production, industrial production, pollution and consumption of non-renewable resources. The timescale for the model was 1900-2100.
The Latin American World Model (or Bariloche Model)	The Bariloche Model was developed in reaction to World 3. Whereas World 3 worked from the premise that five key variables determine the future limits to growth (population, natural resources, food production, industrial production and pollution), the Bariloche model holds that pollution and natural resources pose no serious global threat and eliminates them. This model's principal focus is the pursuit of the question, 'What future world would be best for humankind?' through the use of mathematics optimization.
World Food Model (WFM)	The WFM was developed and applied by FAO, for medium-term projection and simulations. It provides a framework to forecast supply, demand and net trade for approximately 150 countries.

In contrast to short term projections, some models that assume smaller populations and a higher degree of technological change have different results in the long term, with indications that agricultural land could be reduced by as much as 20% by 2100 (Trumper et al, 2009). This is in contrast to projections to 2050. For example, Foresight (2011) reviewed several quantitative scenarios of the food system to 2050. They highlight the large regional differences in changes to crop harvested area. According to results, developed countries experience a decline in harvested area of 9–13% whereas low-income developing countries have an increase of 18–25%. Several developing countries experience area increases of more than one million hectares (including Nigeria, Brazil, Niger, Sudan, Ethiopia and the DRC. This seems consistent with results from the IMAGE model (cited in Nellemann et al., 2009), where further expansion of agricultural land is projected to 2050, particularly across central and southern Africa (see Figure Four below).

FIGURE FOUR - Projected land use change to 2050



5. How do we steer another course?

As is made clear by current and emerging trends, the visions of a sustainable or green agriculture are a long way from the trajectory that food and agricultural systems are on. The question is, how do we steer another course? Again, there are many initiatives and proposals for creating a new path. Table Three below outlines some of the principles and recommendations that different organisations have developed to increase the sustainability of the agricultural sector and improve food security.

TABLE THREE - Principles to increase the sustainability of agriculture

Publication	Author Organisation	URL	Principles/ Recommendations
Achieving food security in the face of climate change: Summary for policy makers from the Commission on Sustainable Agriculture and Climate Change	CSACC (CCAFS)	www.ccafs.cgiar.org/commission	1. Integrate food security and sustainable agriculture into global and national policies; 2. Significantly raise the level of global investment in sustainable agriculture and food systems in the next decade; 3. Sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture; 4. Target populations and sectors that are most vulnerable to climate change and food insecurity; 5. Reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster healthy and sustainable eating habits worldwide; 6. Reduce loss and waste in food systems, particularly from infrastructure, farming practices, processing, distribution and household habits; 7. Create comprehensive, shared, integrated information systems that encompass human and ecological dimensions.
Agriculture for Development: World Development Report 2008.	World Bank	http://go.worldbank.org/ZJIAOSUFU0	Effective instruments for using agriculture for development: 1. *Reforming trade, price, and subsidy policies* (eg. agricultural protection, agricultural taxation , trade liberalization, transitional support); 2. *Bringing agriculture to the market* (eg. commodity trading , product standards, risk management, modern supply chains); 3. *Supporting smallholder competitiveness through institutional innovations* (eg. land rights, reallocating resources, financial services for smallholders, Insurance to manage risk, efficient input markets, Producer organizations); 4. *Innovating through science and technology* (eg. complementing genetic improvement, Investing in R&D, extension and ICT innovations); 5. *Making agricultural systems more environmentally sustainable* (eg. agricultural water management, managing intensive livestock systems, reversing degradation, payment for environmental services); and 6. *Moving beyond the farm* (eg. Rural employment , Schooling, training, and transition to the labor market, Providing safety nets to reduce vulnerability).
A Green Growth Strategy for Food and Agriculture: Preliminary Report	OECD	http://www.oecd.org/dataoecd/38/10/48224529.pdf	A comprehensive and coherent strategy is needed: 1. *To increase productivity in a sustainable manner* - increasing resource use efficiency throughout the supply chain; 2. *To ensure that well-functioning markets provide the right signals* - prices that reflect the scarcity value of natural resources as well as the positive and negative environmental impacts of the food and agriculture system; 3. *To establish and enforce well defined property rights* - property rights to help ensure optimal resource use, in particular for marine resources, land and forests, greenhouse gas emissions, air and water.
An Ecosystems Approach	CBD (COP 5	http://www.cbd.int	Principles of the ecosystem approach:

