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Mitigating climate change through agriculture

September 19, 2011

An untapped potential

Agriculture is a major emitter of greenhouse gases (GHGs). It accounts for 14% of global GHG emissions, or 25% if agriculture-driven deforestation is included. This makes agriculture as big a contributor to climate change as the energy sector.

Agriculture offers tremendous potential to mitigate climate change, 18% of total emissions together with forestry, or 1/3 of the total abatement potential. This makes agriculture/forestry one of the three major areas of GHG abatement opportunities (along with energy efficiency and low-carbon energy supply).

Climate-friendly agricultural practices focus on increasing the carbon content in soil (e.g. by using cover crops, farming with perennials, reduced tillage or rotational grazing), minimizing the need for chemical fertilizers (responsible for nitrous oxide emissions) and managing livestock systems to reduce methane emissions. Low-emission farming systems include conservation agriculture, agroecology and organic farming. Conserving and restoring forests and grasslands is also key.

Shifting towards climate-conscious consumption is another route. The main avenues involve 1) reducing food losses – globally for harvest and post-harvest losses, at consumption stage in middle- and high-income countries, 2) switching to second or third generation biofuels and 3) curbing meat consumption.

Realizing the mitigation potential of agriculture is challenging. Scaling up climate-friendly practices is impeded by difficulties in measuring and monitoring agriculture-related emissions and by the variety of sources of emissions and of mitigation strategies. The number of players, located mainly in developing countries, also adds to the challenge.

A number of existing policies need to be turned around in order to make possible the transition to a low-emission agriculture. Reforms of agricultural policies at national and international levels (particularly in the areas of land tenure and support for agricultural inputs) and reform of international trade policies are called for in order to prevent market distortions.

Building on synergies is key to success. Some trade-offs will need to be made but major synergies exist between climate change mitigation, adaptation to climate change, food security, environmental sustainability and rural social and economic development.

The financing available currently and expected in the future is not enough to meet climate change and food security challenges. An increase in carbon emission offset trading can potentially provide an important source of funding to move towards climate-friendly agriculture.

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*Section 7 was written by Bruce Kahn, Deutsche Bank Climate Change Advisors (DBCCA)

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Climate change mitigation: a challenge for the world and for agriculture

"We recall the triple challenge for agriculture: meeting food security objectives while adapting to climate change and reducing its contribution to greenhouse gas emissions"

Ministerial declaration. Meeting G20 Agricultural Ministers, Paris, June 2011

Three objectives of food systems

— Ensure **food availability** for everyone

— Combat **hunger and poverty**, especially by increasing the income of smallholder farmers

— **Environmental sustainability** so as not compromise the ability to satisfy future needs, taking into account **climate change**, biodiversity, water and soil conservation

Source: O. De Schutter, Special Rapporteur on the right to food to the UN (2010)

Among the major challenges currently faced by humanity are food security and climate change. Agriculture plays a significant role in both. Adapting to climate change is expected to be an increasing issue for agriculture and food security in the next decades[1]. At the same time, agriculture is part of the solution in mitigating climate change: by both reducing and sequestering terrestrial greenhouse gas emissions, interventions in agriculture can reduce human-caused net emissions of greenhouse gases.

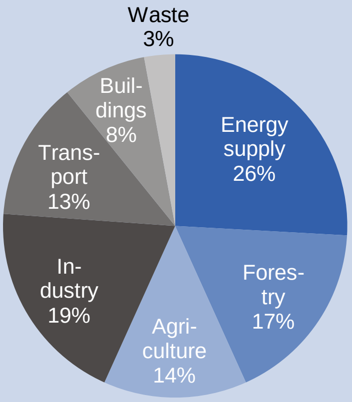
Agricultural producers, the food industry, governments, consumers and the financial sector are all key players in shifting policy and investment priorities

This significant contribution can be achieved not only without jeopardizing food security but also while promoting sustainable development. However, significant hurdles stand in the way of scaling up beneficial practices. Implementing the right policies will be key to overcoming these hurdles. Reforms are especially required in the areas of land tenure, support for agricultural inputs and international trade policies. The central players in driving a response to climate change are farmers – managing the land –, and the food industry – influencing the choice of crops, products consumed, quality standards and the path to profitability. The financial sector has a clear role to play in scaling up the investment for climate-smart agriculture. Consumers' behaviour is also crucial.

1. Agriculture: a major emitter of greenhouse gases

GHG emissions by sector

Shares in 2004



Note: The agricultural sector does not include CO_2 emissions/removals from agricultural soils.

Source: IPCC (2007) 1

There is a broad consensus that climate change is a significant challenge to the planet and that it can be mitigated by reducing the net emission of greenhouse gases (GHG)[2]. The International Energy Agency reported a record 30.6 billion tons of CO_2 emissions from fuel combustion in 2010. The level of global human-induced GHG emissions was 49 billion tons of carbon dioxide equivalent in 2004, the most recent year for which emission figures are available for all sectors including agriculture.

1.1 High share globally

Agriculture and food supply chains are heavy emitters of heat-trapping greenhouse gases. Estimates of their shares vary depending on where the line is drawn: 14% for agriculture production, or 25% if agriculture-driven deforestation is included, and considerably more if the whole food system is taken into account – encompassing food processing, storage and distribution. Data on the global food supply chain are scarce. In the EU-25, the food system was estimated to contribute 31% of total GHG emissions, or 40% if the hotel and restaurant sector was included[3].

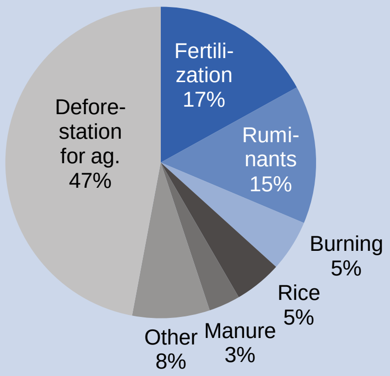
[1] See for instance Kahn and Zachs (2009).

[2] Some scientists (including Jasper Kirkby from the European Center for Nuclear Research CERN) attribute global warming to increased solar activity, with variation in cosmic rays potentially affecting cloud cover.

[3] European Commission (2006).

GHG from agriculture

Shares of various activities, 2004



Source: IPCC, FAO, DB Research **2**

Agriculture contributes to the release of the three main GHGs: carbon dioxide CO_2, methane CH_4 and nitrous oxide N_2O. Compared to other sectors, agriculture contributes disproportionately heavily to the emissions of methane and nitrous oxide, possibly in the 40-60% range[4]. The German agricultural sector contributed close to 50% of national CH_4 emissions and 65% of national N_2O in 2006[5]. These are the two most potent GHGs in terms of global warming potential[6]: the greenhouse impact of 1 unit of methane is equivalent to 25 units of carbon dioxide, that of 1 unit of nitrous oxide is equivalent to around 300 units of carbon dioxide. (In order to allow comparisons, GHG emissions are usually expressed in mass of CO_2 equivalent). The main sources of agricultural GHGs are emissions of nitrous oxide from soil (mostly through fertilizer use and manure being transformed by soil bacteria) and methane production by ruminant animals (enteric fermentation).

Greenhouse gas emissions from agricultural production

2004

	Annual Emissions million tons CO_2 equiv.	GHG
Agriculture	**5,630**	
Soil fertilization (inorganic fertilizers and applied manure)	2,130	Nitrous oxide
Gases from food digestion in cattle	1,800	Methane
Biomass burning	670	Methane, nitrous oxide
Flooded rice production (anaerobic decomposition)	620	Methane
Livestock manure	410	Methane, nitrous oxide
Industrial factors	**1,010**	
Fertilizer production	410	Carbon dioxide, nitrous oxide
Irrigation	370	Carbon dioxide
Farm machinery	160	Carbon dioxide
Pesticide production	70	Carbon dioxide
Deforestation, at large	8,500	
For agriculture and livestock	**5,900**	Carbon dioxide
Total	**12,540**	

Sources: IPCC, FAO, Bellarby et al, DB Research **3**

Main sources of agricultural GHG emissions:

— N_2O from soils in industrialised countries, Africa and most of Asia

— CH_4 from ruminants in Central and South America, Eastern Europe, Central Asia and the Pacific

Source: Wright (2010)

1.2 Large, increasing contribution from the South

There are wide regional differences between the GHG emissions generated by agriculture. About 75% of total agricultural GHG emissions are the result of agriculture in low and middle-income countries[7] and this share is expected to increase in the future. In the period 1990-1995, these countries experienced the most rapid increase in agricultural GHG emissions, 35%, whereas industrialized countries as a group showed a decrease of 12%[8].

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[4] Smith et al. (2007). Wreford et al. (2010) mention a high degree of uncertainty around this figure.

[5] vTI (2009).

[6] Sulphur hexafluoride SF_6, a minor GHG, is actually the most potent according to the IPCC, with a global warming potential of 22,800 that of CO_2.

[7] This has to be seen in context: these countries collectively also have a high share of land under cultivation.

[8] Smith et al. (2007).

The main sources of agricultural emissions also vary geographically (see box). As expected, emissions from biomass burning and rice production come almost exclusively from less industrialized countries. Emissions from manure are more evenly spread geographically.[9]

Agriculture-driven GHG emissions are expected to increase in response to population growth and income growth in developing countries, resulting in increased consumption of meat and dairy products.

Estimates of future agricultural sector emissions

Source/region	Change	Comments
Agricultural N2	Increase of 35-60% to 2030	Mainly increased nitrogen fertilizer use
Agricultural CH4	Increase of 60% to 2030 Increase 16% 2005-2020	Mainly increased livestock production Increased irrigated rice production
Land use change	Remaining 7.5 Gt CO_2 per year to 2012, reducing to 5 Gt per year by 2050	Under current trends and assuming countries will halt deforestation when only 15% of their forests remain
Middle East, North Africa and sub-Saharan Africa	Overall emissions to increase 95% from 1990 to 2020	Highest regional growth in overall emissions, but from lower comparative base
East Asia	Enteric fermentation increase by 153% from 1990 to 2020, manure emissions increase by 86%	Highest regional growth in these categories, mainly linked to rising meat production
North America and the Pacific	Increase of 18% and 21% over all emissions, respectively	Only industrialized regions with projected increase – mainly from manure and soil
Western Europe	Declining emissions	Only region with projected decline – mainly through policy interventions

Sources: Wright (2010), US EPA, UK (2011), DB Research 4

1.3 Reduction targets for GHG emissions

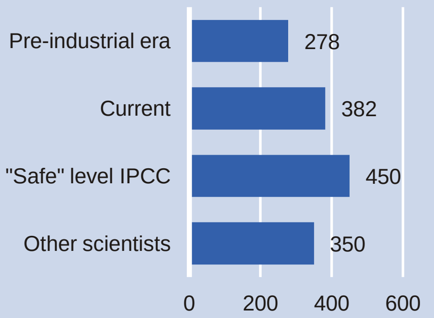
Most scientists agree that in order to prevent massive problems on the planet, global warming should be limited to 2°C above the pre-industrial level. This implies a drastic decrease in global GHG emissions. The main (now weak) international mechanism for reducing GHG emissions is the Kyoto Protocol, linked to the United Nations Framework Convention on Climate Change: the UNFCC member countries adopted in Kyoto in 1997 a protocol which entered into force in 2005.

Setting targets

The Kyoto Protocol sets targets to reduce GHGs by 5% over the period 2008-2012 (on average, 1990 levels as basis) for 37 industrialized countries and the EU – the so-called Annex 1 countries, not including the US which did not ratify the Protocol. These countries collectively account for around 60% of global emissions. Emerging countries (e.g. China, India and Brazil) are part of the international process but do not have binding targets for absolute emission reductions. This is in recognition of the greater responsibility of industrialized countries for current GHG levels – given their history of over 150 years of industrial activity – according to the so-called principle of “common but differentiated responsibilities”. The process of how to introduce into an international framework with the responsibility of lower-income countries to contribute to reduce emissions is ongoing as a consequence of the climate change conference in Copenhagen.

GHG in the atmosphere

Parts per million of CO_2



Sources: IPCC, Worldwatch, DB Research 5

The Kyoto Protocol will be discussed at the UN climate conference in Durban at the end of November. Its future will heavily depend on whether the US and China join the legally binding international effort.

[9] Stern (2006). Wright (2010).

The EU-27 is committed to reduce its emissions by 8% by 2012, with specific targets for member countries. The EU has also adopted a legislation aimed at delivering a 20% cut by 2020, a key contribution to which will come from the EU Emissions Trading Scheme[10].

The Clean Development Mechanism

Countries may partially compensate for their GHG emissions by increasing carbon sinks on their territory or abroad, through emissions trading on the "carbon market". Indeed, the "Clean Development Mechanism" (CDM) allows industrialized countries to pay for projects in poorer nations to cut or avoid emissions and be awarded credits (thus serving a dual purpose of mitigation and development).

Soil and plants: a significant carbon reservoir

Carbon content, billion tons of CO_2 eq.:

Sediments and fossil fuels	$3\ 10^8$
Water	$1.5\ 10^5$
Soil and organic matter	6,000
Atmosphere	3,000
Terrestrial vegetation	2,000

Sources: FAO (2006), Scherr and Sthapit (2009) 6

Agriculture and land use have been mostly absent from target-setting negotiations in spite of their significant potential to contribute to fighting climate change and their unique role in sequestering carbon (see next sections). There may be several reasons for this reluctance to consider terrestrial carbon a solution for climate change, including the diversity of emission sources in agriculture, the difficulty in measuring and monitoring them, the variety of mitigation practices, the challenges in scaling them up (see Section 5) as well as political sensitivity in addressing powerful farmers' lobbies.

The crucial role of terrestrial carbon

Soil is the largest carbon pool on Earth's surface. The amount of carbon present on the Earth's surface and in the atmosphere is tiny when compared to the quantity stored deep below the surface (in sediments and fossil fuels) or in oceans. However, land accounts for a quarter of the Earth's surface. Soil and plants hold close to three times as much carbon (the so-called terrestrial carbon) as the atmosphere. Even small changes in carbon stored in the soil could thus have a significant impact on the global carbon balance.

Terrestrial carbon is crucial to climate change due to its mobility. Indeed it moves from the atmosphere to the land and vice-versa. Plants use carbon dioxide from the atmosphere to grow. When organisms breathe, grow, and eventually decompose, carbon is released to the atmosphere and the soil. Carbon stored in soils is the balance between dead plant material as inflow and decomposition and mineralisation processes as outflow. Human activity can speed up decomposition and mineralisation: deforestation, agriculture and livestock grazing are the major land use changes that increase the release of carbon into the atmosphere. The flip-side is that other kinds of land use can play a positive role in stabilizing the climate.

Terrestrial carbon sequestration is the process through which CO_2 from the atmosphere is absorbed by trees, plants and crops through photosynthesis and stored as carbon in soils and biomass (tree trunks, branches, foliage and roots). Forests, croplands and grazing lands are "sinks" when they sequester more carbon than they release over a period of time.

Sources: Scherr and Sthapit (2009), US EPA

2. Agricultural practices to capture carbon and reduce emissions

There is an opportunity to achieve a climate-friendly agriculture by both sequestering carbon and reducing emissions[11]. The main strategies are 1) enriching soil carbon (for instance through using perennials), 2) promoting climate-friendly livestock production systems, 3) minimizing the use of inorganic fertilizers and 4) restoring degraded lands and preventing deforestation – which

[10] For a status of current regulatory policies worldwide, see Fulton and Kahn (2011).
[11] Key references for this section: Smith et al. (2007). Bellarby (2008). Wright (2009). Scherr and Stahpit (2009). See also vTI (2009).

largely occurs for agricultural purposes. The farming systems incorporating a mix of these practices are reviewed in section 2.5[12].

2.1 Increasing carbon content in soil

Soil is made of minerals, water, air and organic materials. Organic matter originates from dead plant, animal and microbial matter as well as living roots and microbes. These organic materials retain air and water in the soil. They also provide nutrients for plants and soil fauna. Agricultural practices which manage organic matter, and thus build and conserve soil carbon (as plant residues and manure) instead of depleting it, also provide in the long-term soils which are rich in carbon and require fewer chemical fertilizers.

Managing soil cover and residues

A number of techniques can be used here:

Avoid bare soils

Green manures for soil protection and enrichment

Bare soil is susceptible to erosion and nutrient leaching and its soil carbon content is very low. Crops growing during fallows (sometimes called green manure) can be ploughed into the soil, while green or shortly after flowering, in order to increase its fertility by adding nutrients and organic matter. Grasses and cereals make a good choice because they leave a large amount of residues on the soil surface, they decompose slowly due to a high carbon/nitrogen ratio and they improve the soil faster due to their aggressive and abundant rooting system[13].

Use nitrogen-fixing cover crops

Cover crops for higher nitrogen-content in soil

Cover crops such as legume cover crops enrich the soil with nitrogen through a symbiotic relationship with bacteria. They convert biologically unavailable atmospheric nitrogen gas N_2 to biologically available mineral nitrogen NH_4^+. When the system has stabilised, cover crops with an economic function such as livestock fodder may be used as cover crops.

Composting refers to the decomposition of food and plant waste into dark organic matter.

Increasing yield

Increase yields through:

— Fertilisers; organic or not
— Improved, locally adapted seeds
— Intercropping
— Sustainable water use

A higher yield will increase the amount of carbon which is sequestered by the plant and released into the soil either during growth or when plant residues are incorporated into the soil. Yield increases may also lead to lower cropland requirements (see 2.4). Apart from using chemical fertilizers (see 2.3), crop yields can be increased by several means.

Livestock manure or compost may be used.

Improved locally adapted crop varieties
Crop varieties could be improved to increase yields in several ways, for instance greater efficiency in water or nutrient use. Generating varieties and breeds which are tailored to ecosystems and the needs of farmers is crucial.

Intercropping
A judicious combination of compatible crops will increase yields on a

[12] Sections 2 and 3 are mainly descriptive. Section 5 elaborates on the obstacles standing in the way of scaling up these practices and Section 6 discusses levers to overcome them.
[13] FAO Conservation agriculture web site.

given piece of land: for instance a deep-rooted crop with a shallow-rooted one or a tall crop with a shorter one requiring some shade. The introduction of leguminous species into grassland can increase yields, thus resulting either in higher productivity for same input or lower amount of fertiliser required. Intercropping also promotes biodiversity by providing a habitat for a larger variety of insects and soil organisms than in a single crop environment.

Water management

The effectiveness of irrigation depends on water availability, its cost to farmers (dependent on water price and level of subsidies for water and energy) and energy requirements. Water harvesting is a key feature of sustainable water use.

Reducing tillage: fewer emissions and increased carbon storage

Growth in no-till

About 95 million ha or 7% of the world's arable land is under no-till management, predominantly in South and North America. This figure is growing rapidly, especially since rising fuel prices increase the cost of tillage.

Source: Dumanski et al. (2006)

In order to improve crop growing and uproot weeds, the soil is normally tilled, or turned over. This tilling, however, exposes anaerobic microbes to oxygen and suffocates aerobic microbes, which releases carbon dioxide.

No-till is often practised in farming systems combining it with other soil conservation practices such as crop rotation and green manure crops. For instance, conservation agriculture achieves minimal soil disturbance by combining no-till, permanent organic soil cover and crop rotation. These techniques result in healthier soil, enhanced carbon sequestration, decreased erosion as well as reduced use of water, energy and labour. This brings benefits in terms of productivity/profitability and sustainability, including mitigation of climate change. The latter occurs by preventing carbon dioxide from escaping from the soil during tillage, by returning carbon to the soil by decomposition of the crop residues maintained on the surface, and by fewer passes over the field with fuel-driven machinery.

Farming with perennials

Increasing the use of perennial crops, shrubs and trees provides an important way of mitigating climate change by storing carbon in soil while crops are growing.

Large scope to increase crop diversity

- 10 annual cereal grains, legumes and oilseeds claim 80% of global cropland (although over 3,000 edible plant species have been identified)
- Wheat, rice and maize cover half that area
- 2/3 of arable land is used to grow annual grains

Source: Glover et al. (2007)

Indeed, unlike annual grains, perennial grasses retain a strong root network between the growing seasons so that a large amount of biomass remains in the soil instead of being released as GHG. Their large roots also help hold soil organic matter and water together, which reduces both soil erosion and GHG emissions. The need for annual tilling, seed bed preparation and application of agro-chemicals is reduced, which further reduces emissions. Perennials are also beneficial in terms of enriching the soil and having more conservative use of nutrients. Indeed, their roots allow them to support microorganisms and other biological activity as well as accessing nutrients and water in larger volumes of soil. The latter also makes them suitable for cultivation in areas considered as marginal[14].

Shifting from producing annual to perennial grains is not without challenges: the breeding of perennials takes longer and their seed yields tend to be lower. However, researchers have already developed perennial relatives of cereals (rice, wheat and sorghum), forages and sunflower that are nutritious and good tasting[15]. Further research in this area will support the switch towards high-carbon

[14] Glover and Reganold (2010). Glover et al. (2007). Scherr and Sthapit (2009).
[15] Scherr and Sthapit (2009).

agricultural systems. Finding perennial substitutes for livestock feed is particularly promising given that one-third of global cereal production is used to feed livestock. Large areas of land are being converted to grow biofuel crops – which often have a net negative impact on GHG emissions once cultivation, fertilization and fossil fuel use are factored in. Therefore growing perennial biofuel crops could offer a significant opportunity for biofuels of the second or third generation[16].

Agroforestry: multiple wins

Agroforestry examples:

— Shade-grown coffee and cocoa plantations (Ivory Coast)

— Mango trees interspersed in rice paddies (Nepal)

— Citrus trees in cabbage fields (Indonesia)

Source: Scherr and Sthapit (2009)

Planting trees in crop fields and pastures provides another way of increasing carbon storage in agriculture. Agroforestry was practised traditionally for agriculture in forest and woodland ecosystems. It is nowadays being introduced into subsistence and commercial systems. The trees may provide products (fruits, nuts, medicines, fodder, firewood, timber, etc.), benefits to farm production (increased crop fertility through nitrogen fixation from leguminous tree species, reduced risk through diversification) and ecosystem services (habitat for pollinators, improvement to micro-climate and reducing pressure on deforestation by meeting demand somewhere else).

Rice management

Cultivated wetland rice soils emit significant amount of methane. These emissions can be reduced by various practices such as draining wetland once or several times during the growing season, adjusting the timing of organic residue additions, producing biogas or keeping the soil as dry as possible between seasons.

Decomposition, biochar, silicates

Biochar in numbers

— Global production potential of 600 million tons CO_2 equivalent in biochar per year using waste materials (forest residues, riche husks, urban waste, etc.)

— Applying biochar systematically on 10% of world's cropland could store 30 billion million tons CO_2 equivalent, offsetting almost all emissions from fossil fuel burning

Source: Lehmann et al. (2006), Scherr et al. (2009)

Provided it takes place within the soil and not on the surface, decomposition of plant matter increases carbon content in the soil.

Another way is biochar, a charcoal not used as fuel: burning biomass in a low-oxygen environment results in a stable solid rich in carbon content which can be used to lock carbon in the soil: it keeps carbon in soil for long and slowly releases nutrients as already experienced by Amerindians some 2,000 years ago[17]. So, planting fast-growing trees in degraded areas (keeping in mind competition for water with other crops), converting them to biochar and adding to soil provides a way of taking carbon from the atmosphere and turning it into a slow-release organic fertilizer benefiting plant and soil. It is a promising option for carbon emission offset payments.

Some researchers propose to mitigate GHG by spreading calcium or magnesium silicates, such as olivine, as fine powder over land areas in the humid tropics[18]. Through chemical reaction with the silicate and water, CO_2 is transformed into bicarbonate, which washes down to the oceans where it ultimately precipitates as carbonate. On top of mitigating climate change, this process may bring additional benefits, enriching soils with mineral nutrients and reversing the acidification of soils, rivers and oceans. However, before proceeding to large-scale deployment, more needs to be understood about the environmental impact, particularly in ecosystems adapted to acid conditions, in terms of biodiversity, etc.

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[16] Scherr and Sthapit (2009).
[17] Lehmann et al. (2006). Scherr and Sthapit (2009).
[18] Schuiling and Tickell (2010)

GHG emissions from livestock amount to 7.1 billion tons of CO_2 equivalent per year, including 2.5 billion tons released through land clearing and 1.8 billion tons through rumination. This total accounts for over 14% of human-induced GHG emissions and represents half of all emissions from agriculture and land use change.

Source: IPCC (2007)

2.2 Climate-friendly livestock systems

Livestock production generates massive amounts of GHGs in various ways. Methane is produced from the fermentation of feed in the ruminant's stomach; manure releases methane and nitrous oxide. Land clearing for pasture and feed crops, soil degradation as well as the consumption of fossil fuels also result in the release of GHGs.

