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Sustainable Agricultural Innovation Systems (SAIS) for Food Security and Green Economies

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Abstract

The aggravation of global food insecurity and the most recent famine in the Horn of Africa coupled with greater international awareness over the risks of increasing greenhouse gas (GHG) emissions and greater food price volatility provide an opportunity to strengthen the political consensus necessary to accelerate the adoption of sustainable agricultural development strategies, including the necessary investments for implementation.

Current agricultural technologies and practices are a major source of GHG emissions, land degradation, biodiversity loss, and water scarcity and pollution. Degradation of natural resources in turn, reduces the capacity of rural communities, women and vulnerable groups to meet minimum food needs. Strengthening the productive capacity of small-scale farmers through rapid diffusion of sustainable agricultural technology and practices and supporting services to increase food production would help to improve food security and environmental sustainability. Furthermore, a strategy that assigns a prominent role to small-scale farming would also translate into faster economic growth and poverty reduction in countries with a large agricultural sector.

The paper argues that recent developments in the global food system provide a rare opportunity to advocate for radical changes in the institutions that govern agricultural development and to turn the focus of attention to the needs of small-scale farmers and rural women, particularly in poverty struck and food insecure countries.

Introduction

The aggravation of global food insecurity and the most recent famine in the Horn of Africa coupled with greater international awareness over the risks of increasing greenhouse gas (GHG) emissions and greater food price volatility provide an opportunity to strengthen the political consensus necessary to accelerate the adoption of sustainable agricultural development strategies, including the necessary investments for implementation.

Current agricultural technologies and practices are a major source of GHG emissions, land degradation, biodiversity loss, and water scarcity and pollution. Degradation of natural resources in turn, reduces the capacity of rural communities, women and vulnerable groups to meet minimum food needs. Strengthening the productive capacity of small-scale farmers, including rapid diffusion of sustainable agricultural technology and practices with the necessary supporting services to increase food production would make a remarkable contribution to improving food security and environmental sustainability. Furthermore, a strategy that assigns a prominent role to small-scale farming would also translate into faster economic growth and poverty reduction in countries with a large agricultural sector.

Improving food security through the incorporation of sustainable agriculture requires a major transformation of national policy frameworks and the emergence of new political coalitions to increase public investments in rural areas, secure property rights (including land redistribution if necessary) and expanding access to other productive assets and inputs in support of small scale production.

The paper will maintain that recent developments in the global food system provide a rare opportunity to advocate for radical changes in the institutions that govern agricultural development and to turn the focus of attention to the needs of small-scale farmers and rural women, particularly in poverty struck and food insecure countries.

Food crises: adverse climate, markets and political conflict

Famine in the Horn of Africa

In spite of early signs that conditions of famine were building in the Horn of Africa, international responses were slow to come in the worst humanitarian crisis since the famine in Somalia in 1991-2. Large regions in Kenya, Somalia, Ethiopia, Eritrea and Djibouti were struck this summer by one of the worst droughts in 60 years.

Between July and August, the UN officially declared famine in five areas in Somalia.[1] In the southern regions of the country mortality rates are above alert level (1 death in 10,000 people a day), in Balcad and Cadele they are above famine levels (2 deaths in 10,000 people a day) and in lower Shabelle, the Afgoye corridor and Mogadishu mortality rates are more than double famine levels. Under 5 mortality rates are higher than 4 in 10,000 people a day in the South and more than 13 in 10,000 a day in agro-

[1] A famine is defined when more than 2 people per 10,000 die per day. Recent experiences of famine include Sudan in 1998, Ethiopia in 2001 and Niger in 2005.

pastoral areas. This is equivalent to 10 percent of children under five years of age, dying every 11 weeks (FEWS/Net 2011) and malnutrition among people reaching refugee camps is higher than 30 percent.

Without timely assistance, regions in Somalia and Ethiopia, where 65 percent of the population are pastoralists, will deteriorate and all eight regions in Somalia will be facing famine until at least December 2011 (FAO 2011). In addition, it is estimated that the worst drought in over half a century, has left more than 12 million people in Kenya, Ethiopia, Sudan, and Eritrea in need of food assistance to avoid starvation, in addition to prevention against cholera and measles[i].

Most disturbing is the fact that the famine and acute food insecurity in these countries was hardly a surprise. Monitoring weather systems, including FAO predictions and the Famine Early Warning Systems Network (FEWS-NET) at USAID, predicted low rainfall in the Horn of Africa at least six months before the famine broke (New Scientist 2011).[2]

The situation of famine in the Horn of Africa was produced by a combination of factors including a military conflict in Somalia, exceptional conditions of drought, and unprecedented increases in food prices in the region, especially people with restricted market access, usually the poorest and most vulnerable groups. According to reports from the WFP, for example, pastoralists in July 2011 need to sell 5 goats to buy a bag with 90 kilos of maize, as opposed to one to two goats in January (New Scientist 2011).

While the recent famine in the Horn of Africa is the expression of extreme food insecurity, unsustainable availability, access and utilization of food is becoming a major development concern in other parts of the world; food insecurity has a high human cost in terms of lost lives and permanent damage to the life of children growing up with malnutrition. Outside Africa, there are currently 6.1 million people in the Democratic People's Republic of Korea in urgent need of international food assistance, according to a recent mission from WFP/FAO/UNICEF that identified children, pregnant and lactating women, elderly and people with disabilities as most vulnerable to lack of food (FAO-GIEWS 2011). And food security concerns were raised in many other countries just a few years ago during the 2007/8 food crisis.

Adverse weather

The most recent food crisis unfolding in the Horn of Africa is *prima facie* evidence of the catastrophic impacts of adverse climatic conditions, possibly related to climate change. While it is not possible to establish empirically a direct link between the current drought and human-induced climate change, successive seasons with very low rainfall appear to be part of a long-term shift. Borana communities in Ethiopia report that whereas droughts were recorded every 6 to 8 years in the past, they now occur every 1 to 2 years. Meteorological data also back up the picture on temperatures, with mean annual temperatures having increased from 1960-2006 by 1˚C in Kenya and 1.3˚C in Ethiopia, and the frequency of hot days increasing in both countries. Rainfall trends are less clear, with no statistically significance (IPCC 2007a). However, more recent research suggests that rainfall decreased from 1980 to 2009 during the ''long-rains'' occurring from March to June[ii].

[2] A normal rainfall of 120 to 150 millimetres of rain in April turned out to be around 30 to 40 millimetres.

On the whole, climate change has been shown to impact agriculture in numerous ways, with changes in temperature, precipitation and climatic variability affecting the timing and length of growing seasons and yields, exacerbating land degradation, and contributing to water scarcity (Agrawala and Fankhauser 2008; and table 3). Extreme changes in weather in 2007/8 and 2010/11 have triggered large increases in prices as droughts struck cereal producing countries like the Russian Federation and Ukraine, followed by floods in Pakistan, Australia and the US. Concerns about global food supplies have also exerted upward pressure on prices.

On a global scale, it has been estimated that warming has resulted in annual combined losses of wheat, maize and barley of roughly 40 million tonnes, or $5 billion, over the past three decades, with impacts predicted to worsen over time (Lobell and Field 2007). But the importance of climate change for food security varies by region (Gregory et al. 2005). Notably, with temperature rises, crop productivity is forecast to increase at mid-high latitudes and decrease at lower latitudes (IPCC 2007b). For instance, it is estimated that in Southern Africa yields could fall by up to 50 percent between 2000 and 2020 (IPCC 2007c); and that, by 2080, 600 million additional people could be at risk of hunger as a direct consequence of climate change (UNDP 2007).

In addition, deforestation and desertification-related processes can impact precipitation (Millennium Ecosystem Assessment 2005). For instance, changes in forest cover in the Amazon basin were shown to affect the flux of moisture to the atmosphere and regional rainfall patterns (Baidya Roy and Avissar 2002). Climate change may lead to reduced availability of water in regions affected by reduction in total precipitation (including Southern Africa and the Mediterranean Region) (FAO 2008), with negative implications for agricultural yields.

Furthermore, more frequent and severe weather events such as floods, droughts, fires, and higher temperatures may promote desertification, deforestation, further soil erosion and dust storms (University of East Anglia, Overseas Development Group, 2006), which can lead to reduced yields and cause damage to crops.

Looking ahead, extreme climatic events, higher temperatures and unpredictable rains paint an alarming picture for many developing countries. In East Africa, for example, temperatures could increase by 3˚C-4˚C by 2080-99 (relative to 1980-99) questions the capacity of countries to feed their people[iii].

Table 1: Projections of climatic changes and corresponding impacts on agriculture

Projected change	*Likelihood of future trends based on projections for the 21st century*	*Projected impacts on agriculture*
Warmer and fewer cold days and nights; warmer and more frequent hot days and nights over most land areas	Virtually certain	Increased yields in colder environments; decreased yields in warmer environments
Warm spells/heat waves: frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress at key development stages; increased danger of wildfire
Heavy precipitation events: frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to water-logging of soils
Area affected by drought increases	Likely	Land degradation; lower yields/ crop damage and failure; increased livestock deaths; increased risk of wildfire
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow of trees
Increased incidence of extreme high sea level	Likely	Salinization of irrigation and well water

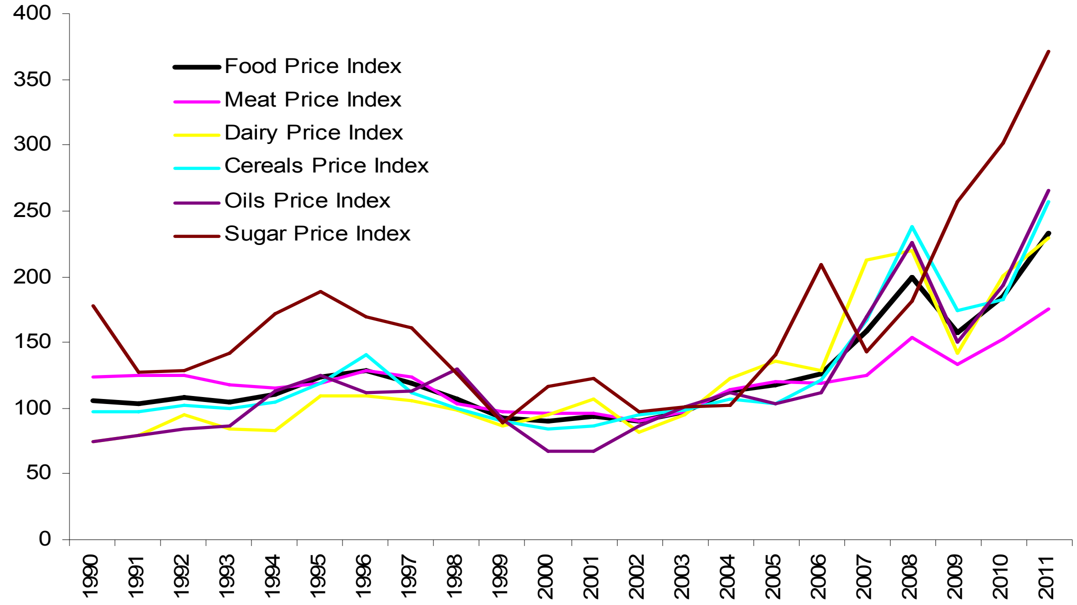
Source: Intergovernmental Panel on Climate Change (2007a), table 3.2.

High food prices

In addition to climatic factors, the recent 2007-2008 and 2010-2011 food crises have been largely driven by rising food prices. Global food prices have more than doubled over the past decade, reaching record highs in 2007-2008 and 2010-2011 (figure 1). International prices for corn, wheat and rice more than doubled between 2006 and 2008. While prices declined in late 2008, food prices have since rebounded, attaining new record highs in February 2011. Despite conflicting evidence, it would appear that recent price rises have also been accompanied by higher volatility, which increases uncertainty, thereby hindering investment in human and physical capital, technology and innovation (FAO 2009). Rising food prices have seen the number of people with insufficient access to food reach one billion (FAO 2010a), and pushed a further 150 million people into poverty since 2007 (World Bank 2008; 2011).

The recent food crises have exposed deep structural flaws in the world food system. Although increased financial activity in commodity future markets may have amplified short-term price fluctuations, the global food price spikes have been the result of a long-term structural food demand and supply imbalance. Demand for food has risen owing to continued global population growth, rising incomes and altered dietary patterns, the depreciation of the United States dollar, and trade policies. At the same time, however, agricultural output has failed to keep pace with growing consumption due to competition for land, adverse climatic conditions, biofuel policies, high energy prices, and dwindling agricultural production and investment.

Figure 1. Food price indices (2002-2004=1000), annual averages, 1990-2011



Source: Food and Agriculture Organization of the United Nations (2011)[iv]

Political economy and conflict

The 2011 food crisis and famine in the Horn of Africa has also been aggravated by the instability and conflict inflicting the region. Looking deeper into the causes of food entitlement failure would require, inter alia, greater attention to issues of conflict and war, some of which may be related to disputes over land tenure and the nature of productive relations in rural areas.

Analysis of the vulnerability to food insecurity would need to account for the possibility that states and politically powerful groups may actively promote famine and obstruct relief as part of a political and military strategy, or for the acquisition of land and other assets (Keen 1994; Cramer 2000). From the mid-1980s onwards there has been increasing significance drawn to the role of conflict in the explanation of famines in countries including Ethiopia, Sudan, Angola, Mozambique, and the Democratic Republic of Congo (Keen 1994; Duffield 1994; deWaal 1997; Cramer 2000). In present-day Somalia, the al Shabab militia group has been blamed for obstructing humanitarian relief in famine struck regions in the southern part of the country (United Nations 2011), and for exploiting the current crisis as a means to recover their waning popularity[v].

Unmasking the causes of the recent food crises requires understanding of issues related to land tenure, labour migration, lack of market access and infrastructure, and prevalence of disease. Notably, the HIV/AIDS pandemic in Southern Africa is thought to explain food shortages in many households with limited prospects for recovery; a 'new variant famine' is emerging among highly vulnerable households where the burden of care reduces the viability of farming livelihoods (de Waal and Whiteside, 2003).[3]

[3] It is hypothesized that aspects to food insecurity in sub-Saharan Africa can be partly attributed to the HIV/AIDS epidemic in the region, given that:

(i) household level labour shortages are attributable to adult morbidity and mortality, as is the rise in numbers of dependants

Structural constraints

But whilst the unfortunate coincidence of drought, high food prices and conflict acted as ‘‘proximate causes’’ of the current food crisis, there are ‘‘deeper’’ underlying determinants linked to a long-lasting neglect of and under-investment in agriculture and rural development which underpinned the current and other recent food crises.

In particular, there are a number of structural impediments to the increase of food production without a major expansion of cultivated areas and a further depletion of natural resources, including declining agricultural investment, partly owing to lower public investments and earlier low food prices. The share of total overseas development assistance (ODA) allocated to agriculture fell from a peak of almost 20 percent in the late 1970s to less than 5 percent in 2009 (United Nations 2008a). In this context, the International Monetary Fund (IMF), the World Bank and other institutions have been criticized for providing foreign aid conditional on the implementation of policies (such as abolishing fertilizer subsidies and favouring cash crops) that have undermined food self-sufficiency and raised imports (Stiglitz 2002). This has been aggravated by increased purchases of farmland by foreign investors – estimated at 56 million hectares of land in developing countries in 2009, representing a 10-fold rise from the previous decade – which have resulted in the favouring of exports over domestic food production in many developing countries (Deininger et al. 2010). At the same time, donor nations have continued to engage in the provision of distortionary agricultural subsidies to producers and consumers – amounting to $376 billion of Organization for Economic Cooperation and Development (OECD) expenditure in 2008 – that undermine the ability of farmers in developing countries to compete (United Nations 2010).

Unsustainable natural resource management as a threat to both food security and the environment

The above analysis demonstrates that in recent years agricultural output has not kept pace with the growing demand for food, owing to a confluence of demographic, socioeconomic, political and climatic factors. The situation is compounded by the need to increase global food production by 70 percent – and by almost 100 percent in developing countries – by mid-century in order to feed a future population of 9 billion people (Bruinsma, 2009)[vi]. Limits to the expansion of cultivated land area means that some 80 percent of the projected growth in food output in developing countries would need to derive from intensification of crop production (Ibid). With current agricultural technology, practices and land-use patterns, this cannot be achieved without further contributing to greenhouse gas emission, land degradation, biodiversity loss, and water scarcity and pollution. But the consequent environmental damage will, in turn, undermine long-term food productivity growth. Unsustainable agriculture and land management can thus also lead to negative socioeconomic consequences including food insecurity, poverty, migration, gender inequality and ill health (IAASTD 2009).

(ii) loss of assets and skills results from increased adult mortality
(iii) the burden of care is large for sick adults and children orphaned by AIDS
(iv) vicious interactions exist between malnutrition and HIV (de Waal and Whiteside, 2003).

Environmental impacts

Land degradation

Attempting a closer look at the environmental impact of unsustainable natural resource management, the past half-century has witnessed shrinkage in the availability of natural resources which has occurred more rapidly than in any comparable time in history.

The issue of land degradation is among the world's greatest environmental challenges, with the potential to destabilize societies, endanger food security and increase poverty (Millennium Ecosystem Assessment 2005). Defined as a long-term decline in ecosystem function and productivity, land degradation is mainly driven by poor land and water management, including over-cultivation, overgrazing, deforestation, and poor irrigation and drainage practices (Bai et al. 2008).[4]

Land degradation is increasing, in severity and extent, in many parts of the world, with about 40 percent of the world's land surface degraded (25 percent has been degraded over the past quarter-century alone) and with an estimated 1.5 billion people directly dependent on it (ibid). Figure 2 depicts global change in land productivity (in terms of carbon dioxide (CO_2) fixation) over the period 1981-2003.[5] Of note is that areas showing little current change are often locations that have already undergone major historical change. Degrading areas are mainly in the part of Africa that is south of the Equator, in South-East Asia and southern China, in north-central Australia, in the pampas and in swathes of boreal forest in Siberia and North America (ibid). Among the worst affected regions are Central America, where three-quarters of land is infertile, Africa, where a fifth of soil is degraded, and Asia, where over a tenth of soil is unsuitable for farming (Sample 2007).

Land degradation has negative effects on the climate, biodiversity, water ecosystems, landscape and other ecosystem services (table 2).

Climate change

While agriculture is vulnerable to the effects of climate change (as demonstrated in the previous section), it also contributes significantly to the problem. Agriculture activity and land degradation generate green-house gas (GHG) emissions leading to warming, as well as impact land surface albedo creating adverse weather patterns (University of East Anglia, Overseas Development Group, 2006). Notwithstanding significant uncertainty in estimates, agricultural activities account for about 30 percent of emissions of greenhouse gases (carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)) (Baumert et al. 2005) (figure 3).

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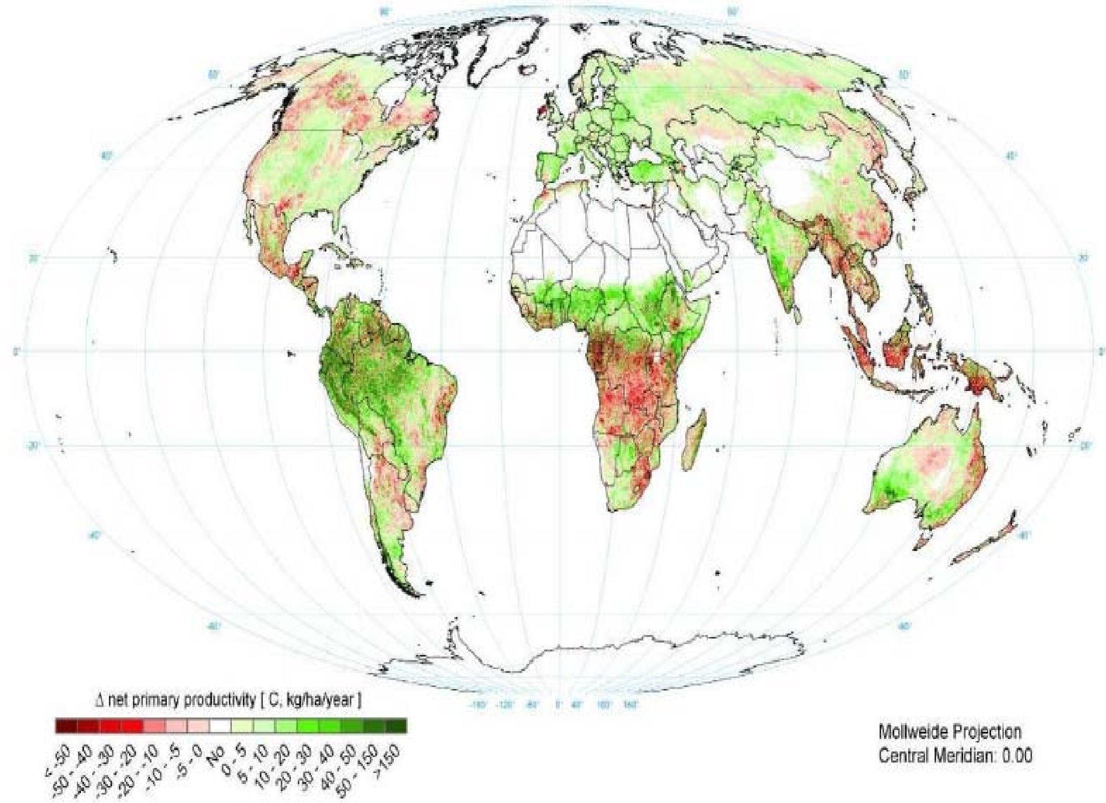
[4] Although degradation processes do occur in nature these are broadly at a rate which is in balance with the rate of natural rehabilitation. *Accelerated* land degradation is most commonly caused as a result of human intervention in the environment (Bai et al, 2008).

[5] Land degradation is measured by the change in the normalized difference vegetation index (NDVI), scaled in terms of net primary productivity (NPP). NPP is the rate at which vegetation fixes CO_2 from the atmosphere less losses through respiration; deviation from the norm is used as an indicator of land degradation or improvement. As a proxy, the remotely sensed NDVI, which has been shown to be related to biophysical variables that control vegetation productivity and land/atmosphere fluxes, is also used to estimate vegetation change (Bai et al., 2008).

Agriculture is a significant emitter of CH_4 (50 percent of global emissions) and N_2O (70 percent) (Bhatia et al. 2004). Emissions from cattle and other livestock account for just over one quarter of CH_4 emissions.

Deforestation and forest degradation in developing countries are the primary sources of CO_2 emissions from these countries, accounting for 35 percent of CO_2 emissions in developing countries and 65 percent in least developed countries (United Nations 2009). In addition to CO_2 emission, other GHGs, such as CH_4 and N_2O, are emitted as a result of the conversion of forests to agricultural lands, which is the major driver of deforestation (Houghton 2005). Current emissions of GHGs from deforestation account for over 15 percent of all anthropogenic GHG emissions (IPCC 2007b). Land clearing, biomass burning and soil mineralization also contribute to CO_2 production. Table 3 summarises the contribution of agriculture to GHG emissions.

Figure 2. Global change in net primary productivity, 1981-2003



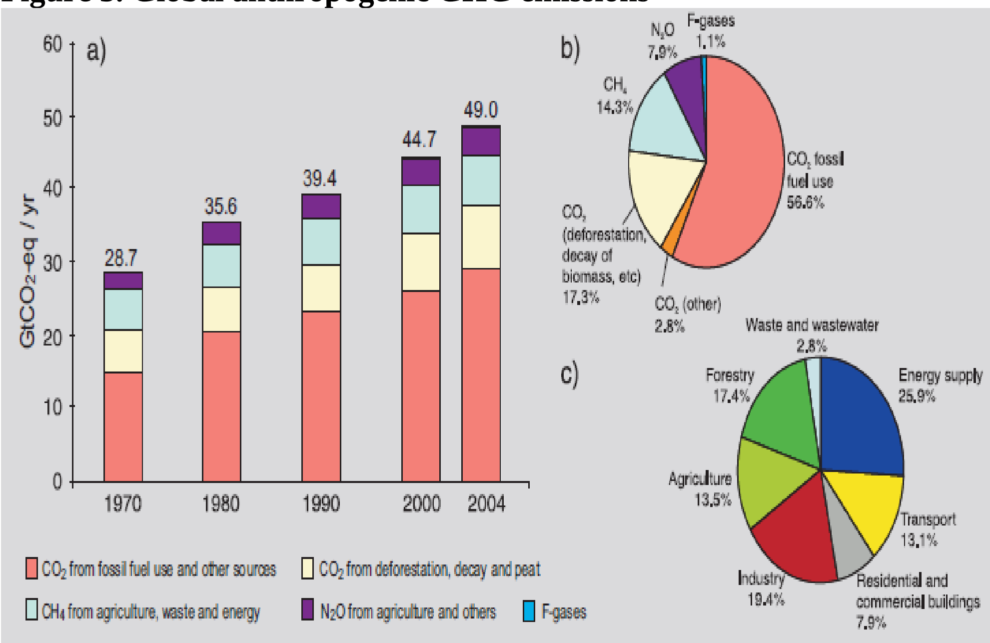
Source: Bai et al. (2008), figure 2.

Table 2. Global environmental impacts of land degradation

Environmental component or process	***Bases of impact of land degradation***
Climate change	• Land-use change, deforestation in particular, is a critical factor in the global carbon cycle • Soil management changes can result in the sequestration of atmospheric carbon • Agriculture is a major source of methane (CH4) and nitrous oxide (N2O) emissions • Land surface change (for example, as regards albedo and roughness) plays an important role in regional and global climate change • Human activities accelerate the occurrence of sandstorms • Biomass burning contributes to climate change
Biodiversity	• Deforestation leads to loss of habitat and species • Land-use change and management, including fragmentation and burning, lead to loss of habitat and biodiversity • Non-point pollution from crop production damages aquatic habitats and biodiversity
Water resources	• Agricultural activities are a major source of water pollution • Land-use and cover change alters the global hydrologic cycle • Atmospheric deposition of soil dust damages coral reefs
Persistent organic polluters (POPs)[6]	• Soil contains a major pool of POPs • Biomass burning produces POPs

Source: University of East Anglia, Overseas Development Group (2006).

Figure 3. Global anthropogenic GHG emissions



[6] POPs are organic compounds that are resistant to natural degradation, and thus persist in the environment. Many POPs have traditionally been used as pesticides. Despite significant progress in eliminating or restricting the production and use of intentionally produced POPs, some remain popular as agrochemicals and for malaria control in developing countries (United Nations 2008b).

(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.
(b) Share of different GHGs in total emissions in 2004 (CO2-equivalent).
(c) Share of different sectors in total GHG emissions in 2004 (CO2-equivalent). (Forestry includes deforestation.)
Source: Intergovernmental Panel on Climate Change (2007b). *IPCC Fourth Assessment Report: Climate Change 2007 (AR4): Synthesis Report*.

Table 3. Contribution of agriculture to global greenhouse gas and other emissions

Greenhouse gas	Carbon dioxide	Methane	Nitrous oxide	Nitric oxide	Ammonia
Main effects	Climate change	Climate change	Climate change	Acidification	Acidification Eutrophication
Agricultural source	**Land-use change, especially deforestation**	Ruminants (15)	Livestock (including manure applied to farmland) (17)	**Biomass burning (13)**	Livestock (including manure applied to farmland) (44)
		Rice production (11)	Mineral fertilizers (8)	Manure and mineral fertilizers (2)	Mineral fertilizers (17)
		Biomass burning (7)	**Biomass burning (3)**		**Biomass burning (11)**
Agricultural emissions as a proportion of the total emissions from anthropogenic sources (percentage)	15	49	66	27	93

Source: Food and Agriculture Organization of the United Nations (2003).
Note: Sources of land degradation are in bold. Percentage contribution of each type of emission to total global emissions appears in parentheses

Water resources

Access to sufficient and safe water is crucial for food production, poverty reduction and human health. Freshwater wetlands provide a range of services including flood control, storage and purification of water as well as being an important habitat for biodiversity (IAASTD 2009). However, increasing and competing demands for water have led to serious depletion of surface-water resources (Smakhtin et al. 2004). Half of the world’s wetlands are estimated to have been lost during the last century, as land was converted to agriculture and urban use, or filled to combat diseases, such as malaria. Loss of forest cover in watersheds has also led to increased erosion, alteration of water quantity and higher likelihood of floods (IAASTD 2009). The capacity of coastal and marine ecosystems to produce fish for human harvest is highly damaged by over-fishing and loss of wetlands and other water habitats. Agricultural irrigation accounts for some 70 percent of all water withdrawals. Disconcertingly, much water used in irrigation is lost to less-than-optimal evaporation, not profiting plant growth (IAASTD 2009).

Moreover, it appears that water quality has been degraded partly owing to intensive agriculture, which has become the main source of water pollution in many developed and developing countries, rendering it unsustainable and a source of risks to human health (Molden and de Fraiture 2004). Intensive livestock production is probably the largest sector-specific source of water pollution (Steinfeld et al. 2006). Waterborne diseases from fecal contamination of surface waters continue to be a serious problem in developing countries (Revenga et al. 2000). Excessive use of agrochemicals (pesticides and fertilizers) also contaminates waterways. For instance, in Lake Victoria, some 90 percent of (nitrogen and phosphorus) nutrient inputs originates from atmospheric deposition and land runoff exacerbated by forest burning and exploitation of land for agriculture (Scheren et al 2000).