	Decision V/6)	/decision/cop/?id=7148	1. The objectives of management of land, water and living resources are a matter of societal choice. 2. Management should be decentralized to the lowest appropriate level. 3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems. 4. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should: (a) Reduce those market distortions that adversely affect biological diversity; (b) Align incentives to promote biodiversity conservation and sustainable use; (c) Internalize costs and benefits in the given ecosystem to the extent feasible. 5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach. 6. Ecosystems must be managed within the limits of their functioning. 7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales. 8. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term. 9. Management must recognize that change is inevitable. 10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity. 11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices. 12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.
An Ecosystem Services Approach to Water and Food Security	UNEP	www.unep.org or www.iwmi.org/ecosystems	Changes required in how we approach ecosystems, water resources management and food security: 1. *Value ecosystem services* - from agroecosystems and non-agricultural ecosystems, 2. *Manage agriculture as a continuum of agroecosystems* - that not only produce food, but also deliver a whole range of other ecosystem services 3. *Collaborate between sectors* - as multiple services from agroecosystems require support from different authorities and experts 4. *Manage all sources of rainwater and runoff for multifunctional agroecosystems* - at river basin level 5. *Use adaptive Integrated Water Resources Management* - supported by capable and empowered institutions to provide water for non-agricultural ecosystems Specific opportunities to enhance food security and increase water productivity include: 1. Strategic placement of multipurpose trees - in agricultural landscapes to tighten water, nutrient and carbon cycles 2. In dryland agroecosystems - with locally adapted cultivars, holistic utilization of water and nutrients, provisions for herds and integrated tree-crop-livestock management 3. In wetland ecosystems - develop synergies with fisheries, aquaculture, livestock grazing, and horticulture and strategic enhancement of tree cover without compromising the water regulating functions

			4. In crop systems - targeted surface water and groundwater management to bridge dry spells, careful nutrient management, innovative field practices and adapted cultivars. 5. In aquaculture and fisheries - provide healthy aquatic ecosystems with clean and oxygenated water for physical support and respiration, seed and feed. 6. In livestock systems - animal management strategies to improve animal health and survival, feeding strategies such as the use of crop residues and other waste products, tree fodder, proper selection of fodder crops and implementing grazing management practices
"Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation	FAO		1. Agriculture in developing countries must undergo a significant transformation in order to meet the related challenges of food security and climate change. 2. Effective climate-smart practices already exist and could be implemented in developing country agricultural systems. 3. Adopting an ecosystem approach, working at landscape scale and ensuring intersectoral coordination and cooperation is crucial for effective climate change responses. 4. Considerable investment is required in filling data and knowledge gaps and in research and development of technologies, methodologies, as well as the conservation and production of suitable varieties and breeds. 5. Institutional and financial support will be required to enable smallholders to make the transition to climate-smart agriculture. 6. Strengthened institutional capacity will be needed to improve dissemination of climate-smart information and coordinate over large areas and numbers of farmers. 7. Greater consistency between agriculture, food security and climate change policy-making must be achieved at national, regional and international levels. 8. Available financing, current and projected, are substantially insufficient to meet climate change and food security challenges faced by the agriculture sector. 9. Synergistically combining financing from public and private sources, as well as those earmarked for climate change and food security are innovative options to meet the investment requirements of the agricultural sector. 10. To be effective in channelling fast-track financing to agriculture, financing mechanisms will need to take sector-specific considerations into account.
Global Food and Farming Futures	Foresight	http://www.bis.gov.uk/foresight/our-work/projects/published-projects/global-food-and-farming-futures/reports-and-publications	1. Substantial changes will be required throughout the different elements of the food system and beyond if food security is to be provided for a predicted nine billion people. Action has to occur on all of the following four fronts simultaneously: • More food must be produced sustainably through the spread and implementation of existing knowledge, technology and best practice, and by investment in new science and innovation and the social infrastructure that enables food producers to benefit from all of these. • Demand for the most resource-intensive types of food must be contained. • Waste in all areas of the food system must be minimised. • The political and economic governance of the food system must be improved to increase food