Curbing global consumption of meat and dairy is likely part of the solution to mitigating climate change (see 3.3) but a number of strategies also exist at the level of livestock production. The influence of grazing intensity on emission of GHG gases is not well-established, apart from the direct effects of the number of animals on emission levels. Grass-fed ruminants have a higher methane production per kg of product than grain-fed ones but their raising is associated with reduced fuel consumption, increased potential for carbon sequestration as well as landscape management and biodiversity conservation.

By using rotational grazing, a 4,800 ha ranch in the US was able to triple the perennial species in the rangelands while almost tripling beef production.

Source: Scherr and Sthapit (2009)

Rotational grazing for soil protection

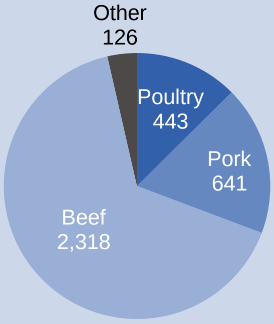
Allowing vegetation to regenerate after grazing protects the soil from erosion and helps maintain its organic matter and carbon. Livestock productivity can even benefit from this practice. Rotational grazing is practiced successfully in the United States, Australia, New Zealand, Europe and Africa (South and East)[19].

Innovative feeding for reduced emissions

Innovative feed mixes, with increased starch content for instance, make digestion easier, in turn reducing methane production. Advanced techniques directly tackle the methane-producing microbial organisms present in the stomach, by replacing them by other bacteria or affecting their action through vaccines[20]. These sophisticated approaches, still in development, will probably be expensive and raise ethical issues. They are potentially useful in large-scale intensive livestock operations.

Livestock differentiated

Million tons of CO_2 eq.



Sources: FAO for 2007, DB Research 7

Manure management: a promising technology for millions of farmers

Manure is both a major source of methane (400 million of CO_2 equivalent according to the FAO) and an opportunity to produce biogas. In a biogas digester, anaerobic microbial action breaks down manure (or food waste) into biogas (methane) – which can be burnt for heat or electricity – and sludge, a potential fertilizer.

The US government is already providing subsidies to large dairies and pig operations to invest in anaerobic digesters. Numerous households in the developing world use manure to produce biogas for their cooking needs. Low-income producers need financial help at the outset but investing in a biogas digester has proved worthwhile, with benefits for both the climate and well-being – through access to energy[21].

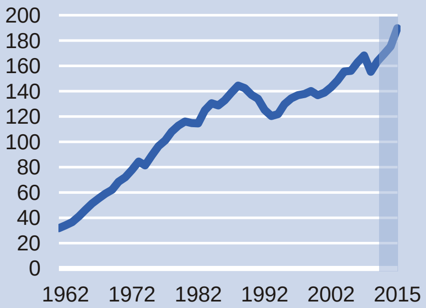
2.3 Fertiliser management

Soils with nitrogen fertilisers release nitrous oxide, the most potent greenhouse gas. Fertilised soils release more than 2 billion tons of carbon dioxide equivalent GHGs every year[22]. Around 160 million

19 Scherr and Sthapit (2009). IFAD (2009).
20 FAO (2006).
21 FAO (2006).
22 Smith et al. (2007).

Global use of fertilisers

World consumption of NPK fertilisers, million tons

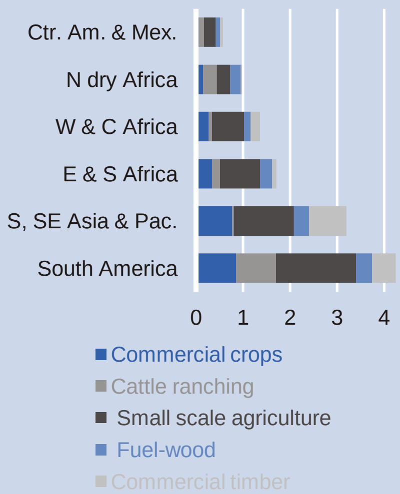


Note: The decline in world fertiliser demand in the early 90's is due to the collapse of the Former Soviet Union, where consumption dropped by over 90%

Source: IFA 8

Agriculture-driven deforestation

Area, million ha



Source: UNFCCC 9

Carbon stocks in vegetation

Billion tons of CO_2 equiv. per mega km² in vegetation and top one metre of soil

Biome	
Wetlands	251
Forest	60-150
Grassland	89
Cropland	30
Desert and semi-desert	16

Sources: Bellarby, IPCC, DB Research 10

tons of inorganic fertilisers (chemical nitrogen, phosphate and potash) are used worldwide, mostly in industrial countries and in irrigated regions of developing countries. After a short decline in 2008 attributed to a demand-driven price spike[23], sustained growth rates in fertiliser demand are expected over the next years in a business-as-usual scenario[24].

Substituting for inorganic fertilisers

A number of practices, such as composting, use of manures or rotations with legume crops, allow for substituting or minimizing the need for inorganic fertilisers by increasing soil organic matter while capturing carbon from the atmosphere.

Improved fertiliser application methods

Nitrogen applied in fertilizers (as well as manures) is not always used efficiently by crops. Timing of application can be optimized to when nitrogen is least susceptible to loss (often just prior to plant uptake). Using remote-sensing techniques, through precision agriculture for instance, allows farmers to understand in-field variability in order to fine-tune chemical usage (as well as water usage and sowing density).

2.4 Conserving and restoring forests and grasslands

Deforestation and forest degradation at large account for 17% of global GHG emissions. This share is the second largest after the energy sector and is higher than that of the entire global transportation sector (see Chart 1). It is driven by agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires, etc.[25].

Avoiding deforestation

The share of deforestation and forest degradation driven by agriculture is estimated at 75% globally and varies regionally between 65% and 80% when one adds up the areas cleared for the purposes of small-scale agriculture, commercial crops and cattle ranching[26]. Between 1980 and 2000, in the tropical zone, around 55% of new cropland area came from primary forests and 25% of the areas came from secondary forests[27].

Yield increases and forest conservation

Forests and grasslands are an important reservoir of carbon (and biodiversity on top of being an important part of the water cycle, locally and sometimes globally. Protecting them with the carbon they hold could have a massive impact in reducing emissions from land use changes. One way to support their conservation may be to promote a judicious use of fertilizers when required and not to minimize the use of inorganic fertilizers at the expense of the forest. For instance, in „The hidden climate costs of chocolate“, the Climate Change Agriculture and Food Security Partnership reports on

[23] Fertilizer prices in April 2008 were twice as high as a year earlier. Depressed global economic growth further reduced demand which caused fertilizer prices to return to pre-2007 levels.
[24] International Fertilizer Industry Association.
[25] UN-REDD website.
[26] Data on drivers of deforestation are scarce. Blaser and Robledo (2007) consider six direct factors, not taking into account infrastructure development, urban development and mining – which is also a direct driver but generally limited in area.
[27] Gibbs et al. (2010). A secondary forest is one which has re-grown after a major disturbance such as fire, insect infestation, timber harvest or windthrow.

serious damage to the West African Guinean rainforest when farmers who grow cocoa for a living seek to maintain or increase their incomes by burning adjacent forests, creating ash-fertilized soil conducive to growing cocoa as well as oil palm and cassava. If fertilisers or arable land had been accessible to farmers, significant deforestation could have been avoided[28]. Increasing agricultural yields may be an important lever to avoid emissions through deforestation.

Incentives required: REDD, product certification, land tenure rights[29]

As opposed to many of the climate-mitigating practices discussed above, protecting large areas of standing natural vegetation often provides fewer short-term financial or livelihood benefits for landowners or managers. Since it may even reduce their income or livelihood security, it is often required to provide stakeholders with incentives for conserving natural habitats.

One approach is to raise the economic value of standing forests and grasslands. This can be done by improving markets for sustainably harvested products or by paying land managers directly for their conservation value. Initiatives are under way to address the significant methodological, institutional and governance challenges related to the implementation of a REDD mechanism (see box).

A second incentive for conservation is product certification, for instance the initiative by the International Finance Corporation for palm oil, soy, sugarcane, cocoa. A third approach is to secure local tenure rights for communal forests and grasslands: local people thus have an incentive to manage them sustainably and protect them from illegal commercial logging, land grabs for agriculture, etc. The burning of forests, grasslands and agricultural fields can be an effective way of clearing and rotating plots for crop production, weed control and soil fertility improvement. However, excesses are harmful to the environment and can be tackled via better regulatory enforcement (in the case of large-scale ranchers or commercial crop producers) or via investments in sustainable production linked to fire control for small-scale, community producers.

The REDD+ mechanism

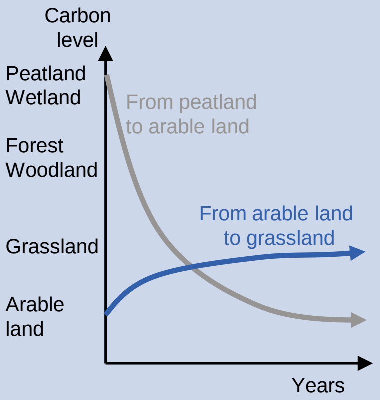
REDD stands for Reducing Emissions from Deforestation and Forest Degradation. REDD+ includes the increasing of carbon stocks through sustainable management of forests and planting. Its principle is to give developing and emerging countries incentives to conserve their forests through financial transfers.

The REDD mechanism is an effort to give a financial value to the carbon stored in forests. As part of the “offset” scheme of the carbon markets, it is designed to produce “carbon credits” via emission-saving projects. These “credits” can be traded within the carbon markets and be used by industrialised governments and corporations to meet their targets, in addition to cutting their emissions.

The UN forecasts that financial flows for GHG reductions from REDD+ could reach up to USD 30 billion a year, thus rewarding a meaningful reduction in GHGs while supporting pro-poor development, biodiversity conservation and ecosystem services.

Source: UN-REDD website

Carbon stock and land use



Sources: Bellarby et al. (2008), DB Research 11

Management of peatland

Apart from driving deforestation, agriculture results in places in the destruction of peatland, a potent carbon sink (containing on average about 10 times more carbon than other soils[30]). Peatland is a wetland that over many centuries accumulates acidic peat, a deposit of dead plant material, mostly carbon. To be used for agriculture, the soils are drained, which aerates the soil, promotes decomposition, and emissions of carbon and nitrogen dioxides ensue. Peat areas are also very sensitive habitats, of high importance for biodiversity.[31]

Restoring degraded areas

A large amount of agricultural lands have been degraded by excessive disturbance, erosion, loss of organic matter, salinisation, acidification, etc. Restoring part of these degraded areas can be a

[28] CCAFS (2011): Farmers could have doubled their incomes, helped to avoid deforestation and degradation on 2.1 million hectares, and generated a value of over USD 1,600 million on 1.3 billion tons of CO_2 eq. avoided by not deforesting.
[29] Scherr and Sthapit (2009).
[30] Reported in Hoffmann (2011).
[31] Over half of the world’s wetlands are peatland. Peat deposits are found in Northern and Eastern Europe, North America, New Zealand, Indonesia, etc. Having the largest amount of tropical peatland and mangrove forests, Indonesia is, however, losing 100,000 hectares of wetland per year, as reported by Waspada online.

winning proposition from multiple perspectives of climate, economic development[32] and ecosystems services, particularly wildlife habitat and watershed functions. (Regarding the latter, poor vegetative cover limits the capacity to retain rainfall in the system or to filter water flowing into streams and lakes.)

Among the various land uses, croplands contain the lowest concentration of carbon, apart from desert and semi-deserts. The reversion of cropland to another land use, for instance grassland, is one of the most effective ways to reduce emissions and increase carbon sinks (through less soil disturbance and reduced carbon removal – especially since no harvest is taking place). On highly degraded soils, some cultivation or re-seeding may be needed.

Producer-level practices for GHG mitigation

Practice	Comments
Replace inversion ploughing with no-tillage (NT) and conservation agriculture (CA)	Possibility to lock up 0.1-1 t carbon/ha/year, cut CO_2 emissions by over 50% by reducing fossil fuel in ploughing. If another 150 million ha of rainfed cropland is converted to NT/CA by 2030, 30-60 Mt carbon/year could be taken up during the first few years. Benefits may be offset if increased pesticides or machinery are used
Increase yields	To increase carbon sequestered during plant growth and incorporated in residues, by improving water management, fertilisation and varieties
Adopt mixed rotations with cover crops and green manures to increase biomass additions to soil. Minimise summer fallows and periods with no ground cover to maintain stocks of soil organic matter	Avoid burning of residues. Values of secondary crops are critical in building financial returns and optimizing GHG per output value
Use soil conservation measures to avoid soil erosion and loss of soil organic matter. Apply composts and manures to increase stocks of soil organic matter	Soil carbon can be built with the use of soil additives including silicates and biochar
Improve pasture/rangelands through grazing, vegetation and fire management to reduce degradation and increase soil organic matter	Avoid overgrazing; select livestock to optimize yields and GHG performance; link with improved livestock practice
Cultivate perennial grasses (60-80% of biomass below ground) rather than annuals (20% below ground)	Includes restoration of arable land to grassland and possible changes of livestock systems
Adopt agroforestry in cropping systems to increase above-ground standing biomass. Convert marginal agricultural land to woodlands	End-use of woods also affects GHG by using wood for energy production or to replace energy-intensive materials such as steel, aluminium and concrete. Can also be used for second-generation biofuels
Restore natural vegetation	It is estimated that restoring Australian rangelands (covering 70% of land mass) could absorb at least half of national annual GHG emissions
Conserve fuel and reduce machinery use to minimise fossil fuel consumption. Use biogas digesters to produce methane	

Sources: Wright, UK government, DB Research **12**

2.5 Low-emission farming systems

Some farming systems use a mix of the climate-mitigating practices described above.

Organic agriculture: A holistic production management system that avoids use of agro-chemicals and genetically modified organisms, minimizes pollution of air, soil and water and optimizes the health and productivity of plants, animals and people.

Source: FAO

Organic farming

According to the FAO, lower GHG emissions for crop production, enhanced carbon sequestration and lower input of fossil fuel dependent resources give organic agriculture considerable potential for mitigating and adapting to climate change. Life-cycle assessments show that emissions in conventional production systems are higher than those of organic systems[33].

[32] Scherr and Sthapit (2009) report that researchers found in Zimbabwe that 24% of the average income of poor farmers came from gathering woodland products.
[33] For more on organic agriculture and climate mitigation, see FAO (2009a).

Organic farming for carbon storage
On average, organic farming produces 20% higher soil carbon levels than conventional farming. If adopted globally, the offset potential would be 11% of global GHGs for at least the next 20 years.
Source: Wright (2010)

The core principles of agroecology
Recycling nutrients and energy on the farm, rather than introducing external inputs; integrating crops and livestocks; diversifying species and genetic resources over time and space and focusing on interactions and productivity across the agricultural system rather than on individual species.
Source: De Schutter (2010)

The principles of Conservation Agriculture
1. Continuous minimum mechanical disturbance
2. Permanent organic soil cover
3. Diversification of crop species, grown in sequences and/or associations

Source: FAO

Integrated Food-Energy Systems examples
- Biogas from livestock residues
- Animal feed from by-products of corn ethanol
- Bagasse for energy as a by-product of sugarcane production for food purposes

Urban agriculture: Vegetables, fruits, mushrooms, herbs, meat, eggs, milk and even fish are being produced in community gardens, private backyards, schools, hospitals, roof tops, window boxes and vacant public lands. This home production can provide a significant share of a family's food requirements.
Source: FAO(2010)

Although the potential of organic farming to feed the world is still being debated, there is little dispute about the fact that many farmers can maintain yields while using significantly less inorganic fertilizer, with major benefits to the environment, the climate, farmers' health and the local economy (higher prices/revenues, higher labour requirements)[34].

Agroecology

Agroecology is the result of the convergence of agronomy and ecology. It is highly knowledge-intensive, based on techniques which are based on farmers' knowledge and not delivered top-down.

According to De Schutter (2010), agroecology has been proven to raise productivity at field level, reduce rural poverty and contribute to improving nutrition as well as contributing to adapting to and contributing to climate change.

Conservation agriculture

This system was mentioned in 2.1 as a system using reduced tillage, permanent organic cover and crop rotations. It is increasingly used and promoted by the FAO, especially in developing and emerging economies. One of its drawbacks is that its adoption is associated with significant use of herbicides and may lead to water contamination. Over time, however, soil cover practices tend to prevent weed emergence and allow reduced use of herbicides. There is also little documentation on the potential of conservation agriculture to feed the world.

Integrated Food-Energy systems

Integrated systems combining various types of crops or trees and crops increase and diversify production. Thus, they minimize risks and enhance the economic resilience of farmers. Integrated crop and livestock systems also increase efficiency and environmental sustainability of both systems as the waste product of one component serves as a resource for the other: manure increases crop production and crop residues as well as by-products are used as animal feed.

Integrated Food Energy Systems simultaneously produce food and energy[35]. One method combines food and energy crops on the same plot of land such as agroforestry systems growing trees for fuelwood and charcoal. Another method is based on the use of by-products/residues of one type of product to produce another (see examples in the box).

Urban and peri-urban agriculture

The share of the global population living in cities is currently around 50% and is expected to rise to 70% by 2050. On top of improving food security and employment opportunities for the urban poor, urban agriculture contributes to reducing emissions by cutting down on transport. Up to 15% of the world's food is produced by urban agriculture and 70% of urban households in developing countries participate in agricultural activities, according to the FAO[36]. Competition for land and issues related to tenure rights are major constraints on the development of agriculture. Environmental impact

[34] For a good literature review on the potential of organic farming, see Wright (2009), de Ponti et al. (2011). Hoffmann (2010) also reports that every year some 300,000 farmers die of agrochemical use in conventional agriculture. See also RNE (2011).
[35] FAO(2010).
[36] UK Government (2011).

and food safety (due to use of waste water and organic material) are also concerns to be addressed.

3. Climate-conscious consumption

Drastic change is needed in regard to both food demand and supply. In an era of scarcity, it is imperative to address production and consumption jointly in order to introduce the necessary feedbacks among them and to decouple food production from resource use. Efficiency and resilience are the new priorities over production levels.

Source: EU SCAR (2011)

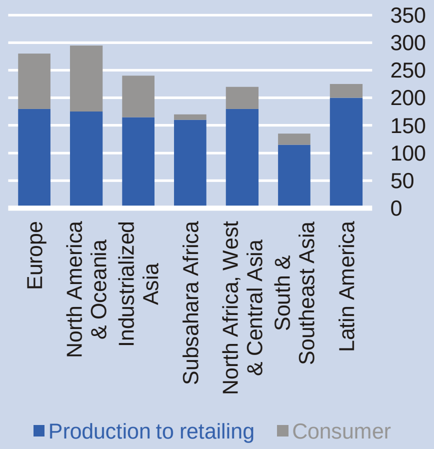
It is a given that the world's population will continue to increase in the next decades and will need to feed itself. It may, however, not be a given that consumption patterns will stay similar to what they are and cannot be changed towards a more sustainable use of resources. It is important to question demand rather than systematically consider it as an exogenous variable.

3.1 Reducing food loss

A recent study[37] identified that around one-third of food produced for human consumption is lost or wasted globally. On top of representing a massive waste of resources exacerbating food insecurity, it means that the GHG emissions occurring along the food chain could have been avoided, as well as the significant amount of methane emissions resulting from food rotting. On a per-capita basis, much more food is wasted in the industrialized world than in developing countries.

Per capita food losses and waste

kg/year



Source: FAO 13

In all regions, food is mostly wasted early in the food supply chain. In medium- and high-income countries, a significant amount of food is wasted at the consumption stage, including food still suitable for human consumption. Food is also wasted due to quality standards rejecting food items which are not perfect in shape or appearance. The causes of food losses and waste in low-income countries are mostly associated with financial, managerial and technical limitations in various areas: harvesting techniques, storage and cooling facilities, infrastructure, packaging and marketing systems. Both private and public sectors have a role to play in investing in these areas.

Food wasted in industrialized countries can be reduced by raising awareness among food industries, retailers and consumers and by putting safe food which is presently thrown away to good use, for instance by directing towards people who need it.

3.2 Recognizing the links between mitigation policies, biofuels and food production

Some biofuel systems have net positive effects for GHG emissions but many first generation biofuels do not contribute to GHG emissions while reducing the area of land available to grow food. A significant amount of bioethanol is produced from sugar cane (in Brazil), sugar beet and grain crops (maize in USA, wheat in Europe) and biodiesel is derived from vegetable oils (rapeseed, palm, soybean or sunflower).

First-generation biofuels not sustainable They compete with food crops, and agro-bioenergy in general does not match the criteria of sufficiency. Arable land resources are limited and further expansion into forest, grassland and woodland areas will result in significant carbon emissions, which offset the primary justification for using biofuels.

Source: EU SCAR (2011)

Second generation biofuels from cellulosic material (leaves, wood, green waste) are promising and expected after 2020. They also provide an opportunity to be combined with livestock production associated with lower methane emission (through feeding on less gas-producing by-products). The use of aquatic algae for biofuel production would be combined with carbon uptake. These third-generation biofuels are still under development.

[37] FAO(2011).

Well-informed policies are needed in order to minimise detrimental competition for land and water, including speeding up the development of second and third generation biofuels[38].

3.3 Modifying diet preferences

Evidence suggests that a climate-friendly diet could be achieved through substituting animal proteins with vegetable proteins (such as pulses) and favouring consumption of food which is locally produced in season (to reduce both transport and cold storage).

The issue of transport in a context of low GHG emissions is not straight-forward (see box). The concept of whole life-cycle emissions (Life-Cycle Analysis) is very appealing but challenging to evaluate. Food multinationals are showing increasing interest in measuring their carbon and water footprint but it is important to develop comparative standards which are able to guide consumer choice and to provide policy options. Raising consumers' awareness is key.

Internalising the environmental costs into the market price of high-carbon foods like meat is likely an effective way to reduce emissions but needs to be associated with measures ensuring adequate nutrition for all, through vegetal proteins for instance. Such a carbon tax attached to food items may raise fairness issues and is likely to meet strong resistance from industry and politicians.

Sceptics do not consider significant changes in food consumption behaviour as realistic. However, there is evidence of a slow but growing awareness – both at the individual and collective levels – of the impact of one's actions on the environment and health. Many governments are implementing measures to promote sustainable consumption, be it water-pricing, labelling, etc.[39].

Local vs efficiently produced

Evidence does suggest that food should be produced closer to consumers if it can be produced efficiently in terrns of productivity and GHG emissions. This is usually the case with seasonal food. However, the GHG impact of production from most favourable locations (in terms of requirements of land and other resources) may be lower than that of less efficient local production if it is shipped efficiently even over long distances. Benefits in income and food security incurred to low-income farming communities from international exports should also not be neglected.

Source: Hoffmann (2011)

A second nutrition transition

"The nutrition transition towards meat-based consumption that is occurring in low and middle income countries has world-wide consequences for food supply and places major stress on natural resources as well as climate change.

Evidence is emerging that a second transition occurs from a diet rich in animal proteins to one that is closer to health guidelines and at the same time puts less pressure on the environment."

Source: EU SCAR (2011)

Insects as climate-friendly meat

An insect-based diet would provide as much protein as meat (as well as key vitamins and minerals) with far fewer emissions. Breeding insects such as locusts, crickets, and mealworms emits one-tenth the amount of methane that raising livestock does.

Source: FAO

The ecological footprint of food

Food	Emissions	Water footprint	Land use	Calories
1 kg	Kg CO_2 eq.	litres	m²	Kcal
Beef	16.0	15,500	7.9	2,470
Milk	10.6	1,000	9.8	610
Eggs	5.5	3,333	6.7	1,430
Chicken	4.6	3,900	6.4	1,650
Wheat	0.8	1,300	1.5	3,400
Rice	-	3,400	-	1,300

Sources: www.waterfootprint.org, UK DEFRA (2006), National Geographic, USDA National Nutrient Database, Oxfam

14

4. The crucial role of agriculture in mitigating climate change

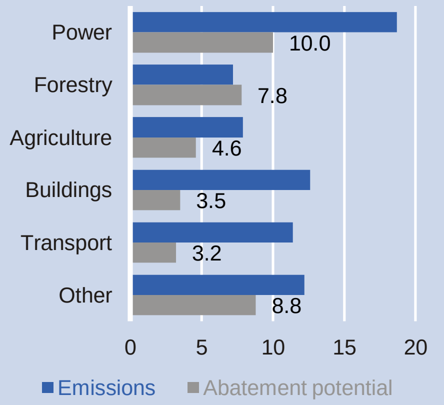
4.1 An enormous potential

Over 4 billion tons of CO_2 equivalent mitigable in agriculture, 1/3 of the total abatement potential together with forestry ...

The IPCC estimates the global technical potential for GHG mitigation in agriculture production at 5.5 to 6 Gt of CO_2 equivalent per year by 2030. These figures do not include improved energy efficiency, biofuels or other changes in demand. This theoretical reduction in emissions, assuming adoption of all technical options is

[38] UK Government (2011).
[39] CIRAD-INRA (2011), EU SCAR (2011), OECD (2008).

GHG abatement potential
Billion tons CO_2 eq .per year until 2030



Source: McKinsey, DB Research 15

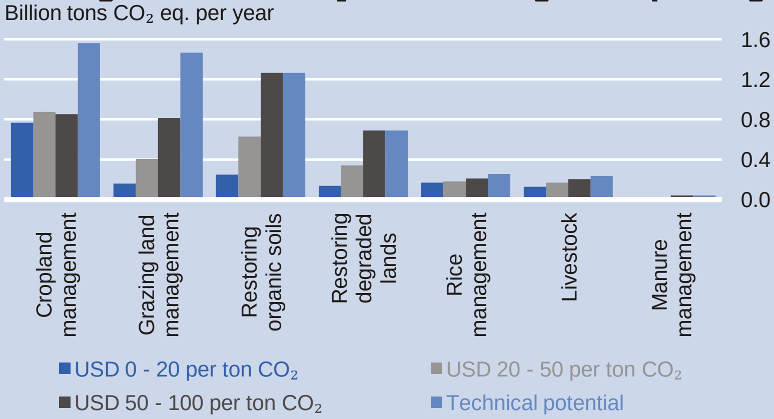
Sequestering the carbon already in the atmosphere

derived mostly (89%) from carbon sequestration in soil, 9% from methane reduction in rice production and livestock/manure management and 2% from nitrous oxide reduction through better cropland management[40]. It does not take into account fossil fuel offsets from biomass use.

The economic potential, taking into account the costs involved, is naturally much lower and depends on carbon prices. For a range of USD 50 to 60 per ton of CO_2 eq mitigated, agriculture has a mitigation potential of over 4 billion tons CO_2 eq. Even at prices below USD 20 per ton of CO_2 eq mitigated, the mitigation potential in agriculture is still substantial at over 1.5 billion tons of CO_2 eq. The current price for carbon is 13 EUR per ton.

McKinsey identifies terrestrial carbon in agriculture/forestry as one of the three major areas of GHG abatement opportunities (at 12 billion tons of CO_2 eq per year in 2030) next to energy efficiency (14 billion) and low-carbon energy supply (also 12 billion). This means that the agriculture/forestry sector accounts for one-third of the total economic abatement potential, while agriculture alone accounts for 12%.

Greenhouse gas sequestration potentials from farming and land use by level of mitigation spending
Billion tons CO_2 eq. per year



The respective total potentials from farming and land use are 1.6, 2.6, 4 and 5.5 (technical) bn tons CO_2 eq.

Sources: Smith, IPCC 16

... and the edge of carbon sequestration

In comparison, most of the promising solutions for reducing emissions in the energy sector are still in development and unlikely to be widely used in the next years or maybe decades. Curbing GHG emissions caused by farming practices and deforestation should be cheaper[41]. Alternative energy systems have the important advantage of lowering GHG emissions by replacing fossil fuels. Many options in the energy sector are subsidized and benefit from high oil prices.

The agriculture and forestry sectors provide the crucial possibility of sequestering the carbon already in the atmosphere. Carbon capture and storage from energy-related emissions is technically possible but not doable on a large-scale until 2020 or so[42]. Most importantly, it is not designed to capture GHGs already present in the atmosphere, which only terrestrial carbon sequestration can do.

[40] Smith et al. (2007).
[41] "UN climate talk". The Economist, September 3-9 2011.
[42] Heymann (2011).

Both the energy route and the agriculture/forestry route need to be pursued

Both the energy route and the agriculture/land-use route need to be pursued in other to tackle climate change. In terms of sectors, the most promising for climate protection are power, forestry and agriculture, followed by buildings and transport[43].

4.2 A worthwhile investment

Effective reduction of net GHG emissions

In building the case for investing in farming and land use for climate change mitigation, three issues are often addressed: permanence (whether emission reductions will be too short-lived), additionality (whether climate benefits will be greater than those expected in the baseline conditions) and leakage (whether emission reductions will only be offset by increases elsewhere)[44].

Long-lasting impact is valuable, even if not permanent

Long-lasting

The carbon stored in soils can be released through cultivation, harvest, a natural disaster or as a result of either ecological processes or dynamic incentives. Thus it is not "permanently" sequestered. However, practices such as farming with perennials can have a long-lasting impact. Even if it results in carbon ultimately released a few decades later, it is perfectly complementary with energy strategies forecasted to kick-in in a few decades.

Moreover, due to the cumulative impacts of carbon in the atmosphere, the ability to delay GHG emissions is highly valuable, even if these techniques should not be rewarded to the same extent as more permanent ones.

Emission-reducing practices which are otherwise beneficial and profitable are worth promoting anyway

Additional benefits

Additionality criteria are met when investments enable farmers to overcome barriers to adopting profitable climate-friendly practices such as lack of technical assistance, lack of regionally available planting materials, lack of investment credit or lack of essential infrastructure.

Source: Scherr and Sthapit (2009)

"In Nicaragua, farmers who were bypassed for carbon and biodiversity payments, despite a history of excellent land husbandry, wondered if they would be eligible if they uprooted trees."

Source: reported in Scherr and Sthapit (2009)

The question is often raised whether it makes sense to reward land-managers for doing what they are already doing, or may soon be doing, because it makes business sense – whether driven by economic or ecological changes. The issue is especially sensitive if the practices involved, be they no-till systems or rotational grazing, are profitable to the land-manager: why grant external payments in this case?

Following this line of thinking may, however, be counter-productive to scaling-up climate-friendly practices on several grounds. Firstly, it is important to reach those farmers who could not otherwise afford the initial investment in sustainable practices. Secondly, profitable and sustainable interventions are most likely the ones with the maximum impact since they do not require continuous financing. Thirdly, failing to reward sustainable producers creates perverse incentives if programmes favour producers who have caused the most climate problems[45].

Displacing the problem is not a serious concern

No evidence of leakage

— Enhancing soil carbon in agricultural fields typically increases crop yields and farm income, thus usually resulting in lower land requirements

— Reducing methane emissions from dairy operations through biogas digesters supplying farm energy needs may increase the farm's profitability

Source: reported in Scherr and Sthapit (2009)

It is important to know whether achieving climate benefits in one place simply displaces land use pressures to another place, which may result in no net reduction in emissions. This concern applies to interventions such as preventing land-clearing in one place or implementing cropping systems which result in lower supply or higher prices: they may lead to non-climate friendly practices taking place somewhere else. There are ways to counter this problem, by

[43] McKinsey (2009).
[44] Scherr and Sthapit (2009).
[45] Scherr and Sthapit (2009)

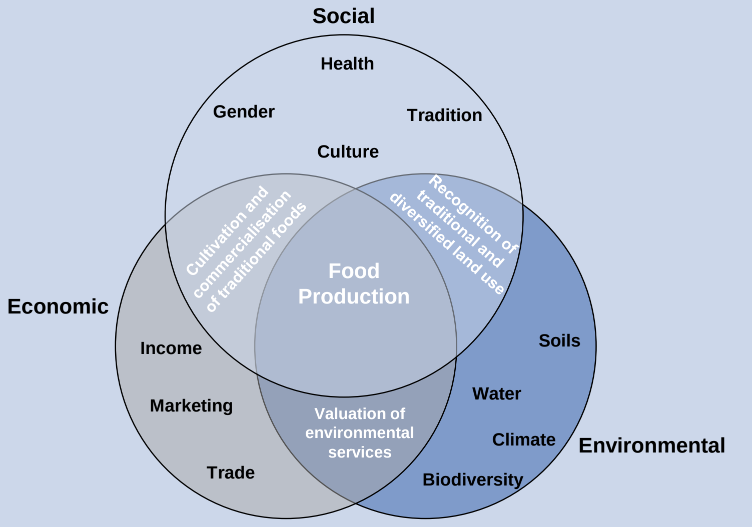
assessing the climate impact on a larger scale (even at country level), or limiting the market access to producers who are certified "climate-friendly".

However, most types of climate-friendly farming involving carbon sequestration or emissions reduction do not lead to this issue of "displacing the problem" or leakage since they do not significantly increase production costs. As discussed above, enhancing soil carbon in agricultural fields will actually normally increase crop yields and farm income, often resulting in reduced need for land, thus preventing land-clearing.

Coherence between food, energy, environmental and health policies and across all levels of governance are prerequisites for a timely transition to sustainable and equitable food systems. A new quality of governance is needed at local, national and global level, with a substantial contribution by the State and civil society.

Source: EU SCAR (2011)

The multi functionality of agriculture



Source: IAASTD 17

Multiple interactions with collateral benefits

Trade-offs need to be dealt with …

Given the multiple roles and functions of agriculture, the issue of climate change is related to other major challenges such as hunger, malnutrition and poverty reduction, sustainability of resources (water, soil, biodiversity), economic, social and gender inequity[46]. Trade-offs will need to be made in some cases, for instance between use of nitrogen fertiliser and land conversion, or between production of biofuel crops and food security. Food availability is obviously a prime objective and a whole system approach is required when evaluating climate mitigation potential. However, there are many synergies between the practices which maximize the various objectives of food security, economic development and environmental sustainability, including those of adapting to climate change and mitigating it[47].

… and synergies leveraged

Indeed, many of the agricultural practices aiming to mitigate GHG emissions will also help to adapt to climate change and will enhance soil health, water and air quality, energy efficiency and wildlife habitat. Some examples of collateral benefits were given above. For instance, increasing soil carbon content locks up carbon and

How soil and yields can improve at the same time: two examples with multiple wins

1. **"Push-pull" strategy to control weeds and insects** (used in East Africa, in over 10,000 households)
   a. Push away pests from corn by inter-planting corn with insect-repellent crops
   b. Pull them towards small plots of Napier grass, a plant which both attracts and traps insects
   c. Feed the insect-repellent crops to livestock

→ Corn and milk production doubles

→ Soil improves (also as carbon sink)

2. **Integrated rice-duck production**
   In many Asian countries, ducks and fish are found to be as effective as pesticides for controlling insects in rice paddies.

→ Insect and weed control without fuel

→ Plant nutrients from duck dropping

→ Additional protein food available

Source: De Schutter (2010)

[46] EU SCAR (2011), CIRAD-INRA (2011), IAASTD (2009). Haerlin (2009). Schaffnit-Chatterjee (2009).

[47] FAO (2010), Hoffmann (2011).

increases soil fertility at the same time. Lower usage of nitrogen fertilisers reduces GHG emissions and energy consumption without necessarily reducing yields; it also benefits the environment while reducing costs. Planted trees protect soil and crops from erosion (mitigation) while acting as wind-breakers (adaptation) and creating habitat and corridors for biodiversity. Intercropping trees with vegetable crops increases the carbon sequestered on the farm while diversifying food production, thus increasing resilience to climate change[48].

Linking sustainable management with climate action can thus increase the base of actors and increase the momentum towards stricter climate regulation and greater investment in mitigation if farmers, nature conservationists, politicians and the agribusiness join forces.

5. Implementation challenges

Even though many of the climate-friendly agricultural technologies or practices are readily available, implementable at low or no cost and bring multiple benefits, they have still not been adopted on a large scale. A number of issues makes their broad implementation challenging, particularly the following three: 1) monitoring, 2) the sheer number of GHG sources and mitigation practices, 3) agricultural and trade policies biased towards other agricultural systems.

5.1 Measuring and monitoring climate impacts

Measuring carbon

Several methods can be used to measure carbon content (changes) in above- and below-ground biomass, soils and wood products:

— Statistical sampling

— Computer modelling

— Remote sampling

Source: US EPA

There is no recognized rigorous methodology for assessing agriculture-related emissions, sequestration and storage and this is a serious constraint to including agricultural GHG emissions in offset schemes. However, it is scientifically possible to measure the carbon content of a soil sample within 1-2% error[49].

Scientists are rapidly developing methodologies for assessing carbon balances for specific components of land use such as soil organic matter enrichment, conservation tillage, agroforestry systems, etc. This will allow an indirect measure of carbon content in a field by measuring adoption of specific practices whose average impact has been validated for a particular agroecosystem.

Since soil carbon content in different portions of an individual field can vary widely, sampling approaches are also being developed to link remote sensing with representative samples of soil. What is still missing is “an integrated approach to landscape-level carbon accounting that would reflect diverse land uses and practices” enabling verification of whether a climate benefit in one component of the landscape is undermined by increased emissions in another component[50].

At the moment, there is no easy way to record attributable emission reduction but progress is ongoing and the outlook is promising[51]. Trade-offs will also need to be investigated using measurement techniques that assess the interactions between the environmental, economic and social impacts of climate-friendly agricultural practices.

[48] Scherr and Sthapit (2009).
[49] FAO (2009b).
[50] Scherr and Sthapit (2009).
[51] FAO (2009b).

5.2 Fragmentation and weak institutions

Fragmentation ...

A high level of fragmentation at several levels complicates the scaling-up of climate-friendly practices. There is indeed a large variety of land uses, of sources and patterns of emissions across ecosystems, of practices to reduce emissions or sequester carbon, and a large number of players: in particular, implementing climate-friendly agricultural techniques means working with hundreds of millions of smallholder farmers and requires community-scale planning, both technically and organisationally.

Poor rural people collectively manage vast areas of land and forest and can be important players in natural resource management and carbon sequestration.

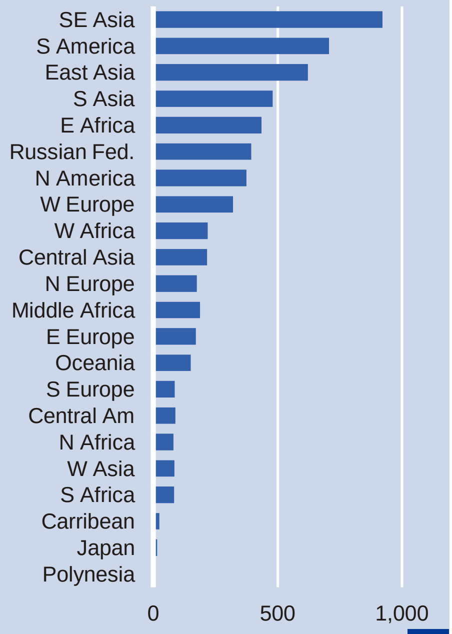
Source: IFAD (2010)

... and weak institutions ...

A large number of these farmers are located in the developing world, which harbours the greatest potential for climate mitigation, with the most cost-effective interventions. This is often in areas with weak institutions, which creates an additional barrier to attracting investments. In developing strategies for carbon payments and trading, there is, according to Scherr and Sthapit (2009), "a concern around poorly developed and poorly integrated market institutions (sellers, buyers, but also regulators, verifiers, certifiers, brokers, bankers and registers) and also poor negotiating power on the part of rural communities". People fear that "most of the value of carbon credits will be taken by intermediaries, with little left over to provide meaningful incentives to land managers."

GHG mitigation potential from agriculture by region

Million tons CO_2 eq. per year (technical)



Sources: Smith, IPCC, DB Research 18

...drive a need for effective climate finance investment

These hurdles actually show that climate finance investment is additional. Most of the climate-friendly agricultural practices described above have proved successful in pilot studies or initiatives within a particular landscape. In order to make a difference to the world's climate, institutional investment, capacity-building and finance are required in order to scale up the institutional models and activities which have proved able at the local level of overcoming these challenges. There are already groups of people expert at these tasks: rural development agencies, famers' organizations, NGOs and private providers of agricultural inputs and services. Making full use of this expertise for climate action will be critical to success.[52]

5.3 Policies biased towards other agricultural systems

A number of market distortions and market structures act as disincentives to transitioning towards sustainable agricultural practices[53].

Agricultural subsidies North vs South

- Average support to farmers in major developed countries: 30% of GDP in 2003-2005 (or close to USD 1 bn per day)
- Cost to developing countries: USD 17 bn per year – equivalent to five times the recent levels of official development assistance in agriculture (ODA)
- Share of agriculture in ODA : 18% in 1979, 3.5% in 2004 (USD 8 bn in 1984, USD 3.4 bn in 2004)

Source: OECD, World Bank, UNCTAD

Agricultural subsidies in developed countries limit change in developing countries

The significant subsidisation, in developed countries, of agricultural production and of agricultural exports to developing countries come at a high cost to the latter countries[54]. By restricting developing country producers' access to markets, it limits their capacity to grow and to afford the shift towards sustainable, climate-friendly, agricultural production on a large scale.

A reform of international trade policies is required and time is running out to reach a successful conclusion to the Doha Round of WTO negotiations, which an increasing number of people consider

[52] Scherr and Sthapit (2009).
[53] Hoffmann(2011).
[54] Schaffnit-Chatterjee (2010), Schaffnit-Chatterjee (2011), Weltsichten (2011).

unrealistic[55]. Appropriate carbon pricing and policies should complement the phasing out of the subsidies.

National agricultural policies often have perverse effects

Governments spend billions of dollars on yearly agricultural subsidies paid to farmers for production and agricultural inputs. This is mostly the case in the United States and Europe but high subsidies are also found in Japan, India, China and other countries.

Often linked to production, these payments and pricing policies of agricultural inputs usually lead to overuse of pesticides, fertilizers, water and fuel or encourage land degradation[56]. Changing the incentive structure can be achieved by increasing the efficiency of the use of agro-chemicals and promoting their replacement by agricultural practices which enrich the soil, reduce emissions and lower both agricultural production costs and import bills (e.g. multi-cropping, crop-livestock integrated production, use of bio-fertilisers and bio-pesticides). Some countries are in the process of redirecting agricultural subsidies towards payments for environmental services, and these can include carbon storage or emissions reduction.

Small farmers in developing countries often do not have stable land tenure and this is not conducive to investing in soil fertility and other sustainable agricultural practices. Agrarian reform is urgent in many developing countries. The share and effectiveness of public expenditures for agricultural development needs to be drastically increased.

Land tenure systems to be improved

— Globally, 60-70% of farms are being run by people who do not have contractual use

— 60-80% of food in many developing countries is produced by women. Women, however, own only a tiny amount of land (1% of titled land in Africa) and often lose their rights to land if they become widowed or divorced.

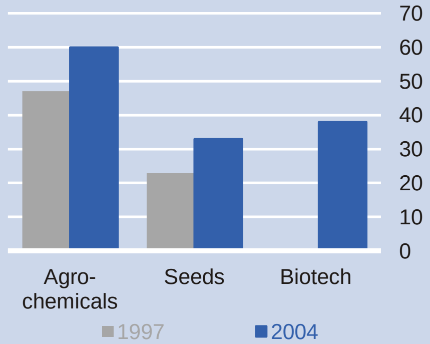
Source: Hoffmann (2011)

High market concentration not always conducive to sustainability

The high concentration of the corporate food system is also a challenge in scaling-up sustainable agricultural practices. A handful of powerful companies dominate the global agricultural input markets of agrochemicals, seeds and biotechnology. Their immediate interest is obviously to sell their products, thus to "maintain an external-input-dependent, mono-culture-focused and carbon-intensive industrial approach to agriculture"[57]. With regard to seeds, industry consolidation tends to result in a narrower choice for farmers and loss of access to some varieties. Due to their size, the major food processors and retailers also influence the global food supply chains into sourcing from "scale-focused mono-crop production" at the expense of diverse "multi-cropping and integrated livestock and crop farming systems".[58]

High concentration

Market share of the four major firms, %



Sales of agrochemicals and seeds, patents for biotechnology.

Sources: World Bank, DB Research 19

There is, however, a growing tendency for these large players to obtain some of their supply from smallholder farmers. Not only driven here by corporate social responsibility objectives, processors and retailers are aware that these farmers are key to securing their supply in a resource-constrained world. As a result, they are actively partnering with smallholders[59]. Input suppliers have also launched initiatives to facilitate smallholders' access to inputs and to train them in applying them appropriately. There is also a small but growing movement towards democratising agricultural research by including farming communities and consumers, rather than confining it to large companies' laboratories[60].

55 Deutsch (2011).
56 Hoffmann (2011).
57 Hoffmann (2011)
58 Hoffmann (2011).
59 Schaffnit-Chatterjee (2010).
60 See www.cambia.org, www.iied.org/natural-resources/media/world-food-day.

6. Actions required for transitioning towards a low-carbon agriculture

Climate-smart agriculture
Agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHG (mitigation) and enhances achievement of national food security and development goals

Source: FAO

All sectors need to contribute to mitigating climate change if its worst effects are to be avoided. Agriculture can play a significant role both at the production and consumption levels, but more action is needed in order to realize the potential[61].

6.1 A mix of approaches to leverage

There is no single approach to climate mitigation since the optimal path will take into account the whole system and depend on the context. Beyond GHG levels, it is essential to also consider the amount of food produced, the quantity of inputs required, food prices, ecosystem services, animal welfare, etc.

Four approaches to lower emissions:

- **Market incentives**
- **Regulation**
- **Demand pressures**
- **Voluntary measures**

Building momentum for emissions reduction in the food system can be achieved using four main instruments: market incentives (in the form of grants, subsidies, levies, carbon taxes or carbon cap and trade schemes, or, more broadly, payments for environmental services), mandatory emission limits (potentially associated with higher production costs and market adjustments), market pressures driven by consumer choice (requiring active and informed consumers, accurate and trusted information such as labelling or certification) and voluntary measures driven by corporate social responsibility[62]. The balance between incentives and regulation will depend on availability of financial resources for creating incentives and enforcement costs and effectiveness.

Pricing negative externalities: effective and efficient

Carbon pricing is key to climate change mitigation

By internalizing the environmental cost of production and removing an implicit subsidy for carbon use, carbon pricing is key to climate change mitigation. Carbon taxes and emissions trading schemes (ETS, also called cap and trade schemes) are the main market-based instruments for pricing GHGs, especially CO_2. They are considered effective in reducing carbon emissions but are expensive and complex to put in place. They also require costly measuring and reporting procedures[63].

Cap and trade vs carbon tax

Principle A cap and trade scheme, also called emissions trading scheme (ETS), sets a limit (cap) on emission levels and allows the price of the emissions to vary. A carbon tax puts a price on emissions but allows the emission levels to change.

Pros and cons A carbon tax is more flexible: it can be increased if emission levels are still too high, whereas permits are allocated for the duration of a cap and trade scheme. However a basic tax does not differentiate between various levels of ability to pay and tends to disproportionately affect low-income groups.

Use Carbon taxes have been introduced in a number of countries for specific sectors (e.g. Finland, France, the Netherlands, Norway, Sweden and some Canadian provinces). ETS have been implemented by a number of go-vernments and municipalities and the EU. Large companies are allocated a permit to re-lease a set amount of GHGs and can trade it.

Source: Kasterine and Vanzetti (2010)

The scarcity of agricultural products under the Clean Development Mechanism (CDM) represents a missed opportunity. The CDM has proven successful in directing private capital towards agricultural mitigation projects, primarily in the areas of managing methane emissions from composting and manure or using residual agricultural organic matter as fuel source. An increase of carbon emission offset trading can potentially provide an important source of funding to move towards climate-friendly agriculture. A lot can be achieved in the short-term via the voluntary carbon market but it is necessary for the long run that the international framework for action on climate change fully incorporates agriculture and land-use.

ETS could provide strong incentives for government carbon funds and the private sector in developed countries to buy agriculture-related emission reductions generated from smallholder agricultural activities in developing countries. A major obstacle to including agriculture in a cap-and-trade scheme is the absence of a cost-effective monitoring and reporting system. The on-going promising

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61 FAO (2010)., FAO (2009). Larson et al. (2011). Kasterine and Venzetti (2010). Hoffmann (2011).
62 UK (2011).
63 FAO (2010), Kasterine and Vanzetti (2010).

developments of measurement methodologies opens the door for including land-use projects under the CDM.

Cap-and-trade systems are expected to generate drastically greater resources for shifting to a low-carbon economy than can be done with government tax revenues[64]. Carbon taxes are, however, easier to implement and may be useful in transitioning to carbon prices[65].

Carbon-trading schemes need to include a way to compensate poor rural people for environmental services that contribute to carbon sequestration and limit carbon emissions.

Source; IFAD (2010)

Payments for environmental services: effective under certain conditions and increasingly important

Payments for environmental services (PES) are one type of economic incentive for land managers to use environmentally-friendly practices. Their effectiveness depends on the level of decision-making the farmers enjoy. PES requires secure property rights, easy access to information about the schemes and affordable transaction costs. The latter can be reduced by simplifying the design of PES schemes. If these conditions are not met, they run the risk of favouring larger farmers.

Payments for ecosystem services

PES describes financial arrangements and schemes designed to protect the benefits of the natural environment to human beings. Payment schemes for watershed and biodiversity services are currently the primary markets for ecosystem services, evaluated globally at around $11 billion in 2008. Smaller, but promising, markets exist for forest carbon sequestration programmes and water quality trading.

Source: Worldwatch Institute

PES is an increasingly important environmental policy tool in both developing and developed countries. PES carbon sequestration projects in the world's forests were worth around $37 million in 2008, up from $7.6 million in 2006[66]. Land-use CDM projects can be viewed as a kind of PES system in the sense that they pay for carbon sequestration. However their funding is organized differently since the Kyoto Protocol creates incentives for private payments.

Product carbon labelling suffers from lack of measurement standards but has appeal to green consumers

Carbon accounting or Life-Cycle Analysis is potentially a useful tool for identifying "high GHG areas" in the agri-food supply chain and taking steps to reduce them. It is designed to provide the consumer with information that drives demand for low-carbon products. Measurement is, however, complex and standards across retailers are difficult to establish. As an example of the challenges involved, the vTI reports that an apple should have its label changed according to how long it is being stored.[67]

Carbon footprint labelling

Assessment involves considering:

- Farming practices (fertiliser usage, soil coverage, etc.)
- Energy on the farm (source and usage)
- Transport
- Energy for transformation and storage
- Packaging (material and amount)

Source: vTI (2009)

If the other tools are not available or affordable, carbon labelling may be used and can reach smallholders, building on the lessons learnt from the development of organic and sustainable agricultural products. Product carbon footprint labelling may continue to interest companies in anticipation of impending regulation. It is not clear whether it will reach consumers beyond a niche market[68].

6.2 Policy and institutional changes are required

The process of methodological development of appropriate climate change strategies is multi-faceted, complex, and ongoing. As an initiative of the research programme Climate Change, Agriculture and Food Security (CCAFS)[69], the Commission on Sustainable Agriculture and Climate Change started working in February 2011 on identifying policy changes and actions needed to achieve sustainable agriculture – contributing to food security, poverty

"To stay within the capacity of system Earth, demand increases need to be mitigated through behavioral change and structural changes in food systems and supply chains. Moreover, environmental externalities need to be internalised in markets through appropriate governance structures. "

Source: EU SCAR (2011)

64 Scherr and Sthapit (2009).
65 Jordan and Zähres (2011).
66 Bierbower (2011).
67 vTI (2009).
68 Hoffmann (2011).
69 CCAFS is a 10 year research initiative launched by the Group on International Agricultural Research (CGIAR) and the Earth System Science Partnership (ESSP) http://ccafs.cgiar.org.

reduction and responding to climate change adaptation and mitigation goals.

New and improved institutional models are needed for scaling up initiatives to reduce and capture terrestrial emissions, by efficiently delivering financial incentives to land users. This will require collaboration between large numbers of land managers in selling climate benefits, developing investment vehicles for buyers, and providing efficient intermediation to achieve economies of scale[70].

Requirements to link carbon finance to mitigation from smallholder agricultural sector

— Institutions able to facilitate the aggregation of carbon crediting among a large number of smallholders

— Policies in agricultural, financial and environmental sectors facilitating the flow of carbon finance from private and public sectors

— Capacity building

— Agreed system of property rights to the carbon benefits that can be generated

Source: FAO (2009b)

For both purposes of efficiency and synergy capture, policy coherence in climate change mitigation will require effective coordination of the various institutions involved in the areas of agricultural development, natural resources/environment including adaptation to climate change, food security, energy and consumption, both at national and international levels.

One key role of these institutions is the production and dissemination of information, including the development of regulations and standards. Building capacity at local levels is key to success, especially through integrative learning: farmers and researchers working together can effectively determine how to best integrate traditional practices and new agro-ecological scientific knowledge[71].

6.3 Financing and investments

"Climate finance is what will enable a steady and increasing flow of action in developing countries, both on mitigation and on adaptation. But climate finance is in its infancy … And it is clear that we need to develop climate finance to scale and with speed."

Christiana Figueres, Executive Secretary UNFCCC, Barcelona, June 2011

Investment gap

— Mitigation costs in developing countries: USD 140-175 billion annually by 2030

— Financing requirement: USD 563 billion (since savings only materialise over time)

Sources: McKinsey, World Bank

Low-cost mitigation opportunities are plentiful in agricultural land-use, especially in developing countries. However, while the share of current climate change flows to agricultural mitigation (and adaptation) are not known at this time, it is doubtful that they would cover agriculture's overall investment requirements.

The many efforts underway to reduce carbon emissions and store carbon have made carbon a valuable economic commodity. There are two main sources of payment for carbon sequestration from agriculture: the CDM and "voluntary" carbon markets.

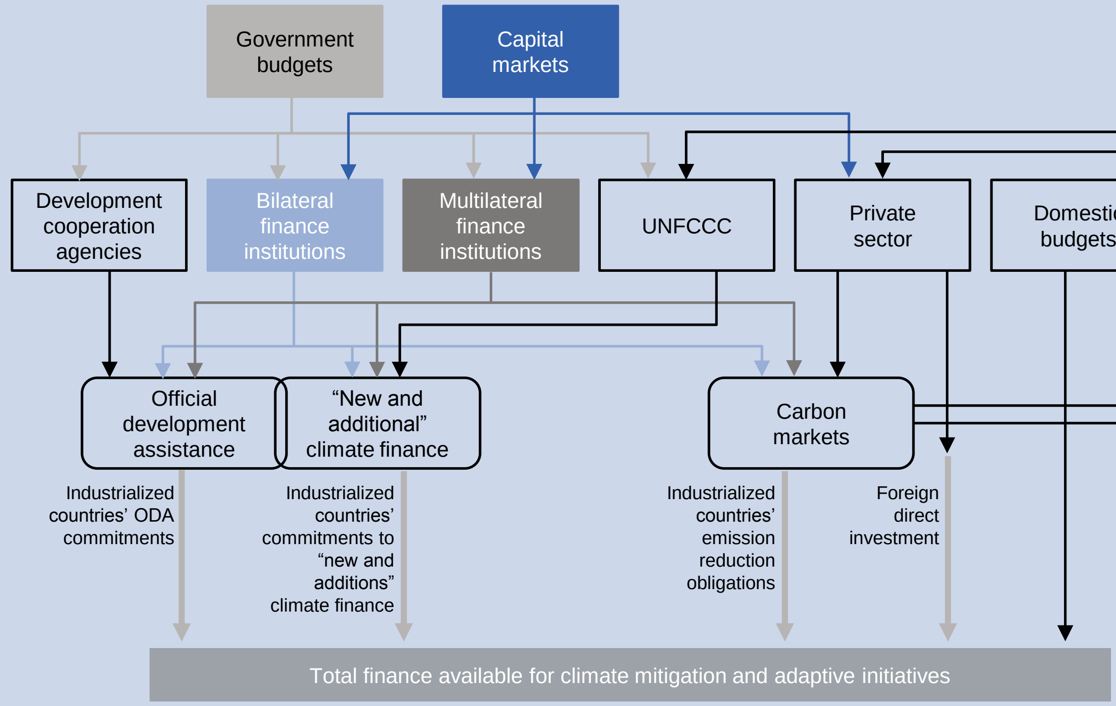
The carbon market, which is already playing an important role in shifting private investment flows, will have to be significantly expanded to address needs for additional investment and financing.

Source: IFAD (2010)

A range of financing mechanisms are needed, from market-based efforts to public sector funds, with the following issues to be addressed: scaling up of funding and delivery mechanisms, reducing transaction costs and improving the contribution to sustainable development by reaching producers including smallholders. Public finance has often acted as a catalyst for action, or a way to fund activities or areas which are neglected by the private sector. Private sector engagement is essential, especially to scale up government-financed development projects and to sustain these projects once government funding is reduced or withdrawn[72]. In poor developing countries, for instance in Sub-Saharan Africa and South Asia, relatively low expected returns discourage investments.

[70] Scherr and Sthapit (2009).
[71] Kotschi (2010).
[72] For more on this, see Hebebrand (2011).

Main climate funds



Sources: FAO, Stockholm Environment Institute, 2009 **20**

6.4 Next steps

Some of the next steps to be taken on the road to transitioning towards a low-carbon agriculture are listed below. They may be considered ambitious but are critical in ensuring that we act before it becomes much more expensive to do so.

1. Include terrestrial emission reduction and sequestration options in climate policy and investment (national legislation, international agreements and investment programmes addressing climate change).
2. Develop market-based measures (e.g. GHG trading systems) to internalize GHG costs in farming and land-use.
3. Remove perverse incentives of agricultural policies, both in the developed and the developing world and switch from spending on private subsidies to granting payments for public goods.
4. Give incentives to use climate-friendly agricultural practices by linking them to co-benefits, e.g. payments for environmental services such as improved soil quality and land productivity as well as sustainable water use. This will help to rally broad-based support.
5. Reduce waste, which will both increase the efficiency of the food system and tackle emissions released through waste disposal.
6. Promote changes in diet preferences by raising consumers' awareness, e.g. via food labelling.
7. Develop new channels and platforms to exchange information and transfer skills. Establish standard methodologies for measuring, monitoring and validating agricultural GHG emissions, capture and storage. Assess full life cycle emission of different foods.

Radical change unavoidable

"A radical change in food consumption and production in Europe is unavoidable to meet the challenges of scarcities and to make the European agro-food system more resilient in times of increasing instability and surprise. Europe has already taken up the climate change challenge in industry and is intending to make new energy technologies a win-win-win strategy for market, labour and human welfare. Now the agro-food sector has an opportunity to positively take the challenge and be the first to win the world market for how to sustainably produce healthy food in a world of scarcities and uncertainty."

Source: EU SCAR (2011)

7. Role of a global bank in investing in agriculture to mitigate climate change[73]

While all of the steps listed above can contribute to the mitigation of climate change and to the creation of sustainable economic development, most of them will require significant amounts of capital. Private capital will form around attractive market conditions and favourable economic impact. It is the role of a global financial institution to provide this capital from its various business areas and through public-private partnerships. A coordinated effort across all business areas brings a specialized industry expertise with full transaction capabilities.

Global Capital Markets

Integrating mitigation strategies into advisory services ...

In providing debt and equity financing through origination, structuring and underwriting, capital markets businesses are integrating mitigation strategies into their advisory services. While the structuring of these deals may be no different, they are given an orientation to identify and originate much needed mitigation opportunities. They include creative structures to finance advanced irrigation systems, tailored agricultural derivatives opportunities that emerge from unique production systems, and corporate treasury solutions for financing commodity movement, risk management and trade finance.

... requires knowledge beyond agricultural commodity markets

The growing grain and resources trade results in increasing storage, transportation, port and logistics infrastructure. When evaluating deals pertaining to agricultural markets at large, maintaining standards to reduce climate emissions is a required core competence. While hedging products like swaps and options are routine for a large bank, tailoring solutions to account for the mitigation requirement of a transaction requires not only a sophisticated knowledge of direct agricultural commodity markets, but also experience with the carbon markets (both voluntary and mandated) as well as technical knowledge of the emissions abatement potential of a given project.

Corporate Finance and Investment Banking

Mitigation activities: a growing, profitable, market

Advising major corporations, financial institutions, financial sponsors, governments and sovereigns on financing climate mitigation activities is another role of banks. Advising clients on M&A opportunities that seek to advance the mitigation mission is also a key core competence of a modern climate sensitive investment bank. Investment banks and/or other institutions can promote these types of investment by financing projects for firms, raising funds dedicated to climate change mitigation, including mitigation clauses in their standard underwriting terms. As mitigation becomes an ever increasing imperative and a competitive business area, corporates will need advice on M&A and innovative financing structures that seize these business opportunities.

[73] This section was contributed by Bruce Kahn, Deutsche Bank Climate Change Advisors, +1 212 454-3017, bruce.kahn@db.com

Equity Research

Along the whole food-supply chain

Building on the results of macroeconomic/trend research, food and agribusiness equity research provides a research platform that can enhance the understanding of the sub-industries and help determine the financial value of mitigation projects to corporate earnings. It is essential that sustainability and climate change risk factors be integrated into valuation models of global agribusinesses.

Asset Management

The Asset Management business is a key provider of capital and of exposure to all aspects of the agricultural value chain as well as across all asset classes.

Funds focused on agribusiness can provide trading liquidity for these firms. Beyond this, asset managers, through their ownership of large blocks of shares, can engage companies and promote mitigation activities. Agricultural commodity funds provide exposure to the sector through futures contracts and are able to manage the optimum roll strategy.

Real asset funds can provide investors with several models of agricultural investing including buy and lease or buy and operate. These funds provide a variety of diversification benefits as well as inflation protection. Moreover, real assets funds focused on mitigation projects, such as carbon efficient logistics, storage facilities and new transportation corridors will provide benefits for mitigation projects and provide financing for smaller projects with mitigation benefits. Sustainability-focused real asset funds that adhere to the UN principles for responsible investment (PRI) will seek to finance mitigation activities or at least consider mitigation in the due diligence of the investments.

Private Equity funds offer thematic investments in growth stage agri-technology companies as well as expansion capital needed for companies providing mitigation solutions, whether they be for farm land, farm management or vertically integrated production, processing and distribution. Technological advances at any point in the food supply chain (production, handling, logistics, processing or distribution) will require financing at various stages of development, across many geographies.

Additional fund opportunities include public-private partnerships that bring both the asset manager and the public entity (government agencies or international aid agencies) closer to their goal. Providing much needed debt capital as well as equity capital with risk protection to projects in under-banked regions such as Africa can help provide mitigation strategies with the required financing.

Principles for responsible agro-investment (RAI)

— Land and resource rights
— Food security
— Transparency, good governance and enabling environment
— Consultation and participation
— Economic viability and responsible agro-enterprise investing
— Social sustainability
— Environmental sustainability

Source: RAI, Knowledge exchange platform developed with The World Bank, FAO, UNCTAD, IFAD

Principles for responsible investment in farmland (PRI)

— Promoting environmental sustainability
— Respecting labour and human rights
— Respecting existing land and resource rights
— Upholding high business and ethical standards
— Reporting on activities and progress towards implementing and promoting the principles

Source : UNPRI (2011)

Financing low-carbon productive agriculture in developing countries

Investment opportunities can enhance the profitability of producers and other actors across the agri-value chain while simultaneously mitigating climate change. Understanding the interdependencies of agribusiness along the value chain is just as important as understanding the sector itself. The agricultural value chain includes input providers, producers and off-takers, but also the manufacturing segment, service providers, processing plants and the extension of large scale farm cooperatives. Financial institutions with the skills to address agribusinesses globally focus on the whole value chain.

In today's global agricultural value chain, there are many inefficiencies in production, processing and distribution as well as deficiencies in management skills. Financing – via smallholder guarantee funds, government-backed loan funds (sometimes with equity allocations) or private equity funds, judicious use of water resources and the promotion of advanced cultivation, storage and distribution techniques could double productivity in some regions of the world while simultaneously storing more carbon in soils, providing a positive feedback loop of enhanced soil fertility and climate change mitigation.

Currently, the established input providers (e.g. seed, fertiliser, pesticides) and off-takers already involved in the agricultural value chain are looking for ways to reduce their carbon footprint, and provide solutions to close the yield gap. Risk insurers are also developing innovative products. Yet, in the most critical areas of the world, the lack of traditional collateral apart from some land and equipment assets, together with production, climate and price risks result in agricultural finance falling outside of the traditional balance sheet lending approach. Therefore, the provision of capital into these underserved agriculture markets, (where much of the agricultural development and climate change mitigation will occur in the coming decades) combined with a focus on climate mitigation, is a large opportunity for a climate sensitive bank that is adept at providing capital markets services.

Furthermore, adherence to a robust due diligence process beyond that of financial metrics include developmental, social and environmental impacts. Important risk mitigants and safeguards are implemented through Social and Environmental Management Systems (SEMS) to protect investments as well as farmers, entrepreneurs and labourers. The degree to which a project can mitigate climate change can be measured, monitored and monetised where applicable, and such metrics can be integrated into deal origination and due diligence.

8. Conclusion

"Climate-smart agriculture is a path to green growth."

The World Bank, September 2011

Given the magnitude of the challenge to stabilize GHG emissions, it is crucial that the mitigation potential of all sectors be tapped fully. We need to pursue agriculture and land-use solutions in addition to improving energy efficiency and transitioning to renewable energy. Agriculture provides a tremendous opportunity to mitigate climate change while generating important co-benefits. Farmers around the world can be part of the solution to climate change.

Climate-smart agriculture: a triple win

In order to address current and future needs in agricultural production, investments must be channelled towards climate-friendly production systems so that increased production does not come at the expense of environmental sustainability (for instance clearing large areas of natural forests and grasslands, leaving soils bare over many months or otherwise depleting organic matter from the soil). On top of mitigating climate change, these approaches will reduce poverty and increase food security globally, as they increase the resilience of rural poor people to climate change by restoring and protecting their land, water and other natural assets.

The multiple co-benefits of these practices in terms of soil health, water quality, air pollution, wildlife habitat, etc. can help generate broad political support and bring together new groups of people interested in promoting climate action: farmers, conservationists, politicians, consumers and the agribusiness and food industries.

Climate change thus provides both the imperative and the opportunity to scale up proven approaches to intensify ecosystem-based, sustainable agricultural production.

Crucial role of the financial sector

The financial sector has a crucial role to play in scaling up the investment for climate-smart agriculture: by developing investment vehicles for buyers, by financing low-carbon farming activities in combination with advisory services and by facilitating carbon trading.

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Bibliography

Bailey R. (2011). Growing a better future – Food justice in a resource-constrained world, Oxfam International 2011.

Bellarby J., B. Foereid, A. Hastings and P. Smith (2008). Cool farming: Climate impacts of agriculture and mitigation potential, Report for Greenpeace International, Amsterdam.

Bierbower (2011). Tropical forests push payments for ecosystem services onto the global stage. Worldwatch Institute, Vital Signs, September 2011.

Blaser J. and C. Robledo (2007). Initial analysis on the mitigation potential in the forestry sector. United Nations Framework Convention on Climate Change.

CIRAD-INRA (2011). Agrimonde: Scenarios and challenges for feeding the world in 2050. Editions Quae, Versailles, 2011.

Climate Change Agriculture and Food Security CCAFS (2011). The hidden climate costs of chocolate. April 2011 http://www.ccafs.cgiar.org/blog/hidden-climate-costs-chocolate

Deutsch K. (2011). Doha or Dada – The world trade regime at an historic crossroads. June 2011. Deutsche Bank Research.

De Ponti, T., Rijk, H.C.A., Van Ittersum, M.K. (2011). The crop yield gap between organic and conventional agriculture. Submitted to Agricultural Systems.

De Schutter O. (2010). Agroecology and the right to food. United Nations. December 2010.

Dumanski J.R. et al. (2006). The paradigm of conservation tillage. Proceedings World Association of Soil and Water Conservation.

European Commission (2006). Environmental impact of products: Analysis of life-cycle environmental impacts. Technical report EUR 22284. Brussels.

European Commission SCAR (2011). Sustainable food consumption and production in a resource-constrained world. Standing Committee for Agricultural Resreach (SCAR). February 2011.

FAO (2009a). Low GHG agriculture. Food and Agriculture Organization of the United Nations. Rome, 2009.

FAO (2009b). Enabling agriculture to contribute to climate change mitigation. FAO. Rome, 2009.

FAO (2010). Climate-smart agriculture. FAO. Rome, 2010.

FAO (2011). Global food losses and food waste. FAO, Rome, 2011.

Fulton M. and B. Kahn (2011). Global climate change policy tracker: Winners and losers. DB Climate Change Advisors, July 2011. Deutsche Bank.

Gibbs H.K. *et al* (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. PNAS, September 2010.

Glover J.D., C.M. Cox and J.P. Reganold (2007). Future Farming: A Return to Roots? Scientific American, August 2007.

Glover J.D. and J.P. Reganold (2010). Perennial Grains: Food Security for the Future. In Science and Technology. Winter 2010.

Haerlin B. And T. Busse (2009). Weltagrarbericht 2008. Zukunftsstiftung Landwirtschaft.

Hebebrand C. Leveraging private sector investment in developing country agrifood systems. Policy Paper Series. The Chicago Council on Global Affairs.

Heinrich-Böll-Stiftung (2010). Landwirtschaft und Klimawandel. Das Magazin der Heinrich-Böll-Stiftung, Ausgabe 2, 2010. Berlin.

Heymann E. (2011). CCS for climate protection – important, tedious and costly. Deutsche Bank Research, July 2011.

Hoffmann U. (2011). Assuring food security in developing countries under the challenges of climate change: Key trade and development issues of a profound development in agriculture. Discussion Paper No. 201, UNCTAD, February 2011.

IAASTD (2008). Global Report. International Assessment of Agricultural knowledge, Science and Technology for Development, Johannesburg.

IFAD (2009). Livestock and climate change. November 2009.

IFAD (2910). Climate change: a development challenge. April 2010.

Jordan T. and M. Zähres (2011). Australian Carbon Scheme. Deutsche Bank Research. August 2011.

Kahn B.M. and D. Zachs (2009). Investing in agriculture: Far-reaching challenge, significant opportunity. DB Climate Change Advisors. June 2009. Deutsche Bank.

Kasterine A. and D. Vanzetti (2010). The effectiveness, efficiency and equity of market-based and voluntary measures to mitigate GHG from the agri-food sector. Trade and Environment Review (2010). UNCTAD, Geneva.

Kotschi J. (2010). Reconciling agriculture with biodiversity and innovations in plant breeding. Ecological perspectives for science and society. 1/2010, Gaia.

Larson D.F., A. Dinar and J.A. Frisbie (2011). Agriculture and the Clean Development Mechanism. Policy Research Working Paper 5621. World Bank, April 2011.

LaSalle T.J. and P. Hepperly (2008). Regenerative Organic Farming: A solution to global warming. Rodale Institute.

Lehmann J., Graunt, J. and M. Rondon (2006). Bio-char sequestration in terrestrial ecosystems – A review. Mitigation and Adaptation Strategies for Global Change. March 2006, p.403-427.

McKinsey&Company (2009). Pathways to a low-carbon economy.

Pirard R. and S. Treyer (2010). Agriculture and deforestation: What role should REDD+ and public support policies play? IDDRI Climate Papers No.10, December 2010.

Rat für Nachhaltige Entwicklung (2011). Gold-Standard Ökolandbau. Rat für Nachhaltige Entwicklung (RNE). July 2011.

OECD (2008). Promoting sustainable consumption: Good practices in OECD countries. Paris, 2008.

Schaffnit-Chatterjee C. (2009) "The global food equation - Food security in an environment of increasing scarcity" Deutsche Bank Research, September 2009

Schaffnit-Chatterjee C. (2010). Agribusiness and hunger – Threat to global food security drives collaborative business models. Deutsche Bank Research. February 2010.

Schaffnit-Chatterjee C. (2010). Risk management in agriculture – Towards market solutions in the EU. Deutsche Bank Research. September 2010.

Schaffnit-Chatterjee C. (2011). Where are food prices heading? Deutsche Bank Research. March 2011.

Scherr S.J. and S. Sthapit (2009). Mitigating Climate Change Through Food and Land Use. Ecoagriculture Partners and Worldwatch Institute. Worldwatch Report 179.

Schuiling R.D. and O. Tickell (2010). Olivine against climate change and ocean acidification http://www.innovationconcepts.eu/res

Smith P., D. Martino et al. (2007). Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Intergovernmental Panel on Climate Change (IPCC). Fourth Assessment Report. Cambridge University Press, Cambridge.

Steinfeld H. et al. (2006). Livestock's Long Shadow. Environmental Issues and Options, FAO, Rome.

Stern, N. (2006). Review on the economics of climate change London HM Treasury.

The UK Government Office for Science (2011). Foresight. The future of Food and Farming. London.

US-EPA (2006). Global mitigation of non-CO_2 greenhouse gas emissions, 1990-2020. Washington, DC. United States Environment Protection Agency.

von Thünen-Institut (Johann Heinrich) (2009). Erfassung, Bewertung und Minderung von Treibhausgasemissionen des deutschen Agrar- und Ernährungssektors. Arbeitsberichte aus der vtI_Agrarökonomie, June 2009.

Weltsichten (2011). Die Agrarpolitik endet nicht an Europas Grenzen. Ein Dossier vom Evangelischen Entwicklungsdienst und "Brot für die Welt". July 2011.

Wollenberg E et al (2011). Actions needed to halt deforestation and promote climate-smart agriculture. Policy brief 4. Climate Change Agriculture and Food Security. June 2011.

World Bank (2007). World development report 2008 – Agriculture for development.

Wreford, A., D. Moran and N. Adger (2010). Climate change and Agriculture. OECD.

Wright, J. (2010). Feeding nine billion in a low emissions economy. A review for the Overseas Development Institute and Oxfam.

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