Biodiversity

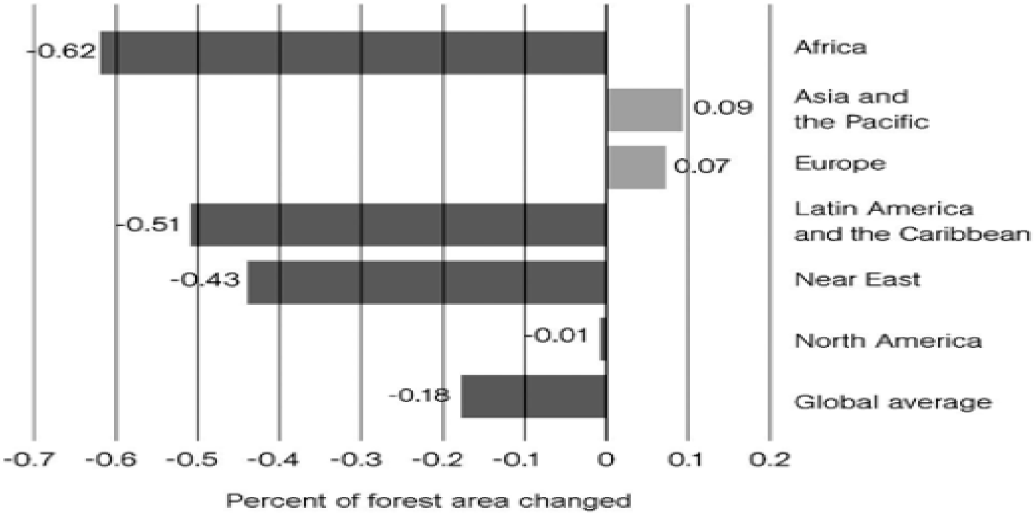
Biodiversity underpins agriculture and food security through the provision of the genetic material needed for crop and livestock breeding, and raw materials for industry, chemicals for medicine, and other ecosystem services (IAASTD 2009). The past century has seen the greatest loss of biodiversity through habitat destruction, primarily through the conversion of forests for agriculture.

About half of the earth's forests are gone, with forests currently covering approximately 30 percent of global land surface (FAO 2010b). While the last quarter-century has witnessed an increase in forest area in industrialized countries, developing countries have experienced an average decline of about 10 percent (FAO 2007) (figure 4). Deforestation has continued at a rate of 13 million hectares per year over the past decade, with net global loss in forest area in 2000-2010 estimated at about 5 million hectares per year, down from around 8 million hectares per year in 1990-2000 (FAO, 2010b). The problem of deforestation is particularly severe in the humid tropics (Moutinho and Schwartzman 2005). Africa and South America suffered the largest net loss of forests from 1990 to 2005, with Africa accounting for over half of recent global losses, even though the continent hosts just over 15 percent of the world's forests (University of East Anglia, Overseas Development Group 2006). Habitat destruction and degradation is the major global threat to birds and amphibians, affecting almost 90 percent of threatened species (IUCN, Species Survival Commission 2004). This is particularly evident in the case of tropical forests, which cover less than 10 percent of the earth's land area, yet harbour 50-90 percent of the planet's terrestrial species (Millennium Ecosystem Assessment 2005).

The spread of industrial agriculture has also promoted the simplification of agro-ecosystems, with reductions in the number of and variety of species. Further, production of monocultures increases environmental risks by reducing biodiversity, ecosystem functions and ecological resilience (IAASTD 2009).

In addition, loss of wetlands and other water habitats and over-exploitation of marine resources is so severe that an estimated 20 percent of freshwater fish species have become extinct (Wood et al., 2000), while certain commercial fish and other marine species are threatened globally (IAASTD 2009).

Figure 4. Annual net change in forest area, 2000-2005.



Source: Food and Agriculture Organization of the United Nations (2007a).

Socioeconomic impacts

Food insecurity

Unsustainable natural resource management also has adverse socio-economic consequences. Over-exploitation of natural resources can undermine the long-term productive capacity of agriculture, thus threatening food security. In particular, land degradation can lead to substantial productivity losses (Sanchez 2002). While productivity impacts vary largely by region, the areas mostly affected are those whose populations are already suffering from poverty and hunger (Oldeman 1998). Biggelaar et al. (2003) found that the same amounts of soil erosion corresponded to 2 to 6 times higher yield declines in Africa, Asia, Australia and Latin America than in North America and Europe. The productivity of some lands has declined by 50 percent owing to soil erosion and desertification (Dregne 1990). Yield reduction in Africa due to past soil erosion may range from 2 to 40 percent, with a mean loss of 8 percent for the continent, with yield reductions by 2020 likely to double (Lal 1995). There are also serious (20 percent) productivity losses caused by erosion in Asia, especially in India, China, Iran, Israel, Jordan, Lebanon, Nepal, and Pakistan (Dregne 1992). Soil compaction has also caused yield reductions of between 40 and 90 percent in West African countries (Kayombo and Lal 1994).

Deforestation can further exacerbate food insecurity, as forests provide food, inputs and services that support crop and livestock production (FAO 2006).

Depletion of water resources can also undermine crop and livestock production. For instance, water scarcity has been a main trigger of the unfolding food crisis in the Horn of Africa, causing animals to perish or be sold at very low prices, leading to hunger and loss of livelihoods for the region’s pastoral communities.

Poverty

Poverty is both a cause and consequence of unsustainable natural resource management. Depletion of natural resources and loss of productive capacity of land due to unsustainable practices can lead to loss of income and livelihoods of farmers and others engaged in rural activities. For instance, the annual global loss of 75 billion tons of soil costs about $400 billion per year, or approximately $70 per person per year (Lal 1998). Nutrient (nitrogen, phosphorus, and potassium) depletion also has a severe global economic impact, especially in sub-Saharan Africa. In South Asia, annual economic loss is estimated at $500 million from waterlogging, and at $1.5 billion due to salinization (FAO 1994). In a case-study analysis of seven developing countries, Berry et al. (2003) estimated that problems of sustainable land management reduced agricultural gross domestic product (GDP) by between 3 and 7 percent.[7]

In addition, deforestation will likely have a particularly adverse impact on many of the 1.5 billion persons who depend on forests for their livelihoods, especially as they represent 90 percent of those living in extreme poverty (World Bank 2004).

But there is often a strong association between the distribution of poor people reliant on agriculture and fragile environments. Poor people are likely to be farming steeper land and drier, less fertile soils and in more remote areas (World Bank 2003). Sub-Saharan Africa and South Asia experience the highest intensity of soil degradation, population growth and food insecurity (Bai et al. 2008; FAO 2010a).

Moreover, adverse rural conditions have spurred male migration towards cities often adding to urban unemployment and exacerbating the vulnerability and marginalisation of those remaining in agriculture such as women, the elderly and children. In the case of Mexico, land degradation was found to differentially affect poor regions and contribute to rural-urban and Mexico-US migration, with 700,000 – 900,000 people migrating annually from Mexico's drylands (Berry et al. 2003).

Natural resource degradation may also exacerbate gender inequalities by increasing the time requirement for fulfilment of female responsibilities such as food production, fuelwood collection, and soil and water conservation. For instance, in rural Rajasthan, India, approximately 50 person-hours per month are required for households gathering fuelwood (Laxmi et al. 2003). In Malawi, women spend between 4 and 15 hours per week collecting firewood (Rehfuess et al. 2006). This can limit female school attendance, and time spent on child care, other duties and leisure.

Human health

Beyond the devastating effects of hunger and chronic malnutrition, there are other ways by which agricultural production systems can adversely affect human health. Water pollution from inorganic fertilizers and livestock waste undermines the safety of drinking water and aquatic food. Pesticides, especially when used without strict attention to recommended usage and safety protocols, can negatively affect the health of farm workers (WWAP 2003). Transportation of crops, livestock and food products has also promoted the cross-border spread of pests and diseases (IAASTD 2009). In addition, desertification-induced dust storms can cause respiratory disorders, including bronchitis, and temporal dynamics of meningococcal meningitis epidemics in Saharan

[7] The countries included Chile, China, Ethiopia, Indonesia, Mexico, Rwanda and Uganda. The calculations are based on assessments of on-site costs such as decline in availability and quality of water, and loss of production in land-based activities (agriculture, livestock, fishing, forestry). It should be noted that the aggregate economic impact of land degradation is difficult to quantify and economic assessments are typically limited to assessing the losses to crop production, ignoring the cost of rangeland degradation, loss of biodiversity and the indirect costs such as malnutrition, poverty and migration.

Africa (Millennium Ecosystem Assessment 2005). Table 4 summarises the potential impact of land degradation on infectious diseases. Malnutrition and increased labour requirements also have serious implications for people living with HIV/AIDS and other diseases. A vicious circle of poor health, reduced working capacity, low productivity and shortened life expectancy is a typical outcome, particularly for the most vulnerable groups, such as those working in subsistence agriculture.

Table 4. Infectious diseases and land degradation linkages.

Disease	Emergence Mechanism	Anthropogenic Drivers	Geographical Distribution	Sensitivity to LD	Confidence Level[1]
Malaria	niche invasion; vector expansion	deforestation; water projects	Tropical	+ + + +	+ + +
Chagas disease	habitat alteration	deforestation; urban sprawl and encroachment	Americas	+ +	+ + +
Leishmaniasis	host transfer; habitat alteration	deforestation; agricultural development	Americas; Europe and Middle East	+ + + +	+ + +
Meningitis	habitat alteration; dust storms	tropical desertification	Saharan Africa	+ +	+ +
Rabies	biodiversity loss, altered host selection	deforestation and mining	Tropical	+ +	+ +
Trypanosomiasis	habitat alteration	deforestation	Africa	+ + +	+ +
Guanarito; Junin; Machupo	biodiversity loss; reservoir expansion	monoculture in agriculture after deforestation	South America	+ +	+ + +
Nipah/Hendra viruses	niche invasion	industrial food production; deforestation; climate abnormalities	Australia; Southeast Asia	+ +	+ +

Source: Adapted from Millennium Ecosystem Assessment (2005).
The key to the health impact table: 1 + = low confidence; + + = moderate; + + + = high; + + + + = very high.

The review in this section helps to identify some of the areas where there is need to accelerate technological innovation to address the challenge of sustainable food security. A truly green revolution in agriculture should address some of the following objectives:

i) Reduce deforestation and further deterioration of natural eco-systems through rapid productivity growth to prevent further expansion of the agricultural frontier.[8]
ii) Reverse the degradation of natural resources through the adoption of technology and practices to reduce land erosion, make efficient use of and reduce contamination of water sources and reduce mono-cultivation
iii) Accelerate replacement of chemicals for organic fertilizers and reduce the toxicity of agricultural inputs
iv) Accelerate innovation in plant breeding and bio-technology to increase the resistance of plants to climate change, extreme climate events (mainly droughts and floods) and resistance to pests.

Transformation in other areas is also needed to bring sustainability to agricultural production and food security. Decreasing the demand for food crops for the production of bio-diesel and decreasing consumption of meat and dairy products would reduce the pressure over agriculture and over extended use of natural resources.

[8] This would include effective constrains to the expansion of urban areas vis-a-vis agricultural land and natural eco-systems

Small scale farming and sustainable innovation

Small scale farming

Food security, poverty eradication and environmental sustainability need not only a radical transformation in the use of technology in agriculture and the management of natural resources but a radical transformation in the focus of development in agriculture to improve the productive capacity and livelihoods of people in rural areas. Between 80 and 90 percent of the food consumed in developing countries is locally produced, mostly by small scale farmers. From the approximately 3 billion people in rural areas in developing countries, about 2.5 billion are involved in agriculture and at least 1.5 billion live and work on small family-run farms (Foresight 2011). Moreover, the majority of the extremely poor and about half of undernourished people in the world live from small scale farming; they constitute the majority of farms worldwide (around 90 percent of farms or 500 million farms) and, on average, they survive on less than 2 hectares of land (Nagayets 2005, as cited by Wiggins et al. 2010). Raising the productivity of small scale farming with environmentally sustainable technology is thus central to achieve food security and sustainable development.[9] They are the source of most of the food produce in developing countries and the most affected by environmental degradation.

The definition of small-scale farming is region and country specific and it varies widely.[10] Data available for developing countries in Africa and Asia shows that the median farm size fluctuates between 0.3 hectares in Congo to 1.2 hectares in Thailand and 3.0 hectares in Turkey. In Latin America land holdings are slightly larger but small farmers account for the largest number of farms (Lipton 2010); including in countries with large commercial farming like Argentina where 66 percent of farms are small in scale (Scheinkerman et al. 2007). Small-scale farmers dominate agriculture in developing countries with a very important presence of women, typically in subsistence farming. In sub-Saharan Africa, Oceania and South East Asia, women account for more than 40 percent of agricultural employment (FAO 2003). In low income developing countries there are 3 billion people in rural areas; 2.5 billion are involved in agriculture and 1.5 billion make a living from small farms (FAO/IFAD/ILO 2010; Foresight 2011).

With small-scale farms dominating the agricultural landscape in the foreseeable future, addressing the challenges faced by small scale farmers is vital to combat poverty and hunger (Dixon et al. 2001). The productivity advantage of small vis-à-vis large scale farmers in poor countries is a well established proposition. It derives from their intensive use of labour and low transaction costs, and from their superior knowledge of the local context. This advantage however may disappear due to the challenges faced by small-holder in terms of scale economies in marketing, quality assurance and access to inputs, credit and information. In the past decades there has been a tremendous increase in labour productivity within industrialized agriculture and stagnating labour productivity in small-scale systems in developing countries (Mazoyer and Roudard 1997). These factors may have arguably led to an overall increase in the optimal (in terms of efficiency) size of farms (Lutz 1998). Increased fragmentation of land among small scale farmers may have reduced their economic feasibility and led to over-exploitation of natural resources and land degradation. Poverty combined with liquidity constraints may cause small-scale farmers to have high discount rates (Pender 1996;

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[9] Sustainable development defined as the simultaneous pursue of three objectives: economic development, social development and environmental protection (WESS 2011, Ch. I)

[10] In most countries, small scale farming is defined as operating units where most labour comes from the family unit, although in many cases, there is occasional use of hired labour from within the local community (Foresight 2011).

Holden et al. 1998), creating incentives for non-sustainable resource extraction as a short-term survival strategy (Lutz 1998). Higher land and food prices may also exert additional pressure on poor and marginalized farmers to migrate to lower quality lands.

Nevertheless, small-scale diversified farming continues to have significant advantages over large-scale monoculture agricultural systems in terms of productivity (20 to 60 percent higher yields), food production and environmental protection (including climate change mitigation) (Altieri 2008). In countries where agriculture contributes 20 to 40 percent of GDP, as in sub-Saharan Africa, a thriving small scale farming sector is also central for overall economic growth (Godfray et al. 2010; Wiggins et al. 2010). In a study comparing the impact of agriculture in overall economic growth in six African countries, Diao et al. (2010) found that the production of staples had larger links with other sectors in the domestic market when compared to the production of crops for exports. This result was largely driven by the presence of small scale farmers in the production of staples. In Ethiopia and Zambia staples represent around 65 percent of agricultural production, 90 percent in Rwanda (when including livestock), 70 percent in Ghana, and about 55 percent in Kenya and Uganda. By contrast, exporting crops may be more profitable for individual farmers but they have lower linkages with the rest of the economy. In Zambia, for example, the export of crops would have to increase by 23 percent to generate an additional 1 percent growth of GPD, whereas an 8 percent growth of staples would produce the same result. Similarly for the other countries in the study, growth of exporting crops would have to be much faster than that of staple crops, most likely at unsustainable rates, to produce the same percentage growth of GDP.

Improving food security with environmental sustainability will critically depend on removing the barriers faced by small-scale farmers to expand their productive capacity. A dynamic agricultural production system based on efficient small scale farmers would also provide the basis for poverty eradication, food security and sustainable economic growth.

Sustainable innovation in agriculture

Small-scale farmers and communities have shown great capacity to introduce productivity-enhancing innovation, often in response to economic shocks and natural disasters, in an effort to build resilience to an adverse and changing environment. There are thousands of localized experiences that resulted in improved pest and weed management, water efficiency and biodiversity (see for example, Pretty et al. 2006; World Bank 2006, 2008, 2010; Spielman and Pandya-Lorch 2009; Africare, Oxfam, WWF 2010).

Well-known examples of rural innovations with large-scale impacts include the integrated pest management (IPM) approach, the Farm Field Schools (FFF), the System of Rice Intensification (SRI), the networks of millers and politicians that popularized the use of NERICA (New Rice for Africa) in Africa, the diffusion of micro-irrigation in Bangladesh, and watershed management in India (Brooks and Loevinsohn 2011; Hall et al. 2010). The policy challenge is to identify and support the adaptation and scaling-up of such local instances of agricultural innovation, particularly in poor and food insecure countries and regions. Agro-ecological conditions vary widely across regions—especially in Africa which has a wide variety of crops and growing conditions—implying that agricultural technologies and practices need to be adapted to local conditions.

An extensive menu of technologies and sustainable practices in agriculture is available providing options for a radical shift towards sustainable food security. These include traditional knowledge and farming practices such as low-tillage farming, crop rotation and inter-planting, green manure utilization, water harvesting and water-efficient cropping. Adoption of these practices can confer important environmental as well as economic benefits for farmers, and their uptake can be promoted through subsidies, education, extension services, credits, crop insurance and information campaigns. Furthermore, new high-yielding and pest and disease-resistant varieties of food crops have and are being developed, which are efficient in water use and require little or no use of agro-chemicals as fertilizers or pesticides. More research is needed, however, to adapt these technologies to local conditions. Modern technologies such as biotechnology, food irradiation, hydroponics and anaerobic digestion, also provide complementary options to raise productivity with sustainable production methods. While much knowledge is already available, governments will have to provide the incentives and support to make them accessible, adaptable and affordable to farmers. Particularly in the case of genetically modified technology, better monitoring systems and dissemination of information are needed to avoid negative impacts on natural eco-systems

Policies for building sustainable agricultural innovation systems to enhance food production

Tackling the twin perils of global food insecurity and environmental degradation will require both short term policy responses to scale up and improve humanitarian relief to alleviate hunger and starvation, as well as longer-term action to expand resources and foster innovation in agriculture to accelerate food production in a sustainable manner.

Short-term humanitarian action

As with the 2008-2009 global food crisis, the 2011 food crisis and famine unfolding in the Horn of Africa, has induced policy reactions at both national and international levels. The United Nations World Food Programme (WFP) has led the response to the humanitarian crisis, reaching about 8 million drought-affected people with food assistance. Plans to reach an additional 3 million people have been partly obstructed by a shortfall of funds, and restricted humanitarian access to southern Somalia due to ongoing conflict.

As of August 2011, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) estimates that almost $2.5 billion in aid is needed for the humanitarian response in the drought-struck regions of Djibouti, Ethiopia, Kenya, and Somalia. However, $1 billion, or 40 percent, of the emergency aid requirements have not been met[vii].

At a high-level meeting on the emergency in the Horn of Africa held on 18 August 2011, governments, UN agencies and international organizations emphasized the need to take immediate steps to improve access to food and nutrition support and increase food availability with additional measures to save the surviving livestock for pastoralists, provide inputs for the next planting season and the expand social protection mechanisms[viii].

Delivery of these actions would necessitate increased financial commitments by governments, international organisations, non-governmental organizations (NGOs) and private individuals. Averting a human catastrophe in East Africa requires strong political commitments to raise funds; implement measures; respond promptly to early warning systems; and strive to improve humanitarian access to the worst-affected areas of Somalia. The latter may involve controversial political choices such as providing aid, even if a portion may be appropriated by local warlords and militias, who are partly to blame for the outbreak of famine. Enhancing working relationship between aid-dependent governments and international donors and NGOs—including the relaxing of stringent, and not infrequently misguided, donor conditionalities—is key to ensuring an effective humanitarian response (Devereux 2009).

Important lessons can also be learnt from policy reactions to the earlier 2007-2008 global food price crisis. At the national level, countries responded with a wide range of mainly short-term policy measures including import tariff reductions, price controls, export restrictions, stock reductions, and food programmes. A study evaluating such responses in 10 emerging economies revealed the importance of providing targeted safety nets for the poor as emergency responses to food shortfalls. While trade protection and building food inventories may enhance national food availability in the short run, such measures may at the same time prove to be costly in terms of government expenditure and contribute to keeping food prices high by restricting food supply in international markets.

Long-term policies to expand sustainable food production

Whilst imperative, emergency reactions to the 2011 food crisis need to be accompanied by policies to strengthen food and nutrition security in the longer-run by addressing the underlying factors driving the crisis. The irreversible degradation of natural resources brought about by current agricultural practices and the consequent impact on long term food production has highlighted the need to initiate a radical transformation in the agricultural production methods and policies towards sustainable practices.

From a policy standpoint, combating hunger and malnutrition in a sustainable manner and guarding against high and volatile food prices will require a radically different approach addressing the structural constraints on food production. This would entail both the establishment of an integrated national framework for sustainable natural resource management, and a harnessing of the technology and innovation needed to increase the productivity, profitability, resilience and climate change mitigation potential of rural production systems. In this endeavour, a sustainable agricultural innovation system (SAIS)—recognising the dynamic nature of learning and innovation and the multiplicity of actors engaged in the innovation process and the institutional contexts within which they interact—provides a useful framework for policy-making. Policies and incentives need to be designed to stimulate innovation to increase food production by small scale farmers whilst protecting the environment.

Governments have an important role to play in expanding access to technology and information, building rural infrastructure; improving access to credits, input and product markets; building and maintaining storage facilities and irrigation systems; providing social safety nets; and securing property rights, including land redistribution. Major policy transformations are needed to strengthen the systems of agricultural innovation and increase resources for rural development and sustainable natural resource management.

Firstly, sustainable agriculture to achieve food security needs to be an explicit component of countries' national development strategies, including the identification of financial resources to expand rural infrastructure and supporting services to small scale agricultural producers.

A holistic, cross-sectoral approach should consider trade-offs and build on synergies between sectors and objectives, to prioritise and promote technically available and economically feasible 'win-win-win' options that ensure food security, poverty reduction and environmental sustainability.

For instance, an integrated national development approach should recognize conflicts and promote synergies between forests and agriculture. In view of competitive uses of land for forestry, agriculture, urbanization and other uses, many solutions will involve difficult choices and trade-offs, which will require enhanced national regulatory authority and strategic planning processes. Open discussions with all stakeholders, including empowering communities to effectively engage in negotiations will be critical to reach environmental and socially sustainable solutions (Someshwar 2008; Burton 2008). Building synergies to generate 'win-win-win' options such as reduced land degradation and increased agricultural productivity among small scale farmers will be time consuming and perhaps politically more difficult to reach but will be essential for sustainable solutions.

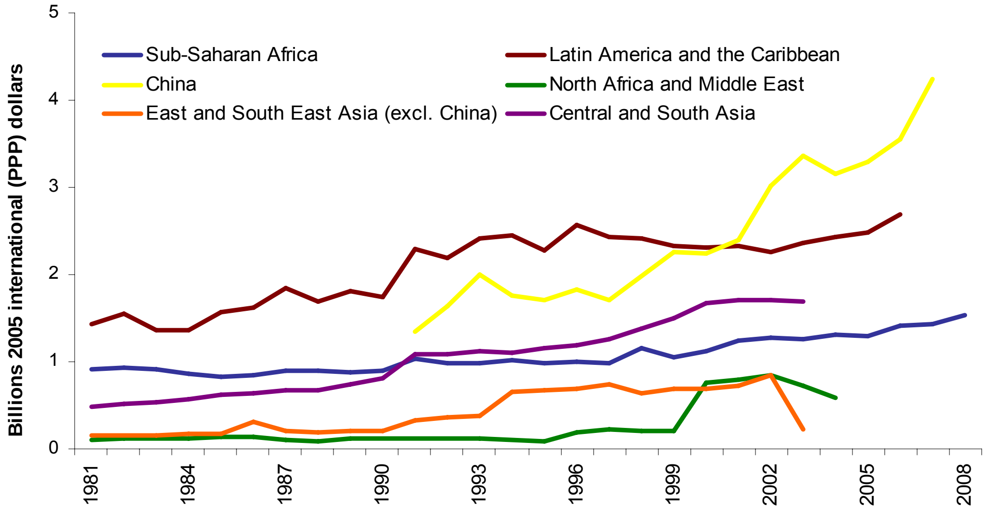
Improved national dialogue and empowerment of communities and traditional small scale farmers is essential in countries engaged in land leasing to foreign investors. A full evaluation of the impact of land grabbing needs to be part of any long term contract to avoid the displacement of small scale producers (often using land with no formal titles) and the invasion of community land used to support rural livelihoods. Additional support to countries engaged in long term land leasing to foreigners is also important to develop the mechanisms for the enforcement of contracts, especially in areas related to employment creation, infrastructure development and the transfer of technology. A full evaluation of the developmental impact of land grabbing needs to be incorporated to countries' decisions and national strategies for food security in a process of open and effective consultation with potentially affected groups.

An integrated ecosystems approach to rural development strategies can boost food security, improve resilience to climate change and provide economic benefits for poor communities (UNEP and IWMI 2011). Such an approach advocates managing and investing in the connections between ecosystems, water and food, through, for instance, diversifying crops, planting trees on farmland, improving rainwater collection, creating corridors to promote the movement of livestock to avoid over-grazing, and cultivating local plants better adapted to dry conditions. As an example, recent conservation work with indigenous communities in the Peruvian Amazon has demonstrated that better ecosystem management resulted in increased incomes for some 600 families, mainly owing to more productive fish farms and agro-forestry (UNEP and IWMI 2011).

Secondly, there is a need to substantially expand resources for agricultural research and development (R&D) and for the adaptation of technology to local conditions, with an explicit focus on meeting the needs of small scale farmers. The past three decades have witnessed a dwindling of investment in agricultural research, especially in Africa, East and South-East Asia (excluding China) and the Middle East where resources remain low (figure 6). The intensification of research efforts to breed new crops, and the development and adaptation of new technology to increase sustainable food production require significant long-term public and private funding of agricultural R&D.

Thirdly, new forms of public-private partnerships, including with civil society organizations, need to be identified to expand the provision of public goods in rural areas.

Figure 6. Public agricultural R&D investment trends in developing countries, 1981-2008



Source: DESA estimates based on Agricultural Science and Technology Indicators (ASTI), International Food Policy Research Institute (IFPRI)[ix]

Successful innovation experiences in the last 30 years demonstrate the importance of building partnerships among multiple stakeholders so as to strengthen the capacity of small-scale farmers to access technology, inputs and larger markets. For small scale farmers, participating in food markets, dominated by large supermarket chains, depends on their capacity to meet strict quality standards and to achieve concerted commercialization of their products through cooperatives and other forms of association. The risk of exclusion, however, is large, especially for farms in remote and difficult to access areas (Berdegué 2005). Through appropriate regulation to prevent monopolistic practices in food markets, and better access to information, technical assistance, credit and risk insurance, small-scale farmers would be in a better position to engage in mutually beneficial partnerships with the corporate private sector.

Most of the recent stories of innovation characterized by pro-poor and positive environmental impacts have also entailed the active participation of international and national civil society organizations, which, amongst others, can serve as intermediaries between research and agricultural practices; facilitate collective action and creation of farmers' organizations for the purchase of inputs and marketing of food; and strengthen the capacity of women to participate in marketing production and innovation.

Effective agricultural research also demands closer collaboration among public research institutions, the private sector and small-scale farmers through innovative partnerships, including via results-based performance contracts, patent buyouts, prizes, joint ventures, co-financing and advance-purchase agreements, comprehensive risk assessments and suitable regulatory schemes (Elliot, 2010; Lipton, 2010; Bhagwati, 2005; Pardey and Beintema 2001).

Fourthly, the institutions responsible for service provision in rural areas, including education and R&D, will need to undergo radical reform to make them responsive to the needs of small scale rural producers through direct participation and consultation with small scale producers and relevant stakeholders. Increased awareness and the accelerated adoption of sustainable technology and crop management practices will require wider dissemination of information and information and communications (ICT) technology through quality education in rural areas (including adult literacy and innovative peer-to-peer learning programmes) and adequate extension services. The model of operation of research institutions also needs to become more flexible and inclusive so at to improve their responsiveness to the needs of small-scale farmers, including through joint experimentation and learning, and adoption of a multidisciplinary focus.

Finally, international commitments towards food security need timely delivery and must be aligned to national development strategies. Delivering on financial pledges—including $20 billion in overseas development assistance over three years pledged at the G8 Summit in L'Aquila, Italy, in 2009, to address food insecurity in a sustainable manner (G8 2009)—would constitute an important down payment on realizing the commitment to the goal of eradicating hunger. The international community can also contribute to a global agenda for food security and environmental sustainability by mobilizing financial resources towards reconstituting the global, regional and national capacities for agricultural R&D.

International action is further needed to reform agricultural subsidies in OECD countries, which undermine the ability of farmers in developing countries to compete. This includes re-thinking subsidies to bio-fuels, and support to new generation bio-fuels to reduce the diversion of agricultural land use from food production. These reforms should be accompanied by the elimination of non-tariff barriers to food trade which restrict participation of small-scale producers in global markets.

In the midst of the global catastrophe unfolding in the Horn of Africa, increasing international awareness of the risks posed by climatic changes and degradation of natural resources in aggravating food insecurity in vulnerable regions provides a window of opportunity to build the political consensus required to implement radical changes in the institutions that govern agricultural development and focus attention on the needs of small scale farmers in the food insecure countries and regions of the world.

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[iii] www.guardian.co.uk/global-development/poverty-matters/2011/aug/08/famine-east-africa-climate-change, accessed 29 August 2011.

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