			system productivity and sustainability. 2. Addressing climate change and achieving sustainability in the global food system need to be recognised as dual imperatives. Nothing less is required than a redesign of the whole food system to bring sustainability to the fore. 3. It is necessary to revitalise moves to end hunger. Greater priority should be given to: • rural development and agriculture as a driver of broad-based income growth • more incentives provided to the agricultural sector to address issues such as malnutrition and gender inequalities • reducing subsidies and trade barriers that disadvantage low-income countries 4. Policy options should not be closed off. Throughout, the Project's Final Report has argued the importance of, within reason, excluding as few as possible different policy options on *a priori* grounds. Instead, it is important to develop a strong evidence base upon which to make informed decisions. 5. This Report rejects food self-sufficiency as a viable option for nations to contribute to global food security, but stresses the importance of crafting food system governance to maximise the benefits of globalisation and to ensure that they are distributed fairly. Key priorities for action for policy makers: 1. Spread best practice. 2. Invest in new knowledge. 3. Make sustainable food production central in development 4. Work on the assumption that there is little new land for agriculture 5. Ensure long-term sustainability of fish stocks 6. Promote sustainable intensification 7. Include the environment in food system economics 8. Reduce waste – both in high- and low-income countries 9. Improve the evidence base upon which decisions are made and develop metrics to assess progress 10. Anticipate major issues with water availability for food production 11. Work to change consumption patterns 12. Empower citizens
How to Feed the World in 2050	FAO	http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf	Prerequisites for global food security: 1. Enhancing investment in sustainable agricultural production capacity and rural development; 2. Promoting technology change and productivity growth; 3. Trade, markets and support to farmers.
International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)	IAASTD	http://www.agassessment.org/	1. Improve Productivity and Sustainability of Crop Systems 2. Improve Productivity and Sustainability of Livestock Systems 3. Breeding Options for Improved Environmental and Social Sustainability 4. Improve Forestry and Agroforestry Systems as Providers of Multifunctionality

			5. Sustainable Management of Fishery and Aquaculture Systems 6. Improve Natural Resource Management and Habitat Preservation 7. Using AKST to Improve Health and Nutrition 8. Adaptation to Climate Change, Mitigation of Greenhouse Gases
Millennium Ecosystem Assessment	Millennium Ecosystem Assessment	http://www.maweb.org/en/Reports.aspx#	Key Steps Available to Reduce the Degradation of Ecosystem Services: *1. Change the economic background to decision-making:* • Make sure the value of all ecosystem services, not just those bought and sold in the market, are taken into account when making decisions. • Remove subsidies to agriculture, fisheries, and energy that cause harm to people and the environment. • Introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage, that are of value to society. • Establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way. *2. Improve policy, planning, and management:* • Integrate decision-making between different departments and sectors, as well as international institutions, to ensure that policies are focused on protection of ecosystems. • Include sound management of ecosystem services in all regional planning decisions and in the poverty reduction strategies being prepared by many developing countries. • Empower marginalized groups to influence decisions affecting ecosystem services and recognize in law local communities' ownership of natural resources • Establish additional protected areas, particularly in marine systems, and provide greater financial and management support to those that already exist. • Use all relevant forms of knowledge and information about ecosystems in decision-making, including the knowledge of local and indigenous groups. *3. Influence individual behaviour:* • Provide public education on why and how to reduce consumption of threatened ecosystem services. • Establish reliable certification systems to give people the choice to buy sustainably harvested products. • Give people access to information about ecosystems and decisions affecting their services. *4. Develop and use environment-friendly technology:* • Invest in agricultural science and technology aimed at increasing food production with minimal harmful trade-offs. • Restore degraded ecosystems. • Promote technologies to increase energy efficiency and reduce greenhouse gas emissions.
Realizing a New Vision for Agriculture: A roadmap for stakeholders	World Economic Forum	http://www.weforum.org/reports/realizing-new-vision-agriculture-roadmap-	The three goals of the New Vision: 1. *Meet nutritional demands while providing affordable choices across the food value chain:* Increase agricultural production by 20% each decade and drastically reduce waste, towards the end of eliminating hunger and undernourishment; 2. *Conserve or enhance the quality and quantity of natural resources and meet the challenges of changing*

		stakeholders	*climate:* Sustainably reduce impact of agriculture on the environment; reduce resource intensity of the footprint by 20% each decade; 3. *Drive rural and national economic development around the globe with well-targeted investments:* Decrease portion of rural inhabitants living on less than $1.25/ day by 20% each decade.
Resource Scarcity, Fair Shares and Development	Center on International Cooperation, New York University	http://www.oxfam.org/en/grow/policy/resource-scarcity-fair-shares-and-development	1. *Invest in improving the data:* current systems to survey resource scarcity have major gaps and are poorly integrated across both issues and levels of governance. 2. *Recognize that resource scarcity will become central to advisers in the areas of governance, economics, social development and conflict* – and should be incorporated into training and professional development. 3. *Understand how scarcity shapes politics in poor countries:* donors and NGOs need to understand how scarcity impacts on the wider political economy context and relates to urban–rural tensions, political parties, spending decisions, civil society dynamics, the politics of ethnic groups, and so on. 4. *Start developing policy options now:* as impacts of scarcity and climate change increase in frequency and severity, political space will open up – often after shocks – for a limited time. Having ideas 'on the shelf' means that policy options can be deployed rapidly when opportunities arise.
Rural Poverty Report 2011	IFAD	http://www.ifad.org/rpr2011/	A focus on these two areas – smallholder agriculture and the rural non-farm economy – requires particular attention to, and increasing investment in, four issues: 1. *Improving the overall environment of rural areas*- to make them places where people can find greater opportunities and face fewer risks, and where rural youth can build a future. 2. *Reducing the level of risk that poor rural people face* - and helping them to improve their risk management capacity needs to become a central, cross-cutting element within a pro-poor rural development agenda. 3. *Advancing individual capabilities* - needs far more attention in the rural development agenda. Productivity, dynamism and innovation in the rural economy depends on there being a skilled, educated population. 4. *Strengthening the collective capabilities* - of rural people can give them the confidence, security and power to overcome poverty. Membership-based organizations have a key role to play in helping rural people reduce risk, learn new techniques and skills, manage individual and collective assets, and market their produce.
The Bioenergy and Water Nexus	IEA Bioenergy/ UNEP/ Oeko-Institut	http://www.unep.org/publications/contents/pub_details_search.asp?ID=6209	1. Take a holistic approach and a long-term perspective; 2. Cooperate on a watershed level; 3. Base decisions on impact assessments to ensure sustainable water management; 4. Design and implement effective water-related policy instruments; 5. Establish/supp ort appropriate institutions and processes; 6. Disseminate best practices; 7. Promote technology development; 8. Intensify dialogue on the topic and on capacity building; 9. Conduct further research, fill data gaps, and develop regionalized tools.

The Environmental Food Crisis: The Environment's Role in Averting Future Food Crises	UNEP	http://www.grida.no/publications/rr/food-crisis/	Seven options for improving food security in the short-, mid- and long-term: 1. To decrease the risk of highly volatile prices, price regulation on commodities and larger cereal stocks should be created to buffer the tight markets of food commodities and the subsequent risks of speculation in markets; 2. Encourage removal of subsidies and blending ratios of first generation biofuels, which would promote a shift to higher generation biofuels based on waste (if this does not compete with animal feed), thereby avoiding the capture of cropland by biofuels; 3. Reduce the use of cereals and food fish in animal feed and develop alternatives to animal and fish feed; 4. Support farmers in developing diversified and resilient eco-agriculture systems that provide critical ecosystem services, as well as adequate food to meet local and consumer needs; 5. Increased trade and improved market access can be achieved by improving infrastructure and reducing trade barriers; 6. Limit global warming, including the promotion of climate-friendly agricultural production systems and land-use policies at a scale to help mitigate climate change; 7. Raise awareness of the pressures of increasing population growth and consumption patterns on sustainable ecosystem functioning.
Agriculture: Investing in Natural Capital (Towards a green economy: pathways to sustainable development and poverty eradication)	UNEP	http://www.unep.org/greeneconomy/GreenEconomyReport/tabid/29846/Default.aspx	Investment priorities for greening agriculture: 1. Investments in R&D and Agribusinesses 2. Plant and animal health management 3. Scaling up adoption of green agriculture by partnering with leading agribusinesses 4. Strengthening the supply chains for green products and farm inputs 5. Farm mechanization and post-harvest storage 6. Improving soil and water management and diversifying crops and livestock Enabling conditions: 1. Global policies – Elimination of export subsidies and liberalizing trade in agricultural products – Redress market power asymmetry – Food safety standards – Intellectual property 2. National policies – Support for improved land tenure rights of smallholder farmers – Targeting programmes for women smallholder farmers – Public procurement of sustainably produced food 3. Economic instruments – Capacity building and awareness-raising – Supply chains, extension services and NGOs – Integrating information and communications technologies with knowledge extension – Better food choices

Trade and Environment Review, 2009/2010	UNCTAD	http://www.unctad.org/Templates/Page.asp?intItemID=3723&lang=1	Three areas of sustainable, "green" growth that are of particular and strategic importance for the low-income and least developed countries: 1. Enhancing energy efficiency, often implemented in combination with material and resource efficiency; 2. Mainstreaming sustainable agriculture, including organic agriculture; and 3. Harnessing the use of off-grid renewable energy technologies for sustainable rural development.
The Wageningen Statement: Climate-Smart Agriculture – Science for Action	The Global Science Conference on Climate–Smart Agriculture (GSCSA) October 26, 2011	www.gscsa2011.org	1. Increase farm and landscape level research, education, extension and innovation in climate-smart agriculture: – Sustainable intensification – producing more with more efficient use of inputs and less of an environmental impact – Integrated scientific approach – Breeding for a 2030 world – Climate change mitigation – National decision policies and support to overcome barriers to climate-smart agriculture – Climate risk management – Communicating Science 2. All stakeholders to contribute to platforms and capacity enhancement that improve dialogue and learning about proven policies, technologies and practices for climate-smart agriculture. 3. Implementing agencies from national governments and civil society, and the private sector, to provide the impetus for, and support to, proven climate-smart technologies and practices. 4. All stakeholders to put in place the needed policies, strategies and frameworks to build climate-smart agriculture, and the associated research and development. 5. National governments, regional organisations and private sector to allocate adequate financing to climate-smart agriculture and rural development, and the associated research and development.
FOOD AND NUTRITION SECURITY: COMPREHENSIVE FRAMEWORK FOR ACTION Summary of the Updated Comprehensive Framework for Action	High Level Task Force on Global Food Security	http://un-foodsecurity.org/node/842	*Twin-tracks* to food and nutrition security: 1. meet the immediate food and nutritional needs of those at risk; 2. build longer-term resilience by eliminating the root causes of hunger and poverty. A *Comprehensive Approach* requires: 1. addressing all dimensions of food and nutrition security – availability, access, utilization and stability – and taking into account the interconnectedness and interactions between them; 2. addressing the full spectrum of food and nutrition security, including sustainable agricultural production, procurement and distribution of food, and safety-net strengthening; 3. integrating cross-cutting issues such as protection and promotion of human rights, gender equity, support to nutrition, management of sustainable ecosystems, and climate change mitigation and adaptation into law, policy and programme design; and 4. ensuring multi-sectoral engagement and coordination on agriculture, social security, trade and market, employment, health, education, nutrition, and humanitarian assistance. In practice, adopting a comprehensive approach calls for maximum synergy and coordination among all components of food and nutrition security and the sectors which influence them.

As Table Three above shows, there are many principles and recommendations for change. While differences in scope and objective exist, there are areas of overlap. The box below summarises some of the most common principles.

Increase productivity sustainably

- Sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture

Reduce resource intensity

- Increase resource use efficiency throughout the supply chain
- Reduce loss and waste in food systems, particularly from infrastructure, farming practices, processing, distribution and household habits;
- Reduce the use of cereals and food fish in animal feed and develop alternatives to animal and fish feed;
- Farm mechanization and post-harvest storage

Increase investment

- Fill data and knowledge gaps and in research and development of technologies, methodologies, as well as the conservation and production of suitable varieties and breeds
- Enhance investment in sustainable agricultural production capacity and rural development
- Invest in R&D and Agribusinesses
- Invest in Plant and animal health management (PAHM)
- Create alternative opportunities for rural employment outside agriculture

Reshape food access and consumption patterns

- Establish reliable certification systems to give people the choice to buy sustainably harvested products
- Strengthen the supply chains for green products and farm inputs
- Value ecosystem services by ensuring that well-functioning markets provide the right signals to reflect the scarcity value of natural resources
- Align incentives to promote biodiversity conservation and sustainable use

Manage ecosystems within the limits of their functioning

- Adopt an ecosystem approach, work at landscape scale
- Ensure intersectoral coordination and cooperation and greater consistency between agriculture, food security and climate change policy-making at national, regional and international levels
- Restore degraded ecosystems and improve soil and water management
- Manage all sources of rainwater and runoff for multifunctional agroecosystems - at river basin level

Support smallholders

- Support smallholder competitiveness through institutional innovations and
- Support smallholder transition to climate-smart agriculture through institutional and financial support
- Establish and enforce well defined property rights to help ensure optimal resource use

Innovate through science and technology

- Diversify crops and livestock
- Breed for a 2030 world
- Improve the evidence base upon which decisions are made and develop metrics to assess progress
- Create comprehensive, shared, integrated information systems that encompass human and ecological dimensions

Reform trade rules

- Reform trade, price, and subsidy policies and reduce trade barriers
- Decrease the risk of highly volatile prices, price regulation on commodities and larger cereal stocks

Improve market access

- Commodity trading
- Product standards
- Risk management
- Modern supply chains
- Improve infrastructure

6. Bridging the implementation gap

The challenge is not necessarily to agree a common set of principles or even a single definition of sustainable agriculture. Given the abundance of both principles and definitions, the real challenge is to operationalise these concepts in meaningful ways – to bridge the implementation gap. How do we turn good intentions into action? What does is really mean to "increase resource use efficiency throughout the supply chain" or "value ecosystem services"? What needs to be done and who is best placed to do it?

For example, one intention might be to "improve storage and transport infrastructure" in order to modernise supply chains, improve market access and reduce post-harvest losses. What would be required to do this? What different actions would need to be taken at different levels of the supply chain (increasingly globalised, as Figure One above showed). These questions also apply to other potential actions like:

- Removal of subsidies and blending rations on first generation biofuels;
- Development of alternatives to the use of cereals and food fish in animal feed;
- Increasing crop genetic diversity to improve resilience, yield and pest management;
- Agro-ecological zoning to improve land use planning; and,
- Regulation of groundwater aquifers to reduce unsustainable water withdrawals

What regulatory, economic and technical challenges would need to be overcome? What is the timeline for implementation and how would we measure success? Many policy instruments are available, such as: public procurement; tax measures, standards and regulation; tradeable rights; subsidies and other financial incentives; voluntary agreements; and the mobilisation of the private sector through engagement in public-private partnerships (PBL, 2009). Each approach will have different levels of economic and environmental effectiveness, as well as political ramifications. Which policy instrument would be most effective in what circumstances? How would a balance between market-based and regulatory instruments be achieved? In considering this, it is worth recognising some of the more common policy approaches.

From an economic point of view, it has been estimated that cumulative gross investment requirements for developing countries' agriculture is approximately US$9.2 trillion for the 44 years from 2006 – 2050 (Schmidhuber et al., 2009). Of this total, investments in primary agriculture would account for about US$5.2 trillion, while the remaining US$4.0 trillion would be absorbed by downstream needs (processing, transportation, storage, etc.). Within primary agriculture, mechanisation and improvements to irrigation would be the single biggest investment items. The average annual spend would be approximately US$210 billion gross and US$83 billion net, respectively. US$210 billion is the projected size of the agricultural products market in 2020 (TEEB, 2010). As Schmidhuber et al. (2009) note, these estimates have nothing to do with achieving Millenium Development Goals or any sustainability agenda. They are simply cost estimates for achieving the levels of crop and livestock production that the FAO has forecast as baseline levels through to 2030 and 2050. Nor do such estimates take in to account the potential cost implications of reforms to trading rules and market access.

Assuming US$210 billion was required each year, how much should come from the public and private sectors? Would investments in irrigation and mechanisation have detrimental impacts on other objectives for agricultural, such as maintaining ecosystem health? How would the interlinkages and trade-offs between investment decisions be managed? And by whom? What are investment priorities in the short versus the long-term? What transition pathways are necessary and possible? What about social and environmental considerations?

7. Conclusion

This paper has more questions than answers. The intention is to emphasise that the time has come to move on from high-level statements. We need to make progress on bridging the implementation gap between rhetoric and action, across all levels of the supply chain and all components within global and national agricultural and food systems. If we are to change the trajectory that the world is on, then bridging the implementation gap is essential. If, at Rio+20 the world decided it was ready to take serious action, what would be required? Social, environmental and economic considerations come in to play. Issues of livelihoods, rural development and health are central. There is no right answer. There are many answers, many possible scenarios and many system inter-linkages to consider. We need to get started.

References and Further Reading

AFC Conference, 2010. *Roadmap for Action on Agriculture, Food Security and Climate Change: Chair's Summary.* Global Conference on Agriculture, Food Security and Climate Change (AFC Conference), The Hague, Netherlands, 31 October to 5 November 2010.

Anseeuw, W., L., Wily, A., Cotula, L. and Taylor, M., 2012. *Land Rights and the Rush for Land: Findings of the Global Commercial Pressures on Land Research Project.* International Land Coalition, Rome.

Bai, Z. G., Dent, D. L., Olsson, L. and Schaepman, M. E., 2008. 'Proxy global assessment of land degradation' in *Soil Use and Management*, September 2008, 24, pp. 223–234.

Costanza, R., Leemans, R., Boumans, R. M. J. and Gaddis, E., 2007. 'Integrated Global Models' in *Sustainability or Collapse? An Integrated History and Future of People on Earth.* Costanza, R., Graumlich, L. J. and Steffen, W. (eds). MIT Press, Cambridge.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2010. *Rising Global Interest in Farmland: Can it yield sustainable and equitable benefits?* World Bank, Washington, D.C.

EcoAgriculture Partners, 2007. *Landscapes for people, food and nature.* EcoAgriculture Partners, Washington, D.C. http://www.ecoagriculture.org/documents/index.php?pubID=37

FAO, 2009. *Agriculture: Achieving sustainable gains in agriculture.* Fact Sheet on FAO Programme. FAO, Rome. http://www.fao.org/about/en/

Foley, J. A. 2005. 'Global Consequences of Land Use' in *Science,* 309, pp. 570-574.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., West, P. C., Balzer, C., Bennett, E. M., Carpenter, S. R., Hill, J., Monfreda, C., Polasky, S., Rockstrom, J., Sheehan, J., Siebert, S., Tilman, D., Zaks, D. P. M., 2011. 'Solutions for a cultivated planet' in *Nature*, Vol. 478, pp. 337–342.

Foresight, 2011. *Synthesis Report C4: Food system scenarios and modelling.* Foresight Project on Global Food and Farming Futures. UK Government Office for Science. http://www.bis.gov.uk/foresight/our-work/projects/published-projects/global-food-and-farming-futures/reports-and-publications

Gibbs, H., 2009. *Mapping Land Sources for New Biofuel Croplands.* Presentation from the session "Biofuels, Tropical Deforestation, and Climate Policy: Key Challenges and Opportunities" at the annual AAAS meeting, Feb 14 2009.
http://iis-db.stanford.edu/pubs/22434/gibbs_press_release_feb14.pdf

Green et al., 2005. 'Sparing land for nature: exploring the potential impacts of changes in agricultural yield on the area needed for crop production' in *Global Change Biology*, Vol.10, No.11, pp. 1594-1605.

IAASTD, 2008. *International Assessment of Agricultural Knowledge, Science and Technology for Development: Global Report.* McIntyre, B. D., Herren, H. R., Wakhungu, J. and Watson, R. T. (Eds). International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD).

Khan, S. & Hanjra, M. A. 2009. 'Footprints of water and energy inputs in food production - Global perspectives' in *Food Policy,* Vol. 34, No. 2, pp.130-40.

Kiers, E. T., Leakey, R. R. B., Izac, A., Heinemann, J. A., Rosenthal, E., Nathan, D. & Jiggins, J. 2008. 'Agriculture at a Crossroads' in *Science*, Vol. 320, No. 5874, pp.320-21

McCalla, A. and Revoredo, C. L., 2001. *Prospects for Global Food Security: A Critical Appraisal of Past Projections and Predictions.* Food, Agriculture and Environment Discussion Paper 35, International Food Policy Research Institute, Washington, D.C.

Morton, D. C., DeFries, R. S., Shimabukuro, Y. E., Anderson, L. O., Arai, E., del Bon Espirito-Santo, F., Freitas, R. & Morisette, J. 2006. 'Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon' in *Proceedings of the National Academy of Sciences,* Vol. 103, No. 39, pp.14637-41.

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. G., Kaltenborn, B. P. (Eds), 2009. *The environmental food crisis – The environment's role in averting future food crises.* A UNEP Rapid Response Assessment. United Nations Environment Programme, GRID-Arenal, www.grida.no

OECD-FAO, 2011. *Agricultural Outlook 2011-2020.* OECD and FAO, Paris and Rome. www.agri-outlook.org

PBL, 2009. *Growing within Limits: A Report to the Global Assembly 2009 of the Club of Rome.* Netherlands Environment Assessment Agency (PBL), Bilthoven. http://www.pbl.nl/en/publications/2009/Growing-within-limits.-A-report-to-the-Global-Assembly-2009-of-the-Club-of-Rome

Sampson, R. N., Bystriakova, N., Brown, S., Gonzalez, P., Irland, L.C. Kauppi, P., Sedjo,R., Thompson, I.D., Barber, C. V. and Offrell, R., 2005. '*Chapter 9: Timber, Fuel, and Fiber' in Ecosystems and human well-being: current state and trends: findings of the Condition and Trends Working Group.* The millennium ecosystem assessment series, Volume 1, Island Press, Washington.

Schmidhuber, J., Bruinsma J. and Boedeker, G., 2009. *Capital requirements for agriculture in developing countries to 2050.* Presented at FAO Expert Meeting on How to Feed the World in 2050, 24-26 June 2009, Rome.

TCG, 2011. *Innovative Approaches to Land in the Climate Change Solution: Terrestrial Carbon Policy Development.* Policy Brief 10. Terrestrial Carbon Group. www.terrestrialcarbon.org

TEEB, 2010. *TEEB – The Economics of Ecosystems and Biodiversity Report for Business - Executive Summary 2010.*
http://www.teebweb.org/InformationMaterial/TEEBReports/tabid/1278/Default.aspx

Trumper, K., Bertzky, M., Dickson, B., van der Heijden, G., Jenkins, M., Manning, P., 2009. *The Natural Fix? The Role of Ecosystems in Climate Mitigation.* A UNEP Rapid Response Assessment. United Nations Environment Programme, UNEP-WCMC, Cambridge, UK.

Tweeten, L. and Thompson, S. R., 2009. 'Long-Term Global Agricultural Output Supply-Demand Balance, and Real Farm and Food Prices' in *Farm Policy Journal,* Vol. 6, No. 1, February Quarter 2009.

UNCTAD 2010. Agriculture at the Crossroads: Guaranteeing Food Security in a Changing Global Climate. United Nations Conference on Trade and Development (UNCTAD) Policy Briefs 18 (December 2010).

UNEP, 2011a. *Towards a green economy: Pathways to sustainable development and poverty eradication - A synthesis for policy makers.* United Nations Environment Programme, Nairobi.

UNEP, 2011b. 'Agriculture: Investing in Natural Capital' in *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication.* United Nations Environment Programme, Nairobi. http://www.unep.org/greeneconomy/GreenEconomyReport/tabid/29846/Default.aspx

von Braun, J., 2007. *The World Food Situation: New Driving Forces and Required Actions.* Food Policy Report. International Food Policy Research Institute.

Weikard, H. P. and Seyhan, D., 2009. 'Distribution of phosphorus resources between rich and poor countries: The effect of recycling' in Ecological Economics, Vol. 68, pp. 1749 -1755.

WHO, 2011. *Obesity and overweight.* Fact sheet No.311. Updated March 2011. World Health Organisation. http://www.who.int/mediacentre/factsheets/fs311/en/

World Bank 2008. *Agriculture for Development: World Development Report 2008.* The International Bank for Reconstruction and Development / The World Bank, Washington DC.

Wayt Gibbs, W. 2005. 'How should we set priorities?' in *Scientific American,* September 2005 (Crossroads for Planet Earth) pp.86-93.

World Bank and FAO, 2009. *The Sunken Billions: The Economic Justification for Fisheries Reform.* World Bank and the Food and Agriculture Organization. Washington, DC, and Rome.