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ASSURING FOOD SECURITY IN DEVELOPING COUNTRIES UNDER THE CHALLENGES OF CLIMATE CHANGE: KEY TRADE AND DEVELOPMENT ISSUES OF A FUNDAMENTAL TRANSFORMATION OF AGRICULTURE

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ASSURING FOOD SECURITY IN DEVELOPING COUNTRIES UNDER THE CHALLENGES OF CLIMATE CHANGE: KEY TRADE AND DEVELOPMENT ISSUES OF A FUNDAMENTAL TRANSFORMATION OF AGRICULTURE

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Abstract

For a large number of developing countries, agriculture remains the single most important sector. Climate change has the potential to damage irreversibly the natural resource base on which agriculture depends, with grave consequences for food security. However, agriculture is the sector that has the potential to transcend from being a problem to becoming an essential part of the solution to climate change provided there is a more holistic vision of food security, agricultural mitigation, climate-change adaptation and agriculture's pro-poor development contribution. What is required is a rapid and significant shift from conventional, industrial, monoculture-based and high-external-input dependent production towards mosaics of sustainable production systems that also considerably improve the productivity of small-scale farmers. The required transformation is much more profound than simply tweaking the existing industrial agricultural systems. However, the sheer scale at which modified production methods would have to be adopted, the significant governance and market-structure challenges at national and international level and the considerable difficulties involved in measuring, reporting and verifying reductions in GHG emissions pose considerable challenges.

I. INTRODUCTION

Global warming has the potential to damage irreversibly the natural resource base on which agriculture depends, with grave consequences for food security. Climate change could also significantly constrain economic development in those developing countries that largely rely on agriculture.[1] Therefore, meeting the dual challenge of achieving food security and other developmental co-benefits, on the one hand, and mitigating and adapting to climate change, on the other hand, requires political commitment at the highest level. What is more, time is becoming the most important scarcity factor in dealing with climate change.[2]

According to FAO (2009f), despite increased world food production in the last few decades, the global effort to meet the Millennium Development Goal of reducing hunger by half by 2015 now appears beyond reach. As a matter of fact, the number of people suffering from chronic hunger has increased from under 800 million in 1996 to over one billion recently.

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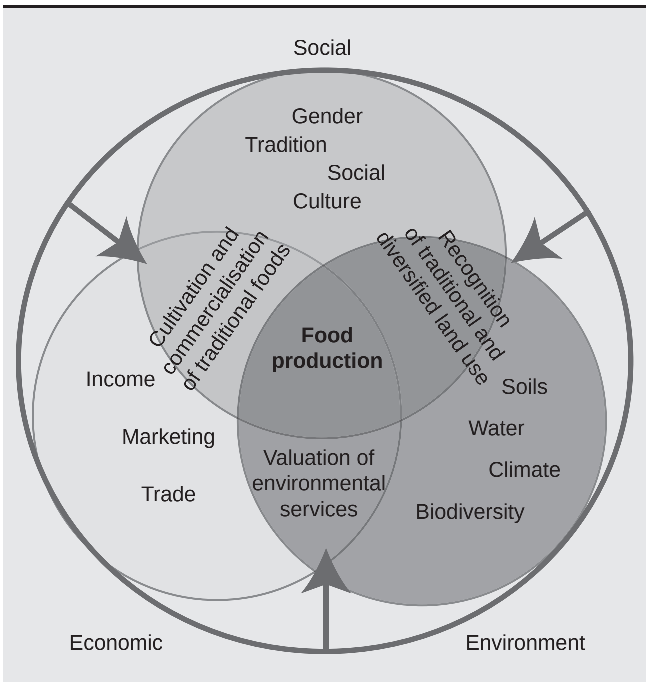
[1] For more information, see Lim Li Ching (2010a).

[2] If current global GHG emission trends remain unchanged, global emission levels will have to be reduced by at least 75 per cent by 2050 to keep temperature rise within a 2.5 degree limit.

Adequate nutrition and sound agricultural practices are central to human and environmental well-being (Raskin et al., 2010: 2642). Agriculture provides essential nourishment for people and is the necessary basis for many economic activities. In most developing countries, agriculture accounts for between 20–60 per cent of GDP. In agriculture-based developing countries, it generates on average almost 30 per cent of GDP and employs 65 per cent of the labour force. The industries and services linked to agriculture in value chains often account for more than 30 per cent of GDP, even in largely urbanized countries. Of the developing world's 5.5 billion people, 3 billion live in rural areas – nearly half of humanity. Of these rural inhabitants, an estimated 2.5 billion are in households involved in agriculture, and 1.5 billion are in smallholder households. Agriculture provides the livelihood for approximately 2.6 billion people (i.e. some 40 per cent of global population) (World Bank, 2008 and Herren et al., 2011).

Figure 1

MULTI-FUNCTIONALITY OF AGRICULTURE



Source: IAASTD (2008).

The current system of industrial agriculture (and related international trade), productive as it has been in recent decades, still leaves 1.3 billion people under-nourished and poverty stricken, 70 per cent of whom live in rural areas. MDG 1 aims at eradicating extreme hunger and poverty. One of the most effective ways of halving both the number of hungry and poor by 2015 is to take the necessary steps of transition towards more sustainable forms of agriculture that nourish the land and people and provide an opportunity for decent, financially rewarding and gender equal jobs.[3] Meeting health targets from MDG 3 and 6 is also linked to major changes in agriculture, resulting in a more diverse, safe, nutritious and affordable diet. Therefore the problems of climate change, hunger and poverty, economic, social and gender inequity, poor health and nutrition, and environmental sustainability are inter-related and need to be solved by leveraging agriculture's multi-functionality (see figure 1) (Herren et al., 2011). Farmers (including pastoralists and agro-pastoralists) should not simply be seen as maximizers of food and agricultural commodity production, but also as managers of the food- and agricultural commodity-producing eco-systems.

[3] The terms sustainable, ecological and regenerative agriculture are used in this paper interchangeably. They all represent aggregate terms for several clusters of sustainable agricultural practices. Sustainable agriculture integrates three main goals: environmental health, economic profitability, and social equity. Sustainable production practices involve a variety of approaches. Specific strategies must take into account topography, soil characteristics, climate, pests, local availability of inputs and the individual grower's goals. Despite the site-specific and individual nature of sustainable agriculture, several general principles can be applied to help growers select appropriate management practices: (i) selection of species and varieties that are well suited to the site and to conditions on the farm; (ii) diversification of crops (including livestock) and cultural practices to enhance the biological and economic stability of the farm; (iii) management of the soil to enhance and protect soil quality; (iv) efficient and humane use of inputs; and (v) consideration of farmers' goals and lifestyle choices. Examples of some of the key specific strategies of sustainable agriculture are: organic farming, low external input sustainable agriculture, agro-ecological and bio-dynamic production systems, integrated livestock and crop farming systems and conservation tillage.

According to Rundgren, agriculture plays four important roles in climate change:

- Farming emits greenhouse gases (GHGs).
- Changes in agricultural practices have a big potential to be carbon sinks.
- Changes in land use, caused by farming have great impact on GHG emissions.
- Agriculture can produce energy and bio-derived chemicals and plastics, which can replace fossil fuel (Rundgren, 2011).

II. THE IMPACT AND CONSEQUENCES OF GLOBAL WARMING FOR AGRICULTURE IN DEVELOPING COUNTRIES

Generally, the impact and consequences of global warming for agriculture tend to be more severe for countries with higher initial temperatures, greater climate change exposure, and lower levels of development. Particularly hard hit will be areas with marginal or already degraded lands and the poorest part of the rural population with little adaptation capacity.

The main impact of global warming on agricultural production can be summarized as follows:[4]

- Higher temperatures affect plant, animal and farmers' health,[5] enhance pests and reduce water supply increasing the risk of growing aridity and land degradation.
- Modified precipitation patterns will enhance water scarcity and associated drought stress for crops and alter irrigation water supplies. They also reduce the predictability for farmers' planning.
- The enhanced frequency of weather extremes may significantly influence both crop and livestock production.[6] It may also considerably impact or destroy physical infra-structure for agriculture.[7]
- Enhanced atmospheric concentrations of CO_2 may, for a limited period of time, lead to 'natural' carbon fertilization and thus a stimulus to crop productivity.[8]
- Sea level rise is likely to influence trade infra-structure for agriculture, may inundate producing areas and alter aquaculture production conditions.

This impact of global warming has significant consequences for agricultural production and trade of developing countries as well as an increased risk of hunger. Preliminary estimates for the period up to

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[4] For more information, see Keane et al. (2009).

[5] It is often overlooked that productivity of outdoor workers is bound to considerably decline because of global warming. In India, for instance, it is estimated that productivity of outdoor workers has already dropped by 10 per cent since the early 1980s and that another 2 degrees temperature increase might result in an additional reduction of 20 per cent (Rundgren, 2011).

[6] For an overview of recent significant climate anomalies, see Tirado and Cotter (2010: 4–5).

[7] The recent catastrophic floods in Pakistan and the massive forest and peat-soil fires in Russia are but two illustrative examples of the impact that can be expected. As the case of Pakistan demonstrates, both the country and the international community are poorly prepared to effectively cope with such extremes. Apart from the dire consequences for future agricultural production, there is also the risk of serious destabilization of society and the political system. Very preliminary estimates of the flood-caused economic damage are as high as 20 per cent of Pakistan's GDP.

[8] It is estimated that elevated atmospheric CO_2 concentration alone may increase crop yields by some 10–15 per cent. Crops that tend to benefit from the effect of carbon fertilization include rice, wheat, soybeans, fine grains, legumes, and most trees. Benefits for other crops, including maize, millet, sorghum and sugarcane are more limited. However, these estimates need to be considered with utmost care, as other changes such as distribution of precipitation, elevation of atmospheric O_3 concentration, enhanced demand for nitrogen, and increases in temperature can make the yield increases highly uncertain (Smith et al., 2007: 25).

Figure 2

PROJECTED CHANGES IN AGRICULTURAL PRODUCTIVITY BY 2080 AS A RESULT OF CLIMATE CHANGE

(Percentage change, taking into account a 15 per cent carbon fertilization effect)

Source: Cline (2007); and Yohe (2007).

2080 suggest a decline of some 15–30 per cent of agricultural productivity in the most climate-change-exposed developing country regions – Africa and South Asia (see figure 2).[9] For some countries in these regions, total agricultural production could decline by up to 50 per cent.[10] The poorest farmers with little safeguards against climate calamities often live in areas prone to natural disasters. More frequent extreme events will create both a humanitarian and a food crisis (FAO, 2009a).

Agricultural trade patterns are also likely to change. Despite all prevailing uncertainties, one can say that the agricultural production potential in temperate zones of North America, Europe and Asia is likely to increase, benefiting from higher mean temperatures and longer growing seasons, whereas agricultural productivity in the other regions, where most of the developing countries are, is expected to decline. As a result, exports from the former are likely to increase, whereas non-temperate-zone regions will need to import more (total net cereal import volume of developing countries, for instance, could increase by

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[9] Climate change is already clearly visible. According to the World Meteorological Organization, the decade from 2001 to 2010 had a global temperature that was 0.46^{0}C above the 1961–1990 average; the highest value ever recorded for a 10-year period. Warming was especially strong in Africa, parts of Asia and the Arctic, Central Asia and Greenland/Arctic Canada (WMO, 2010). According to the global Climate Risk Index (CRI), developed by Germanwatch and Munich Re NatCatSERVICE, the 10 most climate-risk-exposed countries in the period 1990–2009 were: Bangladesh, Myanmar, Honduras, Nicaragua, Viet Nam, Haiti, Philippines, Dominican Republic, Mongolia, and Tajikistan (the CRI reflects both relative and absolute climate impact per country. For more information, see www.germanwatch.org/klima/cri.htm).

[10] For more information, see De Schutter (2009).

some 45–50 per cent in 2050 relative to the year 2000).[11] Some experts argue that this import dependence will likely be exacerbated by increases in agricultural prices, which could rise by up to 20 per cent in the short to medium term.[12] Taken together, this might imply a more than 50 per cent increase in the net cereals' import bill of developing countries.[13]

The above-sketched production and trade consequences should however be interpreted with great caution for the following reasons: First, they basically assume a business as usual scenario as regards production patterns, which, just by the force of nature, is not very realistic. Second, changes in production and trade patterns are directly correlated with progress in implementing adaptation measures, i.e. changing crop and livestock varieties as well as modifying production methods to make agriculture more climate-resilient. Third, unlike industrial production, agriculture is very divergent, location-specific and weather-influenced in terms of production factors that determine productivity.

Despite the above-outlined seriousness of the climate-change impact on agriculture, according to the former head of the International Food Policy Research Institute (IFPRI), Joachim von Braun, governments "underestimate the climate-related threats and there is little work on how the negative effects can be mitigated" (Braun, 2008).

III. GHG EMISSIONS IN AGRICULTURE

Agriculture accounts for about 13–15 per cent of global GHG emissions (as agriculture's share in global GDP is just about 4 per cent, this suggests that agriculture is very GHG intensive[14] (Lybbert and Sumner, 2010: vi)). This figure is confined to direct GHG emissions at production level, not including production of agricultural inputs and fixed capital equipment, processing and trade of agricultural products (in GHG inventory reports, these emissions appear under energy supply, industries[15] and transport) (on carbon accounting along the agri-food supply chain see box 1) as well as land conversion to agriculture (if indirect GHG emissions are included, agricultural emissions double in volume, see figure 3). The GHG share of agriculture rises to approximately 30–32 per cent if land-use changes, land degradation and deforestation are included. Agricultural emissions of methane and nitrous oxide grew by 17 per cent in the period 1990–2005 (IPCC, 2007: 499), roughly proportionate, for instance, to the increase in global cereals' production volume, but about three times as fast as productivity increased in global cereals' production.[16] These GHG emissions are predicted to rise by 35–60 per cent by 2030 in response to population growth and changing diets in developing countries, in particular towards greater consumption of ruminant meats and dairy products, as well as the further spread of industrial and factory farming in developed and developing countries (IPCC, 2007: 63).

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[11] It should be borne in mind that the food import bill of LDCs has already gone up from $9 billion in 2002 to $24 billion in 2008, accounting for between 15–20 per cent of total imports (UNCTAD, 2010c and 2010d).

[12] Based on various scenarios, Nelson et al. (2010) estimate price increases that range from 31 per cent for rice under an optimistic scenario to 101 per cent for maize in the baseline scenarios up to 2050. Nellemann et al. (2009: 7) even predict world food prices to rise by some 30–50 per cent in the coming decades, accompanied by greater volatility.

[13] For an elaborate overview of changing trade patterns see: Nelson et al. (2009).

[14] As will be shown below, there are huge variations between industrialized and developing countries in this regard. Agriculture's contribution to GDP is lowest where it is most GHG-intensive, and its GHG intensity is lowest where its GDP contribution is highest.

[15] A big share (often above 50 per cent) of the energy use in farming is for the production of synthetic fertilizers, in particular nitrogen fertilizers, and pesticides. Thus caused GHG emissions are included in those of the chemical industry, not in agriculture (for more information, see Rundgren, 2011).

[16] Global cereal production volume grew by 17 per cent and cereal yields increased by 6 per cent in the period 1990/1991 to 2005/2006 (author's calculation, based on FAOSTAT).

Box 1

CARBON EMISSIONS FROM ENERGY USE IN THE AGRI-FOOD CHAIN

Carbon emissions from energy use in the agri-food chain are not accounted for as agricultural emissions. There is no comprehensive data on the share of GHG emissions generated by the agri-food sector on a global scale; estimates for the United States suggest that the food sector accounts for about 19 per cent of national fossil energy use (El-Hage Scialabba and Müller-Lindenlauf, 2010: 161).

Preliminary analyses on the breakdown of carbon emissions along the agri-food chain suggest that the structure is very different in developed and developing countries, because most people in the latter consume fresh food mostly produced locally, whereas processed food, with high carbon emissions from transportation and processing, are more common in developed countries. For Sweden and India, the following breakdown was estimated (in percentage) by Rundgren (2011) and Pathak et al. (2011):

	Sweden	*India*
Production	15–19	87
Processing	17–20	2
Distribution and retail[a]	20–29	1
Consumption	38–45	10

a In developed countries, the share of (food) transport in total energy consumption of the agri-food chain is estimated to account for 7–11 per cent. In this regard, often the final stretch has a particular impact. A person driving by car to an out-of-town shopping centre uses much more energy per food unit than a commercial vessel or even a plane for long-haul transport (Rundgren, 2011). In the United Kingdom, for instance, it is estimated that the transport of the country's food causes 19 million tons of CO_2 emissions, of which over 2 million tons is generated by cars travelling to and from shops (The Prince of Wales et al., 2010: 56).

Relative to local produce, global agricultural trade is energy efficient only when an overseas production process is energy competitive, either due to favourable climate (e.g. for tropical products) or seasonality (e.g. fresh fruit and vegetables). While carbon-intensive transport in general suggests a change in consumption patters towards seasonal and local food, regional production does not offer advantages under conditions of greenhouses or long cold storage requirements.

While average energy intensity of agriculture in most developing countries is 3–20 times lower than in developed countries (exceptions are those countries that have a highly mechanized agriculture such as Argentina, Brazil, Malaysia, South Africa or Thailand),[a] specific life-cycle analysis for individual products will have to be conducted to show whether energy-efficient production systems can indeed compensate for energy use from transport and storage. Some illustrative examples are provided below:

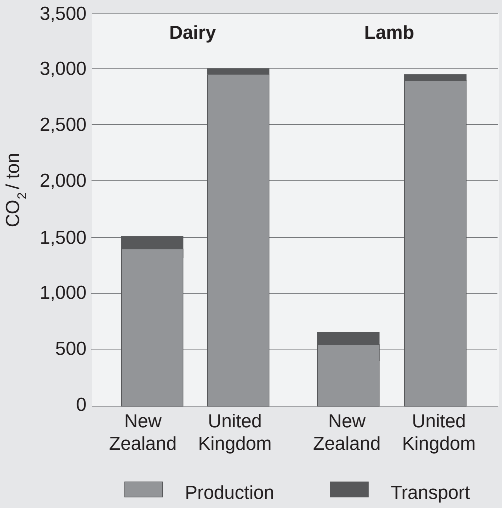
GHG EMISSION COMPARISON: CUT FLOWERS FROM KENYA AND THE NETHERLANDS, DESTINED FOR CONSUMPTION IN THE NETHERLANDS

(kg of CO_2-equivalent for 12,000 cut rose stems)

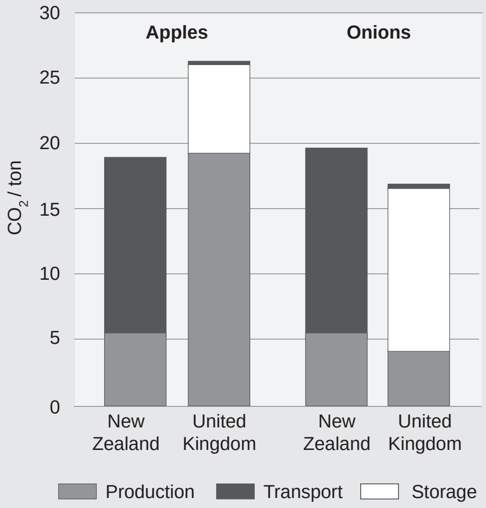
Supply chain section	*Kenya*	*Netherlands*
Production	300	36,900
Packaging	110	160
Transport to airport	18	0
Transport to distribution centre	5,600	0
Transport to distribution centre from airport	5.9	50
Totals	6,034	37,110

Note: Emissions are shown as Global Warming Potential (GWP) expressed in kg of CO_2 equivalents using the IPCC (2001) conversion factors. GWP and CO_2 emissions from Kenya include the IPCC altitude factor.

COMPARATIVE CO_2 EMISSION PER TON OF DAIRY AND LAMB PRODUCED IN NEW ZEALAND AND THE UK FOR UK CONSUMPTION



COMPARATIVE CO_2 EMISSION PER TON OF APPLES AND ONIONS PRODUCED IN NEW ZEALAND AND THE UK FOR UK CONSUMPTION



Source: Kasterine and Venzetti (2010); Keane et al. (2009); and Edwards-Jones et al. (2009).

To sum up, there is a need, on the one hand, to change consumption patterns towards more seasonal and local food, and, on the other hand, to make sure that we make product choices based on a correct understanding of the GHG emissions linked to specific regions of production, transportation of food, and cold-storage requirements.

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[a] For an in-depth analysis on this issue, see Kasterine and Venzettie (2010).

Yet, despite their significant role for climate change, GHG emissions from agriculture and carbon uptake by soils and vegetation are virtually excluded from the flexibility mechanisms under the Kyoto Protocol.[17] Soil carbon sequestration, which (as will be shown below) has the highest potential for generating mitigation from agriculture, is outside the scope of the CDM.[18] According to FAO (2009b), neither climate change mitigation, nor food security, nor sustainable development benefit from this exclusion. The reasons why agriculture has remained relatively marginal within the climate-change negotiations are the variation in agro-ecosystems and farming methods, the large number of farmers that would need to be involved, and the difficulties related to monitoring, reporting and verification of GHG emissions and removals (it needs to be shown that GHG emission reductions are real, additional, verifiable and permanent; for more information, see Kasterine and Vanzetti, 2010).

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[17] There is a 1 per cent cap on the share of carbon credits that can be generated through Land Use, Land-Use Changes and Forestry (LULUCF) within the current commitment period under the Kyoto Protocol (2008–2012). According to FAO estimates (2009g), the revenues generated by even moderate levels of agricultural mitigation (at a price of $20 per ton of CO_2) should yield some $30 billion in annual revenues that could be used to encourage additional investment in mitigation or adaptation.

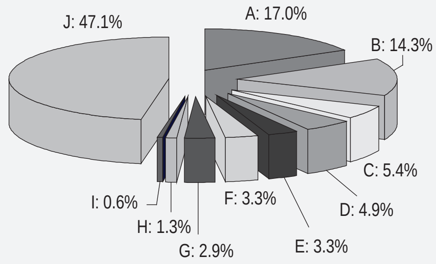
[18] Some very limited (voluntary) trading of soil carbon absorption credits is being done through Canada's Pilot Emission Removals, Reductions and Learning's (PERRL) initiatives programme, under the direction of the Saskatchewan Soil Conservation Association, based on adoption of no-till practices in return for carbon-offset credits. The Chicago Climate Exchange (CCX) also allows GHG offsets from no-tillage and conversion of cropland to grasslands to be traded in its voluntary market trading mechanism (Smith et al., 2007).

Figure 3

SOURCES OF DIRECT AND INDIRECT GHG EMISSIONS OF AGRICULTURE

(Estimates for 2005)

Sources		Million tons of CO_2-eq
Nitrous oxide emissions from soil	A	2,128
Methane from cattle enteric fermentation	B	1,792
Carbon emissions from biomass incineration	C	672
Methane from rice production	D	616
Methane emissions from manure	E	413
Carbon emissions from fertilizer production	F	410
Carbon emissions from irrigation	G	369
Carbon emissions from farm machinery	H	158
Carbon emissions from pesticide production	I	72
Carbon emissions from land conversion to agriculture[a]	J	5,900
All direct and indirect sources		12,530

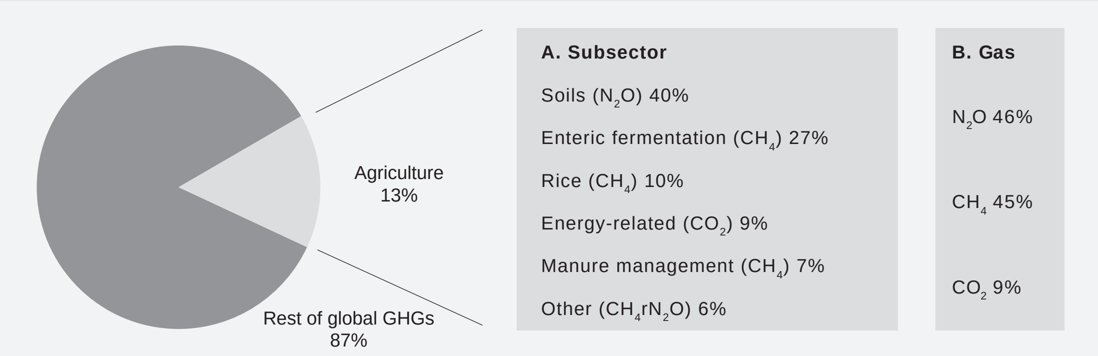


Source: Compiled on the basis of Bellarby et al. (2008).

a This is unlikely to include the significant carbon emissions from changes/conversion of peat soils, swamps and wetlands. According to estimates by Montgomery (2007), approximately one third of the increase of CO_2 in the world's atmosphere comes from the break down of organic matter, including peat soils, swamps and wetlands.

Figure 4

GREENHOUSE-GAS-EMISSION PROFILE OF AGRICULTURE



Source: Kasterine and Venzetti (2010: 88).

The composition of GHG emissions in agriculture is very different from that of other industries. Carbon emissions account for only about 9 per cent, whereas nitrous oxide (N_2O), mainly from fertilizer use, and methane (CH_4) emissions (related to fermentative digestion by ruminant livestock[19], manure management and cultivation of rice in flooded conditions) represent 46 and 45 per cent respectively (see figure 4).

[19] Methane emissions of livestock are principally a function of the industrialization of production. Methane emissions of a typical African cow are, according to researchers at the International Livestock Research Institute, normally offset by carbon sequestration in its pastures (Maarse, 2010). There is a crucial interplay between grassland and ruminant management (45 per cent of all land is grassland and perennial grass is a major stock for carbon). Whilst forests expand their volume by only about 10 per cent per year, savannas can reproduce 150 per cent of their volume (Idel, 2010a; and Paul et al., 2009: 27).

The most potent GHG, nitrous oxide, traps 296 times more heat per unit of mass than CO_2, and methane 25 times. The different GHG emission profile in agriculture requires macro- and micro-economic approaches to reduce GHG emissions that differ from those in industry. In many developing countries, agriculture accounts for the majority or a major share of national GHG emissions.[20] As important as this is from a national perspective, it should be borne in mind that LDCs only contribute a small proportion to global GHG emissions from agriculture.

IV. KEY DRIVING FORCES OF GHG EMISSIONS IN AGRICULTURE

Land-use changes, primarily deforestation,[21] land-degradation, mono-cropping-based industrial agricultural practices, and industrial livestock (and associated animal feed) production that all rely on significant external inputs are the major causes of agricultural GHG emissions.

Deforestation has been largely driven by intensified cattle, animal feed,[22] vegetable oil or pulp production, mostly in the context of export-led strategies.[23] Deforestation for fuelwood and subsistence agriculture by poor and landless rural population has also played a role. Recently, land-use changes for large-scale biomass-derived transport fuel production have become an increasingly important contributing factor.[24]

In the livestock sector, production has been significantly industrialized in recent years, in particular for pork, poultry and egg production, where about 50–60 per cent of global production is conducted under landless, factory conditions (FAO, 2009e: 26). According to FAO, “the move towards modern production systems has implied a decline in integrated mixed farming systems and their replacement by specialized enterprises. In this process, the livestock sector changes from being multifunctional to commodity-specific. There is a decline in the importance of traditionally important livestock functions, such as provision of draught power and manure, acting as assets and insurance, and serving socio-cultural functions. Livestock

[20] For the 49 Least Developed Countries, GHG emissions from agriculture, land-use change and forestry accounted for 71 per cent of total emissions in 2005 (i.e. 28 per cent from agriculture and 43 per cent from land-use change and forestry (UNCTAD, 2010d: 126). In Brazil, emissions from agriculture, land-use change and forestry account for about 80 per cent of national GHG emissions (Lèbre La Rovere and Santos Pereira, 2007).

[21] Apart from deforestation, another very GHG-intensive form of land-use changes is the cultivation of purely orgaogenic soils (i.e. peat and marshlands that are made up of almost uniquely organic matter, i.e. mostly carbon) in Northern Europe and South-East Asia. In South-East Asia, there is a close link between deforestation (in particular for pulp and palm oil production) and carbon releases from peat soil. A considerable share of native rainforest in the region grows on peat soils, which contain on average about 10 times more carbon than ‘normal’ soils (for more information, see Rundgren, 2011).

[22] Currently, about one-third of the world’s cropland is being used to produce animal feed and about half of the global cereal production ends up as animal feed (Steinfeld et al., 2006). Even aquaculture is now shifting to grain feed (Idel, 2010a).

[23] According to Pirard and Treyer (2010), over 83 per cent of new cropland areas in the tropical zone came at the expense of natural forests in the period 1980 to 2000.

[24] Estimates of land requirements for biofuels vary widely, but mainly depend on type of feedstock, geographical location, and level of input and yield increase. The massive scale of land requirements for meeting biofuel blending targets however poses a serious competitive challenge for land for food-crop production. To replace 10 per cent of global transport fuel demand by first generation biofuels in 2030 would require the equivalent of no less than 8 to 36 per cent of current global cropland, including permanent cultures (UNEP, 2009). This contrasts with recent estimates that only about 5 per cent of the arable land on the planet remains unused (Kluger, 2010: 38). Furthermore, a recent study of the Institute for European Environmental Policy on the effects of Indirect Land Use Change associated with the increased use of conventional biofuels that EU Member States have planned for within their National Renewable Energy Action Plans till 2020 (i.e. 10 per cent of consumed transport fuel should come from renewable resources) concludes that meeting this target would lead to between 80.5 and 167 per cent more GHG emissions than meeting the same need through fossil fuel use (Bowyer, 2010: 2).

production is thus no longer part of integrated production systems, based on local resources with non-food outputs serving as inputs in other production activities within the system" (FAO, 2009e: 28–29). In fact, both industrial meat[25] and dairy production require more resources and cause higher GHG emissions than crop production and crop processing.

Yet, according to Idel (2010b), cows are no climate killers per se. A focus on only grass feed and related methane generation of ruminants is too simplistic. The real problem is two-fold: on the one hand, industrial, mass livestock production under landless conditions requires an ever increasing share of cropland being siphoned away for concentrated feed production. The related mono-cropping of feedstuff generates huge amounts of nitrous oxide emissions. Also, relying on concentrated feed for industrial meat production makes livestock food competitors of human beings as regards soy, cereals and corn. On the other hand, grassland, if properly managed, is an important carbon sink: sustainable pasture promotes soil carbon absorption and soil fertility. Every ton of additional humus in the soil relives the atmosphere of 1.8 tons of CO_2. This illustrates the importance of integrated crop and livestock production, sustainable pastoralism, and the particularly problematic role of industrialized (landless) livestock production. According to Idel, generally lower meat consumption and that from sustainable sources of production is required.

Today's advanced food production systems have become heavily dependent on farmers' continuous investment in and use of energy-intensive machinery and fossil-fuel-based agricultural inputs. The yield gains in conventional industrial agriculture correlate perfectly with input increases, a clear signal of un-sustainability given the very real limits of a number of these inputs and the attendant environmental costs of their overuse (Tillman et al., 2002).

At present, industrial agriculture uses 2–3 times more fertilizers and 1.5 times more pesticides for the production of 1kg of food than 40 years ago (Hirel et al., 2007). The prevailing industrial agriculture uses ten times more energy than ecological agriculture and consumes on average 10 energy calories for every food calorie produced (Herren et al., 2011). This imbalance is only possible with cheap energy-based inputs linked to distorted (i.e. subsidized) energy prices. Agriculture has thus been turned from a historical net producer of energy to a net consumer.[26] Industrial agriculture has also drastically reduced the number and variety of species commonly cultivated, increasing specialization at field, farm and landscape levels in monoculture farming that is far more exposed to climate and environmental risks.[27] While input and resource-intensive agriculture is the norm in most developed and middle-income developing countries, many low-income countries continue to rely on low-input agriculture.[28]

Less external-input-dependent sustainable agriculture also provides some clear-cut economic benefits for developing countries in terms of drastic reduction in production and import costs. As can be seen from figure 5, in recent years, the index of external input prices has outpaced that of food prices, even when the latter escalated in the wake of the food-price crisis in 2008.

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[25] According to Bellarby et al. (2008), industrial sheep and beef meat have the highest climate impact of all types of meat, with a global warming potential of 17 and 13 kg CO_2-eq per kg of meat, while pig and poultry have less than half of that. Traditional feedstock production, in particular in integrated crop and livestock farming systems, tends to have a far lower GHG intensity and in fact can even be climate neutral (communication with A. Idel).

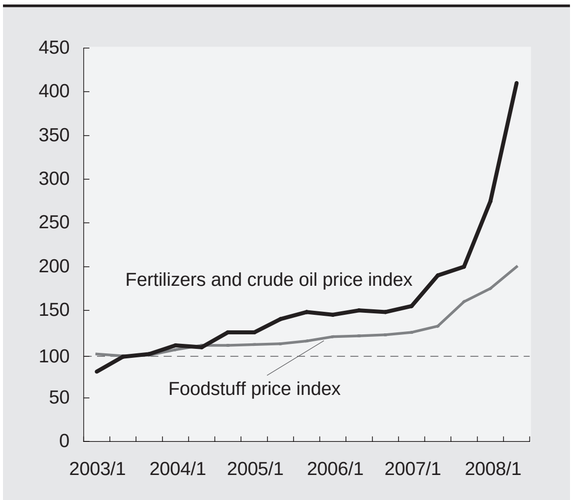
[26] Semi-industrial agricultural systems in India and Indonesia in the 1960s and 1970s, for instance, generated 10–15 times the energy relative to energy input use. For more information, see Rundgren (2011).

[27] Some 80 per cent of world cropland is dominated by just 10 annual cereal grains, legumes, and oilseeds. Wheat, rice and maize cover over 50 per cent of global cropland (Scherr and Sthapit, 2009). According to Moorhead (2009: 25), "of the approximately 50,000 plant species that are edible, we use no more than 50, of which 15 supply 90 per cent of the world's food and just three – wheat, rice and maize – supply 60 per cent".

[28] Smallholders in sub-Saharan Africa, for instance, account for only about one tenth of the global average inorganic fertilizer consumption (UNCTAD, 2010a: 79).

Figure 5

DEVELOPMENT OF FOOD AND MAIN AGRICULTURAL INPUT PRICES, 2003 TO MID-2008



Source: Müller (2008).

Over the next 40 years, global population is estimated to expand by almost 50 per cent, combined with significant increases in per capita demand for meat, dairy and vegetable products. The major new food demand and diet changes are primarily expected in low-income and least developed countries, where food accounts for 40–80 per cent of household expenses and where there is an absolute need to sustainably increase farm output.[29] At the same time, further land degradation, urban expansion and greater use of cropland for non-food production are likely to reduce available cropland for food production by 8–20 per cent by 2050 (Nellemann et al., 2009: 6). Therefore, significant changes must take place in how agricultural production is accomplished in order to make it sustainable. Far too long, agriculture has suffered from significant tunnel vision by concentrating on high and GHG-intensive external-input-dependent production methods and associated land-use changes.

V. THE CLOSE INTERPLAY BETWEEN MITIGATION AND ADAPTATION

It is often overlooked that agriculture and forestry have a very important (and also very cost-efficient) GHG emission abatement potential. As can be seen from table 1, agriculture and forestry account for one third of the estimated total GHG abatement potential till 2030.[30]

According to IPCC calculations (IPCC, 2007: section 8.4.3.), the global technical mitigation potential for agriculture (excluding fossil fuel offsets from biomass) is estimated at 5.5 to 6 Gt of CO_2-equivalent per year by 2030. 89 per cent of this reduction can come from carbon sequestration in soils (i.e. the saturation of carbon-rich organic matter (humus) into the soil);[31] 9 per cent from methane reduction in rice production and livestock/manure management; and 2 per cent would come from nitrous oxide reduction from better cropland management. In essence, soils can be managed as either a source or sink of GHGs, depending on land use and management practices. Carbon stock in soils is also highly correlated with productivity gains, improved adaptive capacity to climate change, and soil conservations (ICTSD-IPC, 2009) and is a relatively affordable form of mitigation (i.e. at low or even negative medium-term costs), for which many technical options are already readily available (FAO, 2009a). In general, a McKinsey study, estimating average mitigation costs for crop and grassland management, restoration of organic

[29] Population of the Least Developed Countries (LDCs) is projected to nearly double from 670 million in 2000 to 1.3 billion by 2030 (UNCTAD, 2010b). According to the International Food Policy Research Institute, the developing countries' share in world meat consumption will rise from 53 to 63 per cent between 2006 and 2020. This growth is five times higher than the predicted increase for meat consumption in developed countries (Hargrave, 2010: 22).

[30] As explained in box 1, a considerable part of the GHG emissions from the food system are in those "key energy-intensive sectors" that include the production of agro-chemicals or transport. One major gain from low-external agriculture would therefore be to minimize GHG emissions outside "agriculture" as defined in table 1.

[31] Carbon sequestration in soils or terrestrial biomass has a maximum capacity for the ecosystem, which, according to IPCC, may be reached after 15 to 60 years, depending on management practices and soil history. However, soil carbon absorption is a cheaply and easily deployable mitigation option that should be fully exploited until more capital-intensive and longer-lasting mitigation options become available (IPCC, 2007: 525).

Table 1

GHG ABATEMENT OPPORTUNITIES TILL 2030

($GTCO_2$-EQ)

	Estimated emissions under business-as-usual scenario	*Estimated abatement potential*
Energy	18.7	10.0
Forestry	7.2	7.8
Agriculture	7.9	4.6
Buildings	12.6	3.5
Transport[a]	11.4	3.2
Key energy-intensive sectors (iron, steel, cement, chemicals)[a]	14.7	4.5

Source: McKinsey (2009).

a This will also include some indirect carbon-related agricultural emissions.

soil and degraded land for the period to 2030, concludes that these activities generate higher benefits than costs (McKinsey, 2009).[32]

Rising temperatures will also require great effort in developing countries to adapt agricultural production to climate change (i.e. agricultural management under water-constrained conditions, higher temperatures, and far more exposed to weather extremes). Resilience[33] to climate stresses is closely linked to enhanced farm biodiversity and improved soil organic matter. Practices that enhance biodiversity allow farms to mimic natural ecological processes, enabling them to respond to change and reduce risk. The use of intra and inter-species diversity serves as an insurance against future environmental changes by increasing the system's resilience. Improved soil organic matter from the use of green manures; mulching and recycling of crop residues and animal manure would increase the water holding capacity of soils and their ability to absorb water during torrential rains. Sustainable production methods also have the potential to eventually become self-sufficient in producing nitrogen through the recycling of manures from livestock and crop residues via composting; and by increased inter-cropping rotations with leguminous, N-fixing crops. Crop rotation and diversification enable farmers to grow products that can be harvested at different times, and have different climate/environmental stress response characteristics. These varied outputs and degrees of resilience are a hedge against the risk of drought, extreme or unseasonal temperature variations that could reduce the yields of one crop, but not of others. In essence, the same soil-regenerating practices that mitigate GHG emissions can enable farmers to better survive the droughts, floods and extreme weather patterns associated with climate change (Ishii-Eitemann and Reeves, 2009).

Sustainable water use is becoming a strategically important issue for agriculture, against the background that agriculture consumes about 70 per cent of the world's freshwater withdrawals[34] and that water scarcity, in particular for African and Asian developing countries,[35] is becoming a very serious issue (see figure 6).[36] It is therefore highly questionable whether there is sufficient water for bringing about the required food production increases for a population in excess of 9 billion if conventional farming practices were to continue. Studies indicate that there is enough rainfall to double or even quadruple yields in rain-fed agriculture in many water scarce regions provided that sustainable practices are used that improve water use efficiency by enhancing the capture and percolation of rainwater into the topsoil

[32] According to the McKinsey experts, the biggest gains can be expected from the restoration of organogenic soils in Northern Europe and Indonesia.

[33] Resilience is the capacity to deal with change and recover after it. For a more elaborate analysis on enhancing resilience, see Tirado and Cotter (2010).

[34] According to World Bank estimates, in low-income countries, agriculture uses 87 per cent of total extracted water, while this figure is 74 per cent in middle-income countries, and 30 per cent in high-income countries (Smith et al., 2007: 22).

[35] According to de Schutter (personal communication), in Africa the problem is not lack of water per se, but lack of investment to use the water that is available in underground aquifers. In Asia it is a "real" (physical) scarcity.

[36] According to the UN Population Fund, fresh water will become the world's most important strategic resource in the next 20 years (Grossmann, 2010: 45).

Figure 6

AREAS OF PHYSICAL AND ECONOMIC WATER SCARCITY

Source: Molden (2007).

with the use of crop residues as cover mulches that facilitate water filtration and reduce water and soil erosion, to give but one example.[37]

VI. PROMISING MITIGATION AND ADAPTATION STRATEGIES

It cannot be overemphasized that unlike for the international financial system, Mother Nature does not provide ecological bailouts. Agriculture is the sector that has the potential to transcend from being a problem to becoming an essential part of the solution to climate change provided there is a more holistic vision of food security, agricultural mitigation, climate-change adaptation and development.[38] What is required is a rapid and significant shift from industrial monocultures and factory farming towards mosaics of sustainable production systems that are based on the integration of location-specific organic resource inputs; natural biological processes to enhance soil fertility; improved water-use efficiency; increased crop and livestock diversity that is well adapted to local conditions and integrated livestock and crop farming systems.[39] Most of these sustainable production systems have demonstrated that they provide synergies between productivity, income-generation potential and environmental sustainability, but more data on this interface needs to be generated.[40] It is however clear that a much more profound agricultural transformation is required than simply tweaking the existing industrial agricultural systems (Ishii-Eiteman and Reeves, 2009: 11).

As The Prince of Wales pointed out in his recent book (The Prince of Wales et al., 2010), “modern high-tech agriculture has now basically turned farming into an arms race against Nature, excluding everything

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[37] For more information, see Herren et al. (2011: Section on Sustainable Water Use in Agriculture).

[38] For more information, see Hoffmann (2010).

[39] These solutions have been highlighted in the report of the IAASTD (2008).

[40] For a more elaborate overview of specific synergies, trade offs and examples see: Altieri and Koohafkan (2008).

from the land except the highly bred crops designed to be resistant to powerful pesticides and grown using industrial production methods" (pp. 54–55). According to the author, "there is an emphasis on linear thinking rather than seeing the world in terms of cycles, loops and systems, and the intention is to master Nature and control her, rather than act in partnership" (p. 17). And he continues that "it is very strange that we carry on behaving as we do. If we were on a walk in a forest and found ourselves on the wrong path, then the last thing we would do is carry on walking in the wrong direction. We would instead retrace our steps, go back to where we took the wrong turn, and follow the right path" (p. 5). But The Prince of Wales warns that "it is probably inevitable that if you challenge the bastions of conventional thinking you will find yourself accused of naivety" (p. 16).

Appropriately shaped sustainable production systems will be able to quantitatively and qualitatively feed the global population by 2050, particularly by substantially improving crop yields of subsistence farmers in tropical regions where rapidly growing population and food insecurity conditions are severe[41] (studies indicate yield increases between 60–80 per cent).[42] Many of those sustainable production systems are likely to be economically self-sustaining once initial investments (in particular in extension services, research and development, and physical infra-structure) are made. These production systems would also support production of feed, fibre and to a limited extent biofuels for local use that all contribute to sustainable economic development in rural areas (Herren et al., 2011).

Based on the 4th IPCC Assessment Report, Bellarby et al. (2008) have summarized the main clusters of mitigation measures in agriculture as follows:[43]

- Improved cropland management (lower use of synthetic fertilizers, reduced tillage etc.);
- Reducing industrial livestock production and improving grazing land management;[44]
- Restoration of organic soils and degraded lands to increase soil carbon sinks;
- Improved water and rice management;
- Land-use change and agro-forestry;
- Increasing efficiency in fertilizer production;
- Behavioural changes of food consumers (notably aimed at reducing the meat content).

To make agriculture GHG efficient and climate-resilient, landscape and farming systems need to change in order to actively absorb and store carbon in soils and vegetation; reduce emissions of methane from rice production, livestock and burning; and decrease nitrous oxide emissions from inorganic fertilizers, on the one hand, and enhance the resilience of production systems and ecosystem services to climate

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[41] As Herrmann (2009) correctly points out, food security is both a demand-side and a supply-side challenge. It is necessary to significantly increase the production of food to feed a rapidly growing global population, but at the same time, it is imperative that incomes of poor households need to rise to ensure necessary food-purchasing power.

[42] The superiority of yields is particularly apparent during seasons with below-normal rainfall (for more information, see Herren et al., 2011). In the most comprehensive study to date, a group of scientists under the lead of Jules Pretty studied 286 completed and on-going farm projects in 57 developing countries, concluding that small-scale farmers increased their crop yields by an average of 79 per cent by using environmentally sustainable techniques (Pretty et al., 2006). The findings of the most recent comprehensive study, commissioned by the United Kingdom Government's Foresight Global Food and Farming Futures project that reviewed 40 sustainable intensification programmes in 20 African countries, confirm these results. Crop yields on average more than doubled over a period of 3–10 years (Pretty et al., 2011).

[43] It should not go without comment that a fundamental reform towards sustainable crop and livestock production will also have a significant positive bearing on deforestation and degradation of forest areas. As Pirard and Treyer (2010: 4) correctly point out, "the long-term viability of REDD+ depends on action in sectors of the economy that have an impact on forests, of which agriculture is the most striking example".

[44] The half life of methane in the atmosphere is only around 7–8 years; as compared to more than 100 years for CO_2 and N_2O. Thus, cutting methane would have a rapid impact on slowing climate change (Paul et al., 2009: 27).

Box 2

REQUIRED CHANGES IN FOOD CONSUMPTION PATTERNS

Although an in-depth analysis of desirable changes in food consumption patterns is beyond the purview of this paper, it should be mentioned that several specific changes may significantly reduce GHG intensity of food. Analysis of household food consumption suggests that reduced GHG emissions (i.e. "climate-smart diets") could result from:

(i) the substitution of crop food products for animal food products[a] (for the replacement of animal proteins it is very important to pay attention also to the nutritive values of foods and getting a balanced diet; animal proteins could be mostly or partly replaced by other protein, such as pulses and vegetables);

(ii) favouring consumption of locally produced and seasonal food to reduce transport and cold storage-related GHG emissions.

Comparisons of GHG intensity of common diets in India showed that a non-vegetarian meal with mutton emitted 1.8 times more GHG than a vegetarian meal; 1.5 times more than a non-vegetarian meal with chicken and an ovo-vegetarian meal; and 1.4 times more than a lacto-vegetarian meal.

The following overview of GHG emission intensity for food value (expressed as grams of CO_2 equivalent per calorie) illustrates the GHG saving potential resulting from dietary changes:

Oil	0.05	Pulse	0.30	Vegetables	0.57
Wheat	0.10	Eggs	0.38	Milk	1.15
Sugar	0.21	Rice	0.43	Mutton	6.18

Changes in consumption patterns are particularly important for developed countries, because, based on prevailing food consumption patterns, the global warming potential of per capita food consumption in a developed country is double that of an Indian food consumer. As Vermeulen (2009: 25) however correctly emphasizes "around 80 per cent of the world lives in poverty, surviving on less than $10 a day. For them, the need is to consume more, not less".

For more information on the above, see Pathak et al. (2011) and Coley et al. (1998).

[a] In Sweden and the Netherlands, for instance, it is estimated that the consumption of meat and dairy products contributes about 45–50 per cent to the global warming potential of total food consumption (Pathak et al., 2011). According to Steinfeld et al. (2006), no less than 18 per cent of global GHG emissions could be attributed to animal products alone.

change, on the other hand (Scherr and Sthapit, 2009). All this in combination with higher yields and profitability of the whole sustainable production system[45] (GHG reductions in agricultural production will of course have to be supplemented by commensurate changes in consumption patterns – see box 2). The sheer scale at which modified production methods would have to be adopted, the required political and economic vision and steps related to changes in economic incentive systems, market structures, and

[45] All too often the impression is created that smallholder farming systems are bound to be less productive than industrial agriculture. Yet several studies have shown that if yields and economic returns are not expressed per product, but for the whole farming system, smallholder farming based on an integrated crop and livestock farming approach can produce 3–14 times as much per acre (i.e. 0.4 ha) as large scale industrial farms and can be considerably more profitable given the input cost savings (Altieri and Nicholls, 2008; Van der Ploeg, 2008; Sachs and Santarius et al., 2007).

more stable systems of land tenure (to name but the most important issues), as well as the considerable difficulties involved in measuring, reporting and verifying reductions in GHG emissions however pose considerable challenges.

In essence, the key task is to transform the uniform and high-external-input-dependent model of quick-fix industrial agriculture (whose health and environmental externalities are largely not internalized) into a flexible approach of 'regenerative' agricultural systems that continuously recreate the resources they use and achieve higher productivity and profitability of the system (not necessarily of individual products) with minimal external inputs (including energy). Successful regenerative systems will look different depending on local eco-system capabilities and constraints (Hellwinckel and De La Torre Ugarte, 2009). A mosaic of regenerative systems may include bio dynamic, organic, agro-ecologic, integrated crop and livestock farming, conservation tillage, agro-forestry[46] and similar practices. While extensively drawing on local knowledge and varieties, regenerative systems will marry them with modern agricultural science and extension services (be knowledge rather than chemical-input-intensive) and give a very pro-active role to small-scale farmers. In other words, what is being talked about here are not low-yield, low-input systems, but sustainable production methods that are sophisticated and effective ecological systems that build on traditional and local knowledge and practices without high external inputs.

The mosaic of sustainable production methods can be technically applied by both small and larger farms, although their application by the former may be easier. Large farms tend to have a higher mono-culture specialization, mechanization and external-input dependence and they often rely on significant input and output subsidies to be profitable. In the absence of a comprehensive subsidy reform (including not only the so-called perverse subsidies, but also some of the "green" subsidies that fall under the green box in the WTO agricultural negotiations[47]), it is unlikely that large farms will make a comprehensive shift to regenerative agricultural practices.

There are significant secondary macro-economic benefits of investment in sustainable agriculture. The most important impact is the 'local multiplier effect' that accompanies investments that direct a greater share of total farming input expenditures towards the purchase of locally sourced inputs (e.g. labour, organic fertilizers, bio-pesticides, advisory and support services etc.) that replace conventional procurement of externally sourced inputs. Conceptually, the same investment in any other competing activity is unlikely to have as many linkages with the local economy and hence unlikely to yield a multiplier as large.

As Rundgren correctly emphasizes "increased incomes for farmers and farm workers stimulate demand for goods and services by local artisans and can in this way induce a virtuous cycle. A dollar in increased income can in this way easily become two. Local wages will increase. There is, however, a big difference in this regard between the situation when growth is triggered by hundreds of smallholders or when it is in a big plantation. When the latter increase their income, a considerable part of the money is spent on imported inputs and machinery as well as on luxury products for private consumption, with little positive impact on local traders. There is thus a strong link between equality and local economic development" (Rundgren, 2011).

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[46] Agro-forestry is a system that integrates trees and shrubs with crops or animals on the same areas of land. According to the World Agroforestry Centre (ICRAF) and UNEP (2009), it is estimated that a global implementation of agroforestry methods could result in 50 billion tons of CO_2 being removed from the atmosphere – a volume some 10 per cent higher than total global GHG emissions in 2005 (UNEP, 2010).

[47] Major subsidizing countries should not be allowed to continue to provide similar total levels of farm subsidies by just modifying the veil (i.e. from trade-distorting to non or minimally trade-distorting). Subsidies should be confined to those 'essentially' required to facilitate the transition to sustainable production methods, i.e. for extension services, R&D, reward environmental services, ensure protection from volatile prices, and specific support to smallholder farmers. They should however not include fuel or chemical input support. Undoubtedly, farmers need some continued support given the existing considerable price distortions and externalized costs.

Apart from profoundly reforming industrial agriculture, it is a key challenge to considerably lift the productivity of small-scale (family) farmers by mobilizing and empowering them to use the modern methods of regenerative agriculture (rather than replacing these small-scale systems by industrialized agriculture). Smallholder agriculture will thus become more knowledge intensive and more concerned with the management of agro-ecosystems. The vast majority of farmers (including pastoralists and agro-pastoralists) in developing countries are smallholders, and an estimated 85 per cent of them are farming on less than two hectares. In countries as diverse as Bangladesh, China, Egypt, and Malawi, 95 per cent of farms are smaller than two hectares, and in many other countries the great majority of farms operate on less than two hectares. According to Mactaggart (2010a), “there are some 500 million smallholder farms worldwide. These support 30 per cent of the world’s population, feeding even more than that two billion. Around 80 per cent of Africa’s and Asia’s farmland is smallholder managed and smallholders produce 80 per cent of the developing world’s food consumption”.[48] Strengthening farmers organizations, extension education and services, improving the networking with researchers and the quality of local infra-structure will all be important for harnessing the productive potential of smallholders. Equally important is the need to jointly consider policies targeting land, capital, and risk for small-scale farmers.[49]

There are already many concrete examples that illustrate the GHG emission reduction potential of certain sustainable agricultural production methods at low or negative costs and with considerable developmental co-benefits (see boxes 3 and 4).

Another regenerative system that offers many synergies between climate change mitigation and adaptation, eco-system restoration, higher productivity and profitability, as well as food security is organic agriculture. As can be seen from box 4, a conversion to organic agriculture can make agriculture almost climate neutral.[50]

Also, developing integrated agricultural and (renewable) energy production (in particular linked to the reduction of post-harvest losses, better irrigation, in combination with water efficiency and “harvesting” techniques, and the development of agricultural support services), which may be linked to improved sanitation,[51] offers plenty of production, value added, and climate mitigation and adaptation opportunities. There is an enormous and relatively inexpensive energy potential from agricultural wastes in the form of methane (coupled with its overriding environmental, health[52] and agronomic benefits). This can be supplemented by off-grid solar and wind-derived energy for drying and irrigation, for instance.

When using the appropriate form of bio-energy, the key question is not the potential contribution of biofuels to reduce dependence on fossil fuels in the context of the existing energy-intensive development

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48 Mactaggart (2010a) also emphasizes that “smallholders are disproportionately poor. This is less a consequence of the smallholder model per se than of attendant problems – degraded soil, deforestation and increasing desertification, land tenure uncertainties, water quality and availability. Then there is climate change, which multiplies the risks faced by the world’s most vulnerable”.

49 For more information, see World Bank (2008: 90–92).

50 For an elaborate review of the climate adaptation and developmental co-benefits of organic agriculture, see Hoffmann (2010: 16–18); UNCTAD (2009a); and Twarog (2006: 142–187).

51 The recycling of human waste, either composted or through biogas, can have enormous health benefits and be as well another pillar in enhancing soil fertility.

52 The use of biogas can significantly reduce very serious health hazards caused by pollutants emitted during biomass combustion for cooking and heating in many rural areas of developing countries (notably carbon monoxide, small particles and benzene). The high indoor concentration of such pollutants results in a higher prevalence of respiratory diseases, obstetrical problems, eye infections and blindness, among others. According to WHO estimates, indoor air pollution could cause as much as 2 million deaths every year – almost three times the death toll resulting from urban air pollution (for more information, see UNCTAD, 2009b).

Box 3

RESTORATION OF DEGRADED LAND IN ETHIOPIA AND THE TRADITIONAL HIGHLAND VIETNAMESE PRODUCTION SYSTEM

In the Tigray Province, one of the most degraded parts of Ethiopia, agricultural productivity was doubled by soil fertility techniques on over 1 million hectares through agro-forestry, application of compost and the introduction of leguminous plants into the crop sequence. By restoring soil fertility, yields were increased to a much greater extent at both farm and regional levels than by using purchased mineral fertilizers.

Restoration of degraded land not only offers income opportunities for rural populations but also has a huge climate mitigation potential by increasing soil carbon sequestration. The total mitigation potential by restoration of degraded land is estimated as 0.15 Gt CO_2-eq (technical potential up to US$ 20 per ton of carbon) and up to 0.7 Gt CO_2-eq (physical potential). As degraded lands usually host market-marginalized populations, organic land management may be the only opportunity to improve food security through an organized use of local labour to rehabilitate degraded land and increase productivity and soil carbon sequestration.

Another proven practice, the traditional highland Vietnamese production system (VAC) that integrates aquaculture, garden, livestock and forest agriculture in small plots, could serve as a template for other tropical regions. VAC illustrates a key principle of regenerative practices - using the waste stream of one component to feed another component. Food scraps are placed in the pond to feed the fish, pond biomass growth is removed and fed to pigs, and pig manure is used to fertilize the garden and fruit trees. In this manner, regenerative systems conserve energy and maintain fertility.

VAC has other notable practices indicative of regenerative systems. It makes full use of vertical space by planting vegetables and fruiting bushes below fruit and nut trees. It uses riparian zones (small ponds) the most productive ecosystems on earth, yielding more net primary productivity per unit of area than any other ecosystem. It also stacks functions of components in the system, such as the use of the pond for waste disposal, microclimate cooling, and fish, duck, feed and fertilizer production.

Source: El-Hage Scialabba and Müller-Lindenlauf (2010); and Hellwinckel and De La Torre Ugarte (2009).

paradigm,[53] but rather the optimal level and feedstock of biofuel production to facilitate the transition to a sustainable agricultural system (Hellwinckel and De La Torre Ugarte, 2009). Localized food and renewable bio-energy systems can provide food and fuel security, based on a green circular economy[54] that turns agricultural wastes into biogas feedstock and organic fertilizer (see box 5).[55]

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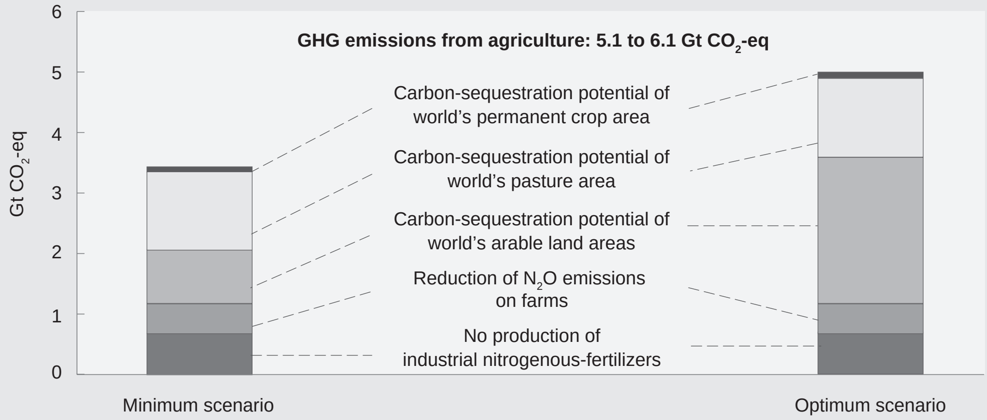
[53] This is the main cause for competition for land with food production. Besides biofuels, an increasing pressure for land can be expected from industrial biotech use of agricultural feedstock to produce bio-chemicals and bio-plastics, whose market size is expected to double or triple in the next few years (The Economist, 2010). The prioritization of the use of biomass for economic over ecological purposes, such as protecting biodiversity and water sources, regenerating soils with humus, retaining moisture in soils or protecting the integrity of ecosystems, is very problematic given the potentially massive increase in bio-energy, bio-chemicals and bio-plastics consumption (Paul et al., 2009: 33).

[54] For more information on integrating circular energy, food and water systems, see Jones et al. (2010).

[55] A word of caution should also be made regarding the sustainable use of biofuels versus firewood. In some production systems, firewood might be more realistic than biofuel, in particular when the former can be produced through ecological agro-forestry. In a bit more advanced and land-poor situations, biogas is likely to be the preferred option. But in land-rich and capital-poor regions firewood will most likely remain important. This would imply placing more emphasis on making firewood production sustainable rather than trying to promote biofuels at all costs (personal communication with G. Rundgren).

Box 4

MITIGATION POTENTIAL OF A CONVERSION TO ORGANIC AGRICULTURE AND ITS DEVELOPMENTAL SYNERGIES



GHG emissions from agriculture amount to 5.1–6.1 Gt CO_2-eq. With improved farm and crop management, most of these emissions could be reduced or compensated by sequestration. A conversion to organic agriculture would reduce industrial nitrogen-fertilizer use that emits 6.7 kg of CO_2-eq per kg of nitrogen on manufacture and another 1.6 per cent of the applied nitrogen as soil-based N_2O emissions. It could also considerably enhance the soil sequestration of CO_2. For the minimum scenario, FAO experts took a sequestration rate of 200 kg of carbon/ha per year for arable and permanent crops and 100 kg of carbon/ha per year for pastures. The optimum scenario combines organic farming with reduced tillage on arable land (with a sequestration rate of 500 kg of carbon/ha per year).

A minimum scenario of conversion to organic farming would mitigate no less than 40 per cent of the world's agricultural GHG emissions. When combining organic farming with reduced tillage techniques under the optimum scenario, the sequestration rates on arable land could easily be increased to 500 kg of carbon/ha per year. This optimum organic scenario would mitigate 4 Gt CO_2-eq per year or 65 per cent of agricultural GHGs. Another approximately 20 per cent of agricultural GHGs could be reduced by abandoning the use of industrially produced nitrogen fertilizers, as is practiced by organic farms. As a result, organic agriculture could become almost climate neutral.

The important climate-mitigation potential and related adaptation opportunities of organic agriculture come in tandem with several important developmental benefits. This concerns economic benefits, in particular for pro-poor development (such as higher prices, revenues, more diversified production, and the particular suitability of organic agriculture for small-scale farmers), food-security benefits (higher and more stable yields under extreme weather events, higher income creates local demand for food), ecological advantages (better water and soil management, preservation of bio-diversity, no pollution from agro-chemical and GMO use), occupational safety gains (every year some 300,000 farmers die of agrochemical use in conventional agriculture (UNCTAD/UNEP, 2008b: iii)) and social and cultural benefits (including gender equality, strengthening of local knowledge and skills as well as communal relations).[a]

Source: FAO (2009c).

[a] For a more elaborate overview of the developmental co-benefits of organic agriculture, see UNCTAD (2008 and 2009a); UNCTAD/UNEP (2008a); and Niggli (2010).

Box 5

ADVANTAGES OF ANAEROBIC DIGESTION OF ORGANIC WASTES FOR LOCAL BIOGAS GENERATION

- Produces an abundant, readily available source of bioenergy that does not take land away from growing food.
- Takes a wide range of feedstock, including livestock and human manure, crop and food residues, paper, bakery and brewery wastes, slaughterhouse wastes, garden trimmings, etc, (the yields of methane are generally better in mixed waste streams).
- Is a clean cooking fuel, especially compared to firewood (and dung).
- Can be used as fuel for mobile vehicles, agricultural machinery and engines or for combined heat and power generation. Methane-propelled engines are currently one of the cleanest in use.
- Biogas methane is a renewable and carbon mitigating fuel (more than carbon neutral); it saves on carbon emission twice over, by preventing the escape of methane and nitrous oxide into the atmosphere and by substituting for fossil fuel.
- Conserves plant nutrients such as nitrogen and phosphorous for soil productivity.
- Produces a high-quality fertilizer for crops as by-product.
- Prevents pollution of ground water, soil, and air.
- Improves food and farm hygiene, removing 90 per cent or more of harmful chemicals and bacteria.
- Recycles wastes efficiently into food and energy resources as part of a circular economy.

Source: Moe-Wan Ho (2010).

According to one estimate, a combination of organic agriculture and biogas generation from agricultural waste in China has the potential to mitigate at least 23 per cent of the country's GHG emissions and save about 11 per cent of energy consumption. In other words, sustainable agriculture with biogas generation saves more than the agricultural sector's GHG emissions and energy use (Moe-Wan Ho, 2010).

Reducing the considerable losses along the food supply chain can be a major source of enhancing efficiency without impacting on GHG emissions. According to various estimates, due to pre- and post-harvest losses only 43 per cent of the potential global edible crop harvest is available for consumption (Nellemann et al., 2009: 30). For Lybbert and Sumner (2010: 11), post-harvest losses represent one of the single greatest sources of inefficiencies in agriculture and therefore one of the best opportunities for effectively improving agricultural productivity, without creating any or much additional GHG emissions. Post-harvest losses (often up to 40 per cent or more depending on food type and location)[56] could be

[56] Global harvest and food-chain losses (before reaching shop shelves) are estimated at around 1,400 calories per person, per day – ironically broadly equivalent to the estimated increase of food to feed a 50 per cent higher global population by 2050 (Spelman, 2010: 4).

reduced and world food supply increased by between 10–30 per cent[57] through the application of readily available technologies and management methods using minimal additional resources.[58]

The steady genetic improvement of crop varieties and livestock species does also have considerable potential for climate-change mitigation (notably as regards methane emissions) and adaptation to climate stress (in particular water scarcity). Agricultural biotechnology has the potential to influence many aspects of agriculture – crop and animal productivity, yield stability, environmental sustainability, and consumer traits. It may also contribute to significant reductions in external input use. According to the World Bank, "in the 1980s and 1990s, for instance, improved varieties are estimated to have accounted for as much as 50 per cent of yield growth, compared with 21 per cent in the preceding two decades". According to World Bank estimates, "without those gains in yields, world cereal prices would have been 18–21 per cent higher in 2000, caloric availability per capita in developing countries would have been 4–7 per cent lower, 13–15 million more children would have been classified as malnourished, and many more hectares of forest and other fragile ecosystems would have been brought under cultivation" (World Bank, 2008: 160).

Although biotechnology holds great technical and economic promise, most of the related investment takes place in the private sector, driven by commercial interests, and the results of research activity are proprietary IPRs, many of them held by a small number of large companies (see table 4 below). This economic constraint considerably limits the effective use of the potential of modern biotechnology, as large segments of farmers cannot afford their application. If modern biotechnology is to play a more mainstream role in the transition to sustainable agriculture, it is imperative that public investment in this area be strengthened at national and international levels[59] that allows small-scale farmers to effectively use the results and to improve the capacity to evaluate the risks and regulate these technologies in ways that are cost effective and address legitimate public concerns (World Bank, 2008: 163). Yet, as can be seen from table 3 below, public R&D spending as share of agricultural GDP has stagnated or even fallen in most developing countries in the period 1981–2000. It only appreciably increased in Brazil and India as well as in developed countries. However, even publicly funded genetic research is far from free of IPR pitfalls. The development of the so-called "Golden Rice" may illustrate the potential opportunities, but also the commercial and IPR-related conflicts that may be difficult to avoid from effectively using the results of publicly funded genetic research (see box 6).

A second factor that limits the effectiveness of the results of biotechnological research is the linear, single-product or -issue centred approach (also termed the "reductionism inherent in modern biotechnology" (Heinemann, 2009: viii)) that often yields less effective or holistic results[60] than conventional breeding using Marker-Assisted Selection/Breeding embedded in a systemic approach under regenerative agriculture.[61]

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[57] For more information, see UNCTAD (2010a: 83); Herren et al. (2011: section 2.1.2.3.); and www.phlosses.net.

[58] It should however not go without comment that, according to Costello et al. (2009) and Vermeulen et al. (2010), it must be anticipated that more frequent climate-change-caused extreme weather events may damage food-storage and distribution infrastructure, with detrimental impacts in particular for the most vulnerable.

[59] Without however crowding out top-priority public investment into sustainable agricultural systems, related research and infra-structure.

[60] The developer of pest-protected Bt cotton Bollgard, Monsanto-Mahyco, for instance, recently revealed that pink bollworm pest had developed resistance to the killer Bt gene, Cry1Ac, in parts of Gujarat in India (Business Standard, 10 March 2010).

[61] For an in-depth discussion of the effectiveness of genetic engineering in developing new varieties of drought-resistant crops, see Tirado and Cotter (2010: section 3.1).

Box 6

OPPORTUNITIES AND CHALLENGES RELATED TO THE DEVELOPMENT AND USE OF GOLDEN RICE

Golden Rice (GR) is a variety of Oryza sativa rice produced through genetic engineering to biosynthesize beta-carotene, a precursor of pro-vitamin A in the edible parts of rice. Because many children in countries where there is a dietary deficiency in Vitamin A rely on rice as a staple food, the genetic modification to make rice produce pro-vitamin A (beta-carotene) is seen as a simple and less expensive alternative to vitamin supplements or an increase in the consumption of green vegetables or animal products. It can be considered as the genetically engineered equivalent of fluoridated water or iodized salt.

GR was created by Mr. Ingo Potrykus of the Institute of Plant Sciences at the Swiss Federal Institute of Technology, working with Mr. Peter Beyer of the University of Freiburg in Germany. The project started in 1992 and at the time of publication of the breading results in 2000 GR was considered a significant breakthrough in biotechnology as the researchers had engineered an entire biosynthetic pathway.

In 2005, a team of researchers at biotechnology company Syngenta produced a variety of GR called “Golden Rice 2”. It produces 23 times more carotenoids than GR, and preferentially accumulates beta-carotene. In June 2005, researcher Peter Beyer received funding from the Bill and Melinda Gates Foundation to further improve GR by increasing the levels or the bioavailability of pro-vitamin A, vitamin E, iron, and zinc, and to improve protein quality through genetic modification. Experts expect that GR will clear final regulatory hurdles and reach the market in about 2 years.

Mr. Potrykus has spearheaded an effort to have GR distributed for free to subsistence farmers. This required several companies, which had intellectual property rights to the results of Mr. Beyer’s research, to license it for free. Mr. Beyer had received funding from the European Commission’s ‘Carotene Plus’ research programme, and by accepting those funds, he was required by law to give the rights to his discovery to the corporate sponsor of that programme, Zeneca (now Syngenta). Messrs. Beyer and Potrykus made use of some 70 IPRs belonging to 32 different companies and universities in developing GR. They needed to establish free licences for all of these so that Syngenta and humanitarian partners in the project could use GR in breeding programmes and to develop new crops.

Lybbert and Sumner (2010: 18) point out that the ‘unlicensed’ use of GR did ultimately “not pose serious problems because GR was intended to be distributed to relatively poor farmers in poor countries. This facilitated the negotiations with patent holders in two ways. First, many of the 70 patents that were implicated in the technology were not effective in poor countries. Indeed, many poor countries had no patent restrictions on GR at all because the inventors had not sought patent protection in small poor countries (and as a matter of practice often do not). Second, there was essentially no overlap between the target clientele of GR (poor farmers) and the target clientele of the commercial patent holders. This created substantial scope for humanitarian use negotiations, which ultimately defined the humanitarian use market as those farmers in selected developing countries earning less than $10,000 per year from farming”.

Free licenses, so called Humanitarian Use Licenses, were granted quickly due to the positive publicity that GR received. There is no fee for the humanitarian use of GR, and farmers are permitted to keep and replant seed.

Source: Lybbert and Sumner (2010: 18); and Kryder et al. (2000).

As Heinemann correctly points out, “few existing problems in agriculture are solely caused by a lack or failure of technology but instead derive from other social, economic or legal frameworks. It is therefore critical to first define what problems are best solved by changing legal frameworks, trade policies or human behaviour and, second, which are best solved using technology. Technology should meet the community’s needs without making local agriculture less sustainable. For example, importing high-cost biotechnology seeds to grow crops for fuel on water-stressed land neither saves water nor reduces the impact this land-use decision has on food production” (Heinemann, 2009: 5). This corroborates the conclusion drawn in the IAASTD report that “GMOs treat the symptoms rather than being a solution that addresses the causes of the major problems” (Herren, 2010).

VII. REQUIRED NATIONAL AND INTERNATIONAL POLICY ACTION AND RELATED CHALLENGES

To profoundly transform agriculture towards the above-outlined mosaic of regenerative practices takes bold and visionary policy measures at national and international level. Although action at both levels should ideally go hand in hand, governments in developing countries can still move ahead with effective measures at national level if international-level progress is slow. This is all the more tempting as climate-change mitigation and adaptation in agriculture have low or negative costs, will significantly draw on local resources, knowledge and skills, as well as will have many developmental and social co-benefits.

Rather than taking measures to favour one or the other specific production method or system, developing country governments should focus on creating an enabling environment and changing the incentive structure as part of a dedicated sectoral and fiscal policy that strengthens in particular research, extension education and services, as well as physical and institutional infra-structure for sustainable agriculture. What are the main clusters of policy measures in this regard?

A. National-level measures

First of all, it is important to remove or modify the existing tax and pricing policies that generate perverse incentives for sustainable production systems, such as overuse of pesticides, fertilizers, water, and fuel or encouraging land degradation. There should be a policy shift towards significantly increasing the efficiency of fertilizer and agro-chemical use and their replacement by soil-fertility-enriching (and carbon-absorptive) production methods that rely on multi-cropping, integrating crop and livestock production and the use of locally available bio-fertilizers and bio-pesticides. As most developing countries import all or the majority of the fertilizers and agro-chemicals used, a drastic reduction of their consumption therefore not only benefits the environment, but also leads to a reduction of the import bill and agricultural production costs.[62]

In India, for instance, overall public expenditures on agriculture have remained at approximately 11 per cent of agricultural GDP, while the share of subsidies for fertilizer, electricity and for price support of cereals and water has steadily risen at the expense of investments in public goods, such as research and development, irrigation, and rural roads (see below). Agricultural spending is about 4 times greater on subsidies than on such important public goods. In Zambia, only about 15 per cent of the 2003/2004 agricultural budget was spent on research, extension services, and rural infrastructure (World Bank,

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[62] Bio-fertilizers, bio-pesticides and increased inter-cropping or rotations with leguminous, N-fixing crops will save energy and GHG emissions for fertilizer and agro-chemical production as well as save money for their purchase. According to Elisio Contini from Embrapa, Brazilian soy farmers had saved up to $5 billion in recent years through the use of biological n-fixation compared to costs of fertilizers (personal communication).

2008: 115). Therefore, reallocating spending on private subsidies to public goods must be a central element of policy reform to encourage sustainable agricultural production.

In addition to removing ‘perverse’ incentives, governments may also consider fiscal or market-based measures (e.g. GHG emission trading systems) to internalize GHG costs (for more information in this regard, see Kasterine and Vanzetti, 2010: 91–93).

Second, assuring stability in land management and tenure systems is a very important policy issue. As the UN Special Rapporteur on the Right to Food put it “in a number of countries, the Green Revolution was effectively a substitute for agrarian reform: instead of encouraging increases in food production by redistributing land to the rural poor, it did so by technology” (De Schutter, 2009). In particular, small farmers need stable tenure systems to invest in soil fertility and production methods for regenerative agriculture.[63] Agrarian reform should therefore continue to take centre stage on the political agenda of governments.[64] This should include issues such as recognizing customary tenure, make lesser (oral) forms of evidence on land rights admissible, strengthen women’s land rights,[65] allocate more land to smallholders with secured tenure, and establish decentralized land institutions (for more information, see World Bank, 2008: 139ff).

Third, the share and effectiveness of public expenditures for agricultural development must be significantly increased. Public agricultural spending has been particularly lacklustre in agriculture-dominated developing countries (see table 2).[66]

Policymakers need to target investments carefully, putting resources into areas that have a large impact on improving physical and R&D infrastructure, linkages between farmers, and greater investment into extension education and services.[67] While national-level investment in improving the transport and storage systems remains important, particular emphasis should be placed on developing locally shared infra-structure and improving value-added activities of farmers, to name but some key issues. Savings from the removal of perverse incentives can significantly reduce additional resource requirements in this regard. There could also be incentives in the form of (time-limited) land tax exemptions or lower cost credit to stimulate private investment. Such approaches are administratively simpler than subsidies and may not run afoul of WTO rules (Herren et al., 2011).

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[63] 60–70 per cent of the farms in the world are being run by people who don’t have contractual land use (Parsons, 2010a: 18).

[64] In the Philippines, for instance, till 2008 – twenty years after the launching of the Comprehensive Agrarian Reform Program (CARP) – only 17 per cent of the 1.5 million ha of land that should have been redistributed through CARP had actually changed ownership (Manahan, 2008: 229).

[65] According to Parsons, 60–80 per cent of food in many developing countries is produced by women. However, only a tiny amount of land is owned by them, just 1 per cent of titled land in Africa, for instance. Furthermore, in many countries, women often lose their rights to land if their husband dies or they get divorced (Parsons, 2010b: 62).

[66] In sub-Saharan Africa, for instance, public spending for farming accounts for 4 per cent of total government spending only. In addition, the agricultural sector is taxed at relatively high level. In their Maputo Declaration of 2003, Member Countries of the African Union (AU) called upon African governments to increase investment in the agricultural sector to at least 10 per cent of the national budget by 2008. An AU/NEPAD survey for 2007 found that 50 per cent of the countries spent less than 5 per cent of their national expenditure on agricultural development, reflecting a decrease from 57 per cent in 2003. Only 8 countries had reached the target level (Comoros, Ethiopia, Madagascar, Malawi, Mali, Niger, Senegal, and Zimbabwe). 9 other countries (Benin, Chad, Mauritania, Nigeria, Sao Tome and Principe, Sudan, Swaziland, Uganda and Zambia) had allocated more than 5 per cent. For more information, see CAADP (2009).

[67] The 2010 Law on Extension and Technical Assistance for Family Farming and Agrarian Reform in Brazil (Lei 12.188/2010) establishes a priority to support rural extension activities on ecological agriculture (based on a communication with O. De Schutter).

Table 2

GOVERNMENT SPENDING ON AGRICULTURE IN DEVELOPING COUNTRIES

(Per cent)

	Agriculture-based countries		*Transforming countries*		*Urbanized countries*	
	1980	*2004*	*1980*	*2004*	*1980*	*2004*
Public spending on agriculture as a share of total public spending	6.9	4.0	14.3	7.0	8.1	2.7
Public spending on agriculture as a share of agricultural GDP	3.7	4.0	10.2	10.6	16.9	12.1
Share of agriculture in GDP	28.8	28.9	24.4	15.6	14.4	10.2

Source: World Bank (2008: 41).

Note: Numbers for agriculture-based countries are based on 14 countries (12 from sub-Saharan Africa), those for transforming countries on 12 countries, and those for urbanized countries on 11 countries.
The country groups are defined as follows:
Agriculture-based countries: Agriculture is a major source of growth, accounting for 32 per cent of GDP growth on average - mainly because agriculture accounts for a large share of GDP - and most of the poor are in rural areas (70 per cent). This group of countries has 417 million rural inhabitants, mainly in sub-Saharan countries. 82 per cent of the rural sub-Saharan population lives in agriculture-based countries.
Transforming countries: Agriculture is no longer a major source of economic growth, contributing on average only 7 per cent to GDP growth, but poverty remains overwhelmingly rural (82 per cent of all poor). This group, typified by China, India, Indonesia and Morocco, has more than 2.2 billion rural inhabitants. 98 per cent of the rural population in South Asia, 96 per cent in East Asia and the Pacific, and 92 per cent in the Middle East and North Africa are in transforming countries.
Urbanized countries: Agriculture contributes directly even less to economic growth, 5 per cent on average, and poverty is mostly urban. Even so, rural areas still have 45 per cent of the poor, and agri-business and the food industry and services account for as much as one third of GDP. Included in this group of 255 million rural inhabitants are most countries in Latin America and the Caribbean and a number in Central Asia. 88 per cent of the rural populations in both regions are in urbanized countries.

According to the President of the International Fund for Agricultural Development (IFAD), "global food security can only be achieved through significant new investment in smallholder agriculture" (cited in Mactaggart, 2010b). Furthermore, governments need to pay special attention to strengthening the agricultural innovation and extension system for ecological farming methods[68], with particular emphasis on providing innovative, locally adapted and locally sourced solutions for smallholders.[69] Paving the way for mainstreaming a mosaic of sustainable agricultural production methods requires integrative learning, in which farmers and researchers in agro-ecological sciences work together to determine how to best integrate traditional practices and new agro-ecological scientific discoveries. For this to take place, new channels and platforms for information exchange and skills' transfer need to be developed (Herren et al., 2011).

Enhanced regional and international South-South co-operation could play a useful role in strengthening agricultural R&D and extension capacity. The establishment of more regional centres of excellence,

[68] Even in Europe, less than one per cent of the total food and agriculture research budget is spent on organic agriculture (Khor, 2009: 16).

[69] According to Lybbert and Sumner (2010: vi), creating the necessary agricultural technologies and harnessing them will require innovations in policy and institutions. Also, the Consultative Group for International Agricultural Research (CGIAR) and its consortium of 15 CGIAR research centres should play an even more pronounced role in guiding and assisting developing countries in this regard. For more information, see: http://cgiar.org/impact/global/cc_exec_summary.html.

Table 3

DEVELOPMENT OF PUBLIC AGRICULTURAL R&D EXPENDITURES

	Public agricultural R&D spending ($ million)		R&D spending as a percentage of agricultural GDP	
	1981	*2000*	*1981*	*2000*
Sub-Saharan Africa	1,196	1,461	0.84	0.72
Asia and Pacific	3,047	7,523	0.36	0.41
China	1,049	3,150	0.41	0.40
India	533	1,858	0.18	0.34
West Asia and North Africa	764	1,382	0.61	0.66
Latin America and Caribbean	1,897	2,454	0.88	1.15
Brazil	690	1,020	1.15	1.81
Developing Countries	6,904	12,819	0.52	0.53
Japan	1,832	1,658	1.45	3.62
United States	2,533	3,828	1.31	2.65
Developed Countries	8,293	10,191	1.41	2.36
Total	15,197	23,010	0.79	0.80

Source: World Bank (2008: 167).

regional public research institutions and closer collaboration among existing research centres would be valuable steps in this direction (UNCTAD, 2010b).[70]

While public investment in agricultural research and development tripled in China and India in the 1980s and 1990s, it increased by barely a fifth in sub-Saharan Africa (declining in about half of these countries) (Pardey et al., 2006). With the exception of Brazil, India, West Asia and developed countries, the share of public R&D spending in agricultural GDP stagnated or even declined (see table 3).[71]

Fourth, agricultural policy is generally implemented by up to a dozen of governmental institutions. Achieving policy coherence and effective coordination of their activities are important for the paradigm shift towards regenerative agriculture as outlined above. Furthermore, coordination between environmental, natural resource, energy and agricultural policies is needed to maintain a consistent set of incentives for adoption of sustainable management systems and to facilitate cross-sectoral interactions, which are often involved in carbon crediting from agriculture. According to Stolze (2010), the creation of Support Platforms, which bring together potential public and private partners, supported by relevant experts, to jointly assess and further develop the priority activities identified may be worth considering.

Fifth, regulations in the financial sector that facilitate the flow of funds for mitigation benefits to local communities are also important and have been a barrier to paying farmers for environmental benefits. Financial constraints in agriculture remain pervasive, and they are costly and inequitably distributed, severely limiting smallholders' ability to compete. Financial constraints originate from the lack of asset ownership to serve as collateral and the reticence to put assets at risk as collateral when they are vital to livelihoods. The demise of special credit lines to agriculture through public programmes or state banks has left huge gaps in financial services, still largely unfilled despite numerous institutional innovations (World

[70] Brazil has just signed an agreement with Ghana, Kenya, Zimbabwe, Ivory Coast and Rwanda that will provide technology and knowledge transfer, as well as financial aid to strengthen production capacity of small-scale and family farmers. Brazil is to provide an initial credit line of $240 million to finance farm machinery and equipment as well as education for small rural producers in those countries (SUNS, 2010).

[71] Only about one third of all global research expenses on agriculture is spent on solving the problems of agriculture in developing countries (Kiers et al., 2008: 320).

Bank, 2008: 13). Therefore, special credit facilities (including micro-credit), community-oriented financial services, and the effective functioning of rural development banks are important in this regard.

Another mechanism for facilitating access to financing for sustainable agricultural development is the broadening of payments for environmental services.[72] Watershed and forest protection, for instance, create environmental services (clean drinking water, stable water flows to irrigation systems, carbon sequestration, and protection of biodiversity) for which providers should be compensated through payments from beneficiaries of these services. Interest in the widespread use of payments for environmental services has been growing, particularly in Latin America. In Nicaragua, for example, payments induced a reduction in the area of degraded pasture and annual crops by more than 50 per cent in favour of silvo-pastoralism, half of it by poor farmers (World Bank, 2008: 16).

Sixth, small-scale farmers, their networks and sustainable production methods must again become an explicit component of national development strategies and an important target for development assistance (for more information, see Cook, 2009).

Seventh, strengthening the performance of producer organizations and empowering the capacity of local communities should also figure prominently on the agenda of governments. Collective action by producer organizations is important for building research and skill capacity, reducing transaction costs, increasing market power, and strengthening representation in national and international policy forums. For smallholders, producer organizations are essential to achieve competitiveness (World Bank, 2008: 14). Strengthening the capacity of local communities in their stewardship of biodiversity, conservation of rangelands and fragile agro-ecological zones must be recognized as an essential strategy. Therefore, a policy framework around the stewardship of biodiversity at all levels needs to be created. Local communities can also play a very pro-active role in facilitating exchange of local knowledge, its blending with modern scientific tools and related dissemination through farmer-field schools, participatory plant breeding and community seed banks. Local communities can also be instrumental in promoting the de-centralized use of bio- and other renewable energy sources.[73]

Finally, agricultural mitigation and adaptation actions should be high priority candidates for being integrated into Sustainable Development Policy and Measures (SD-PAM), Nationally Appropriate Mitigation Actions (NAMAS), and National Adaptation Programmes of Action (NAPAs). According to Stolze (2010), priority should be given to adaptation measures that bring about mitigation consistent with sustainable development objectives. The integration of agricultural mitigation programmes into agricultural development strategies will need to be part of the overall effort to improve the sector’s performance and the livelihoods of small farmers (FAO, 2009a).[74] The role of agriculture has to be closely interlinked with overall national development strategies (or plans) to bring about the structural transformation required for effective climate-change adaptation and mitigation.

B. Policy measures and challenges at international level

A major challenge is to modify at international level a number of key market distortions and market structures that act as a disincentive to the transition to sustainable agricultural practices at national level in

[72] For an elaborate analysis, see FAO (2007).

[73] For more information on the pro-active role of local communities, see Altieri and Koohafkan (2008); and Paul et al. (2009: 40).

[74] As regards organic agriculture, for example, a recent comprehensive UNEP/UNCTAD study, based on in-depth analysis of seven country case studies, has made 35 specific recommendations on what developing-country policymakers can do to best reap the multifaceted benefits of organic agriculture (UNCTAD/UNEP, 2008b).

Table 4

MARKET CONCENTRATION OF MAJOR SUPPLIERS OF AGRICULTURAL INPUTS

	Agrochemicals		*Seeds*		*Biotechnology*	
Company	*2004 sales ($ million)*	*Market share (Per cent)*	*2004 sales ($ million)*	*Market share (Per cent)*	*Number of United States patents*[a]	*Patent share (Per cent)*
Monsanto	3,180	10	3,118	12	605	14
Dupont/ Pioneer	2,249	7	2,624	10	562	13
Syngenta	6,030	18	1,239	5	302	7
Bayer Crop Science	6,155	19	387	2	173	4
BASF	4,165	13	–	–	–	–
Dow Agrosciences	3,368	10	–	–	130	3
Limagrain	–	–	1,239	5	–	–
Others/Private	7,519	23	16,593	66	1,425	34
Public sector	–	–	–	–	1,037	24
Market concentration[b]						
CR4 (2004)		60		33		38
CR4 (1997)		47		23		

Source: World Bank (2008: 136).
a Number of United States agricultural biotechnology patents issued during the 1982–2001 period.
b Market concentration is measured by the concentration ratio CR4, which indicates the market share of the four largest firms participating in the market.

developing countries. This concerns the significant subsidization of agricultural production in developed countries and their exports to developing countries. The average support to agricultural producers in the major developed countries as percentage of gross value of farm receipts was at 30 per cent for the period 2003–2005, representing an amount of almost $1 billion per day (OECD, 2006). These developed-country agricultural policies cost developing countries about $17 billion per year – a cost equivalent to five times the recent levels of ODA to agriculture (Anderson and Van der Mensbrugghe, 2006).[75] As long as these conditions prevail and are not significantly altered by the current Doha Round of WTO negotiations it is difficult to imagine how developing country producers can implement a paradigm shift towards sustainable agricultural production at the required massive scale, both in depth and breadth.

The phasing out of “perverse” subsidies should be accompanied by the introduction of proper carbon pricing tools and policies. For agriculture with its vast number of relatively small producers, carbon or energy taxes and similar fiscal instruments should be explored to set the right incentives for innovation and desirable changes in production and consumption patterns as well as methods.

This needs to be supplemented by a reform of international trade policies that are really supportive of ecological agriculture. According to Ching (2010b), apart from real reduction of domestic support in developed countries, this should include improved market access for developing country produce and policy space to support the agricultural sector, allow expansion of local food production, and the use of effective instruments to promote food security, farmers’ livelihoods and rural development (for more information, see also Feyder, 2010).

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[75] A very illustrative example is rice produced in and exported from the United States. According to a United States Government study, almost 60 per cent of the United States rice farms would not have covered their cost if they had not received subsidies. In 2000–2003, the average cost of production and milling of United States white rice was $415 per ton, but it was exported for just $274 per ton, a price roughly one third below its cost (cited in Khor, 2009: 3–4).

Very problematic is the global market dominance of very few companies, which dominate the world seed, agro-chemical and biotechnology markets. In 2004, the market share of the four largest agrochemical and seed companies (the concentration ratio of the top four, or CR4) reached 60 per cent for agrochemicals and 33 per cent for seeds, up from 47 per cent and 23 per cent in 1997, respectively (World Bank, 2008: 135) (see table 4).[76]

These companies have a vested interest in maintaining an external-input-dependent, mono-culture-focused and carbon-intensive industrial approach to agriculture. Furthermore, international supply chains, often under the leadership of major food processors or retailers, also need to reconsider their sourcing from scale-focused mono-crop production in favour of diverse multi-cropping and integrated livestock and crop farming systems. Whether these challenges can really effectively be addressed is an open question.

International development co-operation needs to refocus on agriculture, making a U-turn in aid going to the sector. Agriculture's share in official development assistance (ODA) declined sharply over the past two decades, from a high of about 18 per cent in 1979 to 3.5 per cent in 2004 (see figure 7). It also declined in absolute terms, from about $8 billion in 1984 to $3.4 billion in 2004. The bigger decline was from the multilateral financial institutions, especially the World Bank (World Bank, 2008: 41).[77] Much more aid should flow into strengthening the agricultural innovation and extension system for ecological farming methods and supportive infra-structure. Furthermore, smallholders must again become a key target of development support.

In this context, there is a need at national and international level to democratize agricultural aid and research. Food and agriculture research all too often tend to ignore the values, needs, knowledge and concerns of the very people who provide the food, often serving instead powerful commercial interests, including from multinational seed and food retailing companies. Agricultural research and aid must shift to focus on what farming communities and food consumers want and need. Farmers and other citizens must play a central role in defining strategic priorities for agricultural research and food policies.[78]

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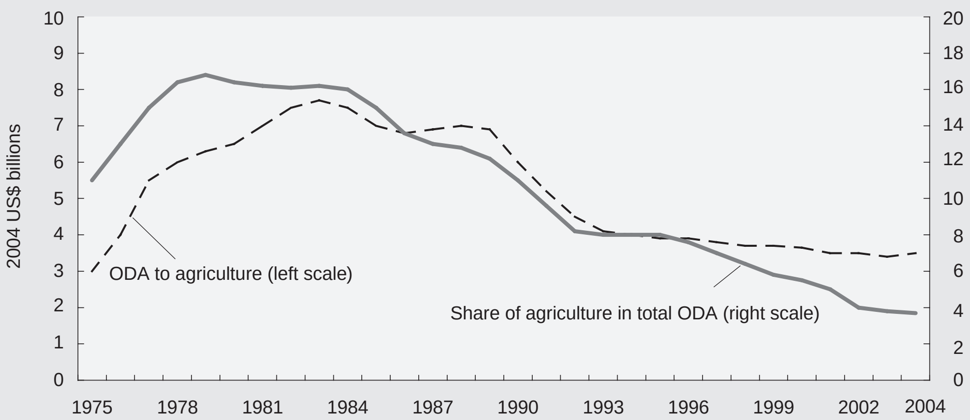
[76] As regards seeds, as the industry consolidates, seed options narrow, and farmers lose access to important varieties. Little attention has been given to this emerging trend, where demand does not factor in as much as a lack of choice (Farmer to farmer campaign, 2010).

[77] The idea of a global food security initiative was first discussed at the G8 "plus" meeting in L'Aquila in July 2009, in which leaders pledged more than $22 billion for what became known as the Agriculture and Food Security Initiative. Leaders at the G20 summit in Pittsburgh in September 2009 then called on the World Bank Group to "work with interested donors and organizations to develop a multilateral trust fund to scale up agricultural assistance to low income countries." The World Bank's Board of Executive Directors approved the Global Agricultural and Food Security Programme (GAFSP) in January 2010. The GAFSP is a multilateral financing mechanism which will allow the immediate targeting and delivery of additional funding to public and private entities to support national and regional strategic plans for agriculture and food security in poor countries. Financial contributions to the GAFSP to date have been provided by or pledged by four G20 member countries (United States, Canada, Spain and South Korea) as well as the Bill and Melinda Gates Foundation. Total commitments to date equal about $900 million, pledged over three years. GAFSP will finance the following clusters of activities: (i) raising agricultural productivity by supporting: (a) adoption of high-yielding technologies; (b) technology generation; (c) water management; and (d) land rights; (ii) linking farmers to markets by supporting: (a) reduction in transaction costs; (b) value addition; and (c) mobilization of rural finance; (iii) reducing risk and vulnerability by supporting: (a) price and weather risk management; (b) strengthening food-related social protection for people who face chronic and transitory rural poverty; and (c) improving nutrition of mothers and young children; and (iv) non-farm rural livelihoods by supporting: (a) investment in climate improvements; and (b) entrepreneurship promotion (World Bank, 2010). The countries that have accessed the GAFSP funds so far are Rwanda, Sierra Leone and Togo, all in the context of the Comprehensive Africa Agriculture Development Programme (CAADP), developed under NEPAD (for more information, see: www.nepad-caadp.net/library.php). The GAFSP is certainly a promising initiative, but not, as put by Cook (2009: 7), "if it simply pours new money into failed approaches and unsustainable methods of production".

[78] For more information, see www.iied.org/natural-resources/media/world-food-day-marked-call-democratise-agricultural-research-and-ensure-food.

Figure 7

LEVEL AND SHARE OF ODA TO AGRICULTURE IN DEVELOPING COUNTRIES, 1975–2004



Source: World Bank (2008: 41).

Stolze (2010) and Herren (2010) highlight that the process of methodological development of appropriate mitigation and adaptation strategies and measures is costly and requires multi-faceted experts. They therefore see the need for an international instrument that provides a global framework for action and support for agriculture, such as transforming the IAASTD into the IPCC for agriculture.

The international community may further study the opportunities and constraints for including land-use changes and terrestrial carbon opportunities under the flexibility mechanisms of the Kyoto Protocol. However, recent discussions on better exploiting the potential of soil carbon sequestration and above ground carbon in agriculture under the Clean Development Mechanism (CDM) run the risk of taking carbon trading to new levels of absurdity by expanding no-till monocultures, tree plantations and minor technical adjustments in the livestock industry.[79] Transitioning to a comprehensive approach to all land uses could enable better management of synergies, trade-offs and leakage involved in mitigation of GHGs from land-based sources and sinks. This would necessitate the development of terrestrial carbon baselines, but, over time, also a rigorous land-use GHG accounting system and appropriate measurement, reporting and verification tools (FAO, 2009d). As these are complex, costly and time-consuming tasks, it is far from clear whether an international consensus on these matters can be achieved within the not too distant future.[80]

According to FAO, new financing mechanisms should be established with broader, more flexible approaches, integrating different funding sources and innovative payment/incentive/delivery schemes to reach producers, including smallholders. A phased approach using aggregating modalities for greater cost-effectiveness, front-loaded payments guaranteed by insurance or performance bonds, simplified rules and recognition of community/individual, formal/informal property rights are some design elements that, according to FAO, would seem to hold promise in this regard (FAO, 2009d). In this context, there may also be merit in extending the existing financing scope or creating an agricultural parallel of the enhanced Reducing Emissions from Deforestation and Forest Degradation in Developing Countries

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[79] For a more elaborate analysis, see Paul et al. (2009). According to the authors, current proposals suggest that "funding would primarily be channelled towards industrial monocultures, combined with agrofuel and agroenergy expansion. Non-industrial, biodiverse farming by small-scale farmers is unlikely to benefit" (p. 16).

[80] For more information, see http://www.iatp.org/iatp/publications.cfm?accountID=451&refID=107713.

Box 7

PRODUCT CARBON FOOTPRINT LABELLING FOR EXPORTED FOOD FROM DEVELOPING COUNTRIES

Companies want to have predictability on the future regulatory or economic-incentive environment for their investment decisions, cost structures and business opportunities. The more uncertain the future international and national climate-change policy framework is in this regard, the more likely that companies develop bottom-up voluntary approaches to fill the vacuum. If first and second best carbon internalization mechanisms (such as carbon trading schemes and fiscal instruments, either individually or as hybrid approach) are not put in place, remain ineffective (such as the current situation under the European Carbon Trading Scheme) or have too high transaction costs (such as under carbon trading in agriculture), product carbon footprint labelling might be resorted to as third-best internalization tool.

Some governments (including Japan, Sweden, Republic of Korea, and the United Kingdom) have encouraged or sponsored such schemes. The Government of France is about introducing legislation (Grenelle 2) making such labelling mandatory over the next few years.

Product carbon footprint (PCF) standards and labels have emerged as stand-alone schemes (e.g. Carbon Reduction Label in the United Kingdom, also applied by TESCO supermarket, ClimaTop label in Switzerland, applied by Migros supermarket, or the Carbon Label of Casino supermarket in France), but are also increasingly being integrated into existing meta-standards on sustainable management of food (e.g. climate certification as a supplement to the Swedish label KRAV for organic products or the Swedish food quality label Swedish Seal).

More than a dozen of different methodologies for calculating the PCF were being used or under development in 2010. The schemes varied greatly in approach and methodology. While all emerging PCF standards claim to base themselves on life-cycle analysis, most tend to exclude emissions that would be too technically difficult to assess, for instance, soil carbon absorption (which, as already mentioned above, accounts for 89 per cent of the technical mitigation potential of agriculture) or the carbon content of capital goods. Furthermore, currently only one standard, the Swiss ClimaTop, differentiates the carbon content of products between organic, integrated crop and livestock, extensive and intensive production methods. All other standards do not or marginally capture direct agricultural GHG emissions, but rather focus on GHG emissions from energy use in the agri-food chain (see box 1) (GHG emissions from energy use in the agri-food chain are not accounted for as agricultural emissions). This basically boils down to the question whether energy-efficient production systems for exported produce can indeed compensate for energy use from transport and storage.

However, energy efficiency is not a major issue as regards direct agricultural GHG emissions. Therefore the currently prevailing PCF standards and labels are mainly applying an industrial-product-typical approach to agricultural products and are thus not sending the right incentives to agricultural producers for changing their production methods. Data on terrestrial carbon uptake are difficult and costly to create and gather and generic data cannot adequately describe the situation in a whole country, as there are diverse ecosystems, soils and microclimates.

According to Plassmann et al. (2010), the PCF of many agricultural products significantly depends on land-use changes. In this regard, Brenton et al. (2010: 2) state that “it is important that these emissions are calculated correctly. This can be difficult in developing countries where relevant data relating to the distribution of current and historical land uses are scarce or absent. Not only are there technical issues surrounding the calculation of emissions from land use change, but in addition there is a fairness issue, because most developed countries do not need to include this source of emissions because they cleared their forests decades or centuries ago”.

Furthermore, the diverse methodologies currently applied to PCF and the lack of their harmonization can result in high transaction costs for foreign suppliers that target several markets.

In the light of the methodological and data complexities, according to Potts (2011) it appears doubtful whether PCF standards and labelling can indeed play more than a niche role in global food markets at least in the short and medium term. According to Potts it is however likely that there is increasing convergence between PCF, sustainable management standards and voluntary carbon offset schemes and markets.

The International Organization for Standardization (ISO) is working on a framework standard for carbon footprint (the future ISO 14067). However, it is as yet too early to say whether the product category rules for agriculture under ISO 14067 will effectively address the shortcomings of the existing PCF standards as flagged above (for more information, see Radunsky, 2009: 16–18).

Source: MacGregor (2010); Kasterine (2010: 30–31); Plassmann et al. (2010: 393–404); and Brenton et al. (2010).

programme (REDD+).[81] This programme already extends to agriculture and bio-energy insofar as they impact forests. A REDD+ strategy can involve market or non-market-based instruments, and be based on performance according to established criteria or based on GHG quantification.

Finally, a potential means of reaching agricultural producers with some additional carbon funds is through agricultural product markets, e.g. through the development of agricultural product standards and labelling related to GHG mitigation benefits (e.g. product carbon footprint standards). Building upon the institutions and lessons learned from the development of organic and sustainable agricultural-products marketing channels for smallholders can greatly facilitate the implementation of such approaches. However, it will significantly depend on the methodologies used in the measurement of GHG emissions whether product carbon footprint labelling will become a boon or bane for farmers in developing countries (see box 7). Furthermore, it is far from certain whether product carbon footprint labelling or standards can indeed graduate from a niche market.[82]

VIII. CONCLUSIONS

For most developing countries, agriculture remains the key economic and social sector, which is of pivotal importance for assuring food security. Global warming has the potential to damage irreversibly the natural resource base on which agriculture depends, with grave consequences for food security. Climate change could reduce total agricultural production in many developing countries by up to 50 per cent in the next few decades, in particular in South Asia and sub-Saharan Africa. At the same time, the population of these countries is projected to nearly double, creating huge tensions between food supply and demand. Although food could be theoretically imported from temperate-zone countries that may benefit from global warming, this may simply be unaffordable given the huge demand, low purchasing power and expected food price increases.

Agriculture is a very GHG-emission-intensive sector. Although agriculture's share in global GDP is just about 4 per cent, agriculture accounts for about 13–32 per cent of global GHG emissions, the former being confined to direct, the latter including indirect GHG emissions from land-use changes, land degradation and deforestation. It is often overlooked that global GHG emissions from agriculture and forestry are higher than from the key energy-intensive industrial sectors (such as iron and steel, cement, chemicals or non-ferrous metals) and even surpass those caused by the global energy sector (i.e. generation of electricity, heat and other fuel combustion). Under a business-as-usual scenario, agricultural GHG emissions are predicted to rise by almost 40 per cent till 2030. Further chemicalization and industrialization of agricultural production that cannot but reinforce this trend are therefore steps in the wrong direction. If properly transformed, agriculture can be turned from being a climate-change problem to becoming an essential part of its solution. The key problems of climate change, hunger and poverty, economic, social and gender inequity, poor health and nutrition, and environmental sustainability are inter-related and need to be solved by leveraging agriculture's multi-functionality. Thus a much more holistic approach is required that not only sees the farmer as a producer of food and agricultural commodities, but also as

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[81] The UN-REDD programme supports nationally-led REDD+ processes and promotes the informed and meaningful involvement of all stakeholders, including indigenous peoples and other forest-dependent communities, in national and international REDD+ implementation. The Programme also works to build international awareness and consensus about the importance of including REDD+ mechanisms in the further development of the international climate regime.

[82] The market potential of product carbon footprint labelling for agricultural products might suffer from (i) the fact that it requires even more altruism than organic standards; (ii) the methods of calculating the footprint are complicated and require the gathering of an enormous amount of data; and (iii) the choices consumers make based on them can be counterintuitive or even counterproductive. Furthermore, the continued existence of perverse subsidies significantly undermines the effectiveness and scaling up of product carbon footprint labelling.

manager of sustainable agro-ecological systems. The required transformation, however, is much more profound than simply tweaking the existing industrial agricultural systems.

In essence, the key task is to transform the uniform, high-external-input-dependent model of quick-fix industrial agriculture into a flexible approach of sustainable (regenerative) agricultural systems (rather than individual crops) that continuously recreate the resources they use and achieve higher productivity and profitability of the system (not necessarily of individual products) with minimal external inputs (including energy). While extensively drawing on local knowledge and varieties, regenerative systems will marry them with modern agricultural science and extension services and give a very pro-active role to small-scale farmers. A key challenge is to considerably lift the productivity of small-scale (family) farmers by mobilizing and empowering them to use the modern methods of regenerative agriculture.

The sheer scale at which modified production methods would have to be adopted, the significant governance and market-structure challenges, in particular at international level, pose considerable challenges to implement the required far-reaching transformation. Undoubtedly, there are very powerful vested interests by large globally active companies that dominate the agricultural input markets to keep the status quo of high external input dependent agricultural production methods. Also, large farmers will be reluctant to give up external-input- and mono-culture-based industrial agriculture, which is often very much dependent on energy, input and product price subsidies, unless there is a far-reaching subsidy reform accomplished under the current Doha Round of WTO negotiations. This would however also have to include green box support measures and energy subsidies.

To profoundly transform agriculture towards the above-outlined mosaic of sustainable (regenerative) practices takes bold and visionary policy measures. Although action at international and national levels should ideally go hand in hand, governments in developing countries can still move ahead with effective measures at national level if international-level progress is slow. This is all the more tempting as agricultural mitigation and adaptation have low or negative costs, have considerable developmental co-benefits and will significantly draw on local resources, knowledge and skills. This will however require a considerable increase of public expenditure for agriculture, with a particular emphasis on public research, extension education and services and the improvement of local infra-structure aimed at empowering in particular small-scale farmers to significantly increase total productivity of the new regenerative agricultural systems.

There are important secondary macro-economic benefits of investment in sustainable agriculture. The most important is the ‘local multiplier effect’ that accompanies investments that direct a greater share of total farming input expenditures towards the purchase of locally sourced inputs (e.g. labour, organic fertilizers, bio-pesticides, renewable energy etc.) replacing conventional procurement of externally sourced inputs. Conceptually, the same investment in any other competing activity is unlikely to have as many linkages with the local economy and hence unlikely to yield a multiplier as large. De facto, this leads to a reduced dependence on global agricultural input and product markets and to a regionalization in focus, which enhances local sovereignty over key decisions rooted in the multi-functionality of agriculture.

The current structures in global agricultural input and output markets do not ease, but rather complicate the required fundamental transformation of agricultural production methods and consumption patterns. Huge price distortions, considerable externalities, market and policy failures, as well as powerful commercial interests create a “minefield” for constructive action being (unilaterally) undertaken at national level. Without a reform of international trade and investment policies that are really supportive of ecological agriculture national-level action may remain ineffective.

There is generally too much emphasis on and simplistic overestimation of the potential of technological development for agricultural transformation. This will only give false hope and excuses for doing nothing really fundamental. In fact, as the above analysis shows, only few problems in agriculture are mainly caused by a lack of technology, many are related to social, economic and cultural issues that require structural changes, not techno-fixes (Paul et al., 2009: 9). It is therefore critical to first of all define what problems are best solved by changing legal frameworks, trade policies, incentive structures or human behaviour and, second, what contribution technology could make within this very context.

Given the complexity of the interplay between climate change and agriculture and the fact that the process of methodological development of appropriate mitigation and adaptation strategies and measures is costly and requires multi-faceted experts, there may be the need for creating an international instrument or process that provides a global framework for action and support for agricultural reform, and which would implement the recommendations of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). This could take the form of an IPCC equivalent for agriculture.

Finally, it is important to bear in mind that "climate change" has become such a dominating issue in economic analysis and policy making that other, not much less important issues such as eco-system services, biodiversity, water management or social issues run the risk of being neglected or de-linked from the climate nexus. There is therefore a risk that governments and the international community optimize "climate mitigation and adaptation" without seeing (despite all synergies) the trade-offs and conflicts with other issues.

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