3. World Food Insecurity and Malnutrition: Scope, Trends, Causes and Consequences

Dimensions of the Nutrition Problem

Apart from any consideration of the impact of current and future climate change and bioenergy demand, the world food security and nutrition situation and outlook are worrisome. Food insecurity and malnutrition represent serious impediments to sustainable development, poverty reduction, equity and achievement of the Millennium Development Goals (MDGs).

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996). It has four dimensions (see Figure 1): food availability, access to food, stability of supply and access, and safe and healthy food utilization. Stability depends on food production, incomes, markets and transfer programmes (both public and private) and can be adversely affected by shocks due to weather, price fluctuations, human-induced disasters and political and economic factors. Utilization refers to the proper use of food and includes the existence of appropriate food processing and storage practices, adequate knowledge and application of nutrition and child care and adequate health and sanitation services (FAO, 2000; FANTA, 2006). Food security is a key factor in good nutrition, together with health, sanitation and care practices (Figure 1).

With regard to food availability, present global food supplies are more than adequate to provide everyone with all the *calories* he or she needs for an active and healthy life, if the food were equally distributed. As Figure 2 indicates, *per capita* daily calorie availability currently exceeds 2,100 (the average energy requirement for adults undertaking light activity) in all global regions, though barely so in Sub-Saharan Africa. However, this abundance of food is *not,* in fact, equally distributed, so hundreds of millions of people in developing countries actually consume less than their minimum requirements. According to the latest data, over 820 million people in developing countries are undernourished, i.e., their diets are calorie-deficient. More than 60 percent of these food insecure people live in South Asia and Sub-Saharan Africa, which form hunger's centre of gravity (Figure 3). This can be viewed as an infringement on the human right to adequate food, which implies availability and accessibility of food in sufficient quantity for all (UNCESCR, 1999).

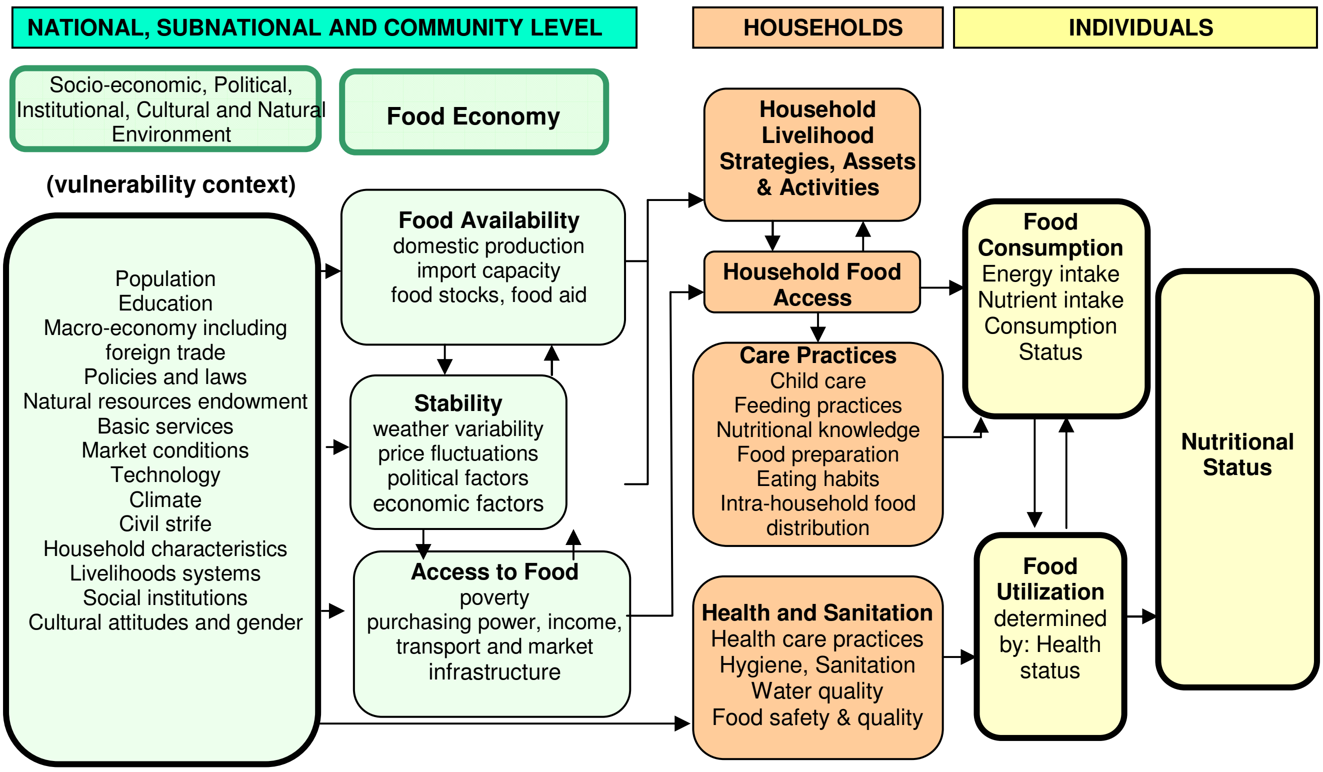
Ironically, fully half of all food-insecure people are small farmers. Even though they grow food, they lack the resources to meet all of their needs through either production or purchase. Another 30 percent of hungry people are fishers, herders, or landless rural people and the remainder are poor urban dwellers (UN Millennium Project, 2005).

Hidden Hunger

Even if a person consumes enough calories, this does not guarantee adequate intake of essential micronutrients – vitamins, minerals and trace elements. Micronutrient malnutrition – often called "hidden hunger" because it is not readily apparent from clinical signs of a wasted body – afflicts a far greater swath of humanity than insufficient calorie intake.

Figure 1

FAO/FIVIMS Framework: linkages between the overall development context, the food economy, households and individual measures of wellbeing

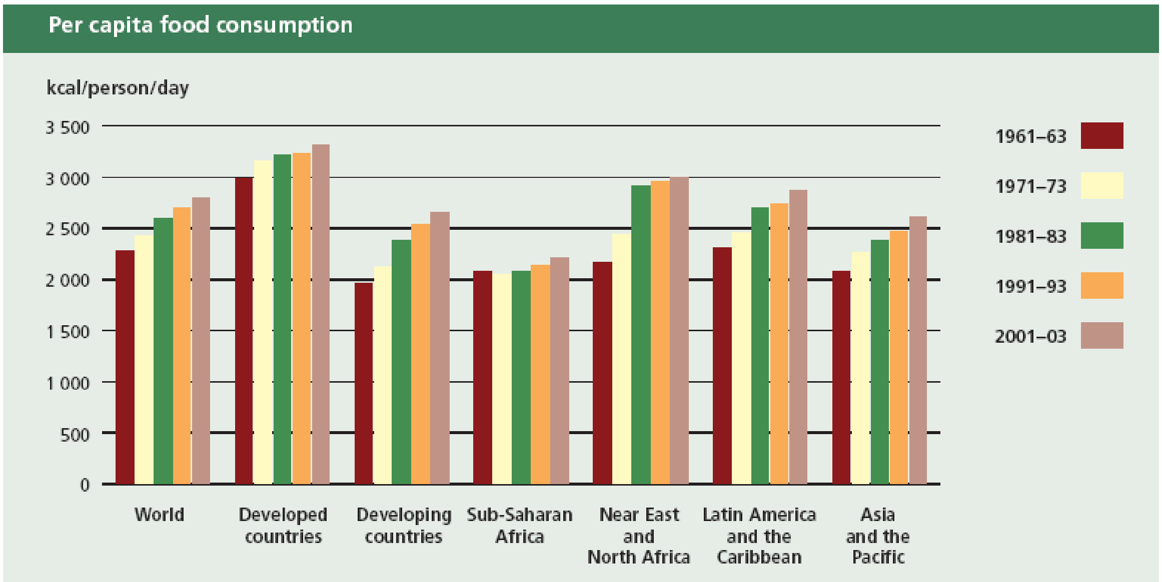


Source: FAO (2000).

Moreover, insufficient calorie consumption often goes hand-in-hand with micronutrient malnutrition (FAO, 2004). Micronutrient deficiencies can have grave public health consequences (as noted below). Micronutrient malnutrition can likewise be viewed as an infringement on the human right to adequate food, which implies availability and accessibility of food in *quality* sufficient to satisfy the dietary needs of everyone (UNCESCR, 1999).

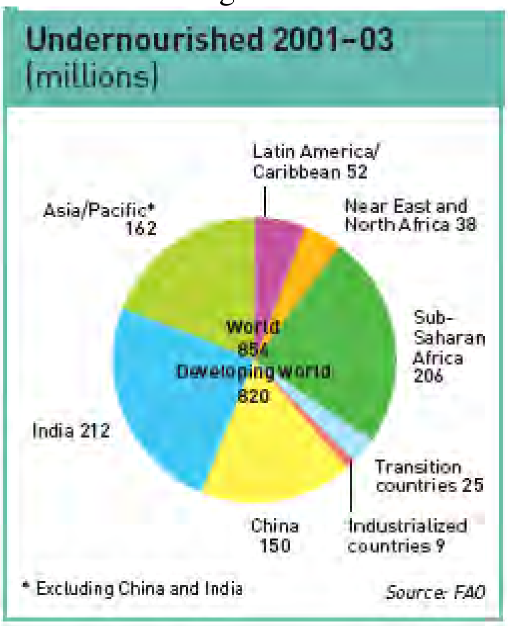
Over one billion people consume diets deficient in iron (Trowbridge and Martorell, 2002). Iron deficiency is responsible for roughly half of the global prevalence of anaemia, which affects about half of all pregnant women, 56 percent of pregnant women in developing countries and over three-quarters of pregnant women in South and Southeast Asia, as well as 63 percent of preschool children in the latter two regions and 39 percent of all developing-country preschoolers (ACC/SCN and IFPRI, 2000; Harvest Plus, 2007).

Figure 2: Foods Available for Consumption (kcal/cap/day)



Source: FAO (2007).

Figure 3



Around 115,000 women die in childbirth each year as a result of iron deficiency anaemia, accounting for 20 percent of global maternal mortality (ACC/SCN and IFPRI, 2000; Black *et al.*, 2008). Anaemic mothers are more likely to deliver prematurely, to deliver babies with low birthweights and to have babies who die as newborns. Anaemia among children can impair health and development, limit learning capacity, impair immune systems and reduce adult work performance. Iron deficiency can reduce work performance even if it does not result in anaemia (ACC/SCN and IFPRI, 2000).

Lack of adequate iodine in maternal diets can lead to spontaneous abortion and stillbirths. The children who survive face cretinism, a serious and irreversible form of mental retardation, as well as milder retardation (WHO, 2006).

Insufficient vitamin A intake among developing-country children causes blindness and contributes to infections and death. About 20 million pregnant women in developing countries have vitamin A deficiency (VAD); they face increased risk of mortality and mother-to-child HIV transmission, as well as blindness (WHO, 2001). VAD impairs the immune system of about 40 percent of the children under the age of five in developing countries, causing about one million child deaths annually. In India, the prevalence of VAD among preschoolers is 60 percent. The prevalence of VAD declined in all developing regions during the 1990s, but at extremely slow rates and has remained unchanged in Sub-Saharan Africa since the mid-1990s (MI and UNICEF, 2005).

Inadequate dietary zinc can lead to stunting (i.e., lower than expected height for one's age) and greater susceptibility to infections. Over 60 percent of the populace of the developing world is thought to be at risk of low zinc intake; the figure is 70 percent in Southeast Asia and fully 95 percent in South Asia (de Benoist *et al.*, 2007).

The Deadly Scourge of Child Malnutrition

Malnutrition takes a particularly severe toll among preschool children. One in three developing-country preschoolers – 178 million children under the age of five – suffers stunting as a result of chronic undernutrition (Black *et al.*, 2008). Eighty-percent of these children live in just 20 countries in Africa and the Asia-Pacific region (see Box 3.1). In India, 61 million preschoolers (51 percent of the children under the age of five) are stunted. Both the number and the prevalence of under-five stunting in India exceed the figures for all of Africa (57 million and 40 percent) (Black *et al.*, 2008).

Box 3.1: Twenty countries are home to 80 percent of the world's stunted preschoolers

Africa	**Asia-Pacific**
Democratic Republic of Congo	Afghanistan
Egypt	Bangladesh
Ethiopia	India
Kenya	Indonesia
Madagascar	Myanmar
Nigeria	Nepal
South Africa	Pakistan
Sudan	Philippines
Tanzania	Viet Nam
Uganda	Yemen

Source: Bryce *et al.* (2008).

Stunting is associated with higher rates of illness and death, reduced cognitive ability and school performance in children and lower productivity and lifetime earnings for adults. Indeed, height-for-age among two-year-olds is the best predictor of adult human and physical capital. Chronic malnutrition during the first two years of life usually results in irreversible harm. Children become stunted not only as a result of insufficient calorie intakes, but also because of poor quality diets. Children who become stunted in the first two years of life and gain weight rapidly after that may be at high risk of nutrition-related chronic diseases, such as obesity, diabetes and hypertension (Hoddinott *et al.*, 2008; Victora *et al.*, 2008; World Bank, 2006; FAO, 2004).

Another 55 million preschool children in developing countries are wasted (i.e., they have lower than expected weight for their height) due to acute malnutrition. Severe wasting afflicts more than a third of these children (19 million) (Black *et al.*, 2008).

Each year, over 19 million babies are born in developing countries with low birthweights (less than 2.5 kilograms), accounting for 16 percent of the developing world's annual births. In South and Central Asia, the figure is 27 percent. These children face four times the risk of neonatal death of those with normal birthweights and if they survive, they have much higher rates of illness and stunting in both childhood and as adults (Black *et al.*, 2008; FAO, 2004).

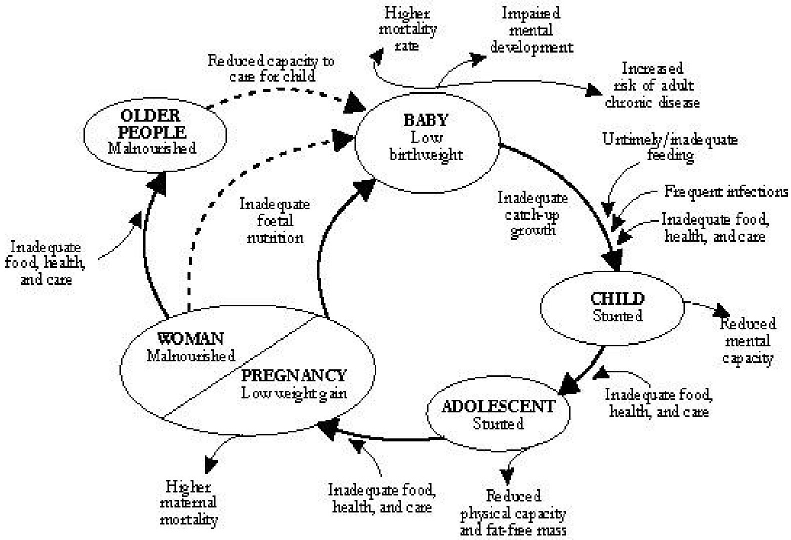
Nutrition Throughout the Lifecycle

As Figure 4 indicates, at each stage in the lifecycle, malnutrition has consequences for each successive stage and/or the next generation, particularly among low-income households in developing countries. Mothers who suffer chronic caloric or micronutrient deficiencies are more likely to have low birthweight babies: in effect, they pass their malnutrition on to the next generation (Black *et al.*, 2008; World Bank, 2006; FAO, 2004). These mothers also face increased risk of death in childbirth. Low birthweight babies face higher mortality rates, impaired mental and physical development and increased risk of adult chronic diseases. If these conditions are combined with poor care and feeding practices, inadequate food and health and, as a result, frequent infections, the child will either die prematurely or face high risk of reduced mental capacity. Stunted children living with inadequate food, health and care remain stunted as adolescents and face reduced physical capacity. The girls among them, with continued inadequate food, health and care, grow up too often as another generation of malnourished mothers who have low birthweight babies of their own. Adults affected by malnutrition may have a low body mass index or nutritional oedema (retention of fluid). If malnourished adults continue to have inadequate food, health and care into old age, they remain malnourished and are less able to assist in caring for children (Victora *et al.*, 2008; SCN, 2004).

HIV/AIDS and Nutrition

HIV/AIDS currently affects 33 million people, 70 percent of whom are in Sub-Saharan Africa and is spreading rapidly in some other developing regions (UNAIDS, 2007). The disease interacts negatively with malnutrition. Poor nutrition and food insecurity can accelerate the spread of HIV, both by increasing people's exposure to the virus and by increasing the risk of infection following exposure. In turn, HIV infection can lead to nutritional deficiencies through decreased food intake and malabsorption, which hasten the onset of AIDS. The disease impairs the immune system and so can lead to additional infections, such as tuberculosis and malaria that worsen nutritional status and may be fatal (Gillespie and Kadiyala, 2005).

Figure 4: Nutrition throughout the life cycle



Source: ACC/SCN and IFPRI (2000).

Water, Sanitation, and Nutrition

Efforts to achieve the MDG hunger target aim principally at increasing food and therefore caloric intakes among the hungry. But the human energy balance depends on caloric use as well as on caloric intake. Many impoverished people expend significant calories collecting water over great distances or waste them because their bodies are unable to absorb food properly because of diarrhoeal disease. Populations suffering from hunger are often the same as those that lack adequate water and sanitation. Globally, one billion people are currently without access to safe water and over 2 billion lack adequate sanitation facilities.[1] Roberto Lenton, former director of the UN Development Programme's (UNDP) Sustainable Energy and Environment Division has commented, "We need to develop strategies ensuring that policies that target caloric intake are accompanied by strategies to reduce caloric losses through better water, sanitation and hygiene" (Rahman, 2008).

Hunger Crises

In 2008, the United Nations is appealing for food and other humanitarian assistance for 25 million people in 24 countries affected by conflict and its aftermath or serious political and economic breakdown (OCHA, 2007). Refugees and internally displaced people are particularly susceptible to malnutrition because they frequently depend on food aid rations that are often inadequate in both quantity and quality. An analysis of 41 mortality and

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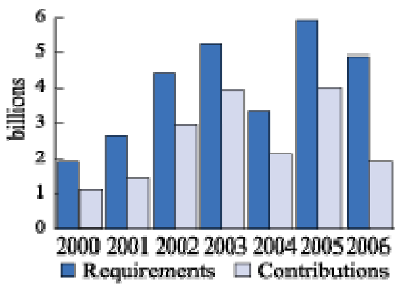
[1] See HTTP://WWW.WSSINFO.ORG/EN/WELCOME.HTML, website of the World Health Organization/UN Children's Fund Joint Monitoring Programme for Water Supply and Sanitation.

malnutrition surveys carried out in refugee camps in 2005 found that half indicated an acute malnutrition emergency and among these emergency situations, 90 percent featured a "critical" prevalence of global acute malnutrition, in excess of 15 percent (CE-DAT, 2006). According to the Office of the UN High Commissioner for Refugees, micronutrient deficiencies are widespread in camps due to unbalanced rations. For example, lack of B vitamins is a serious problem in camps in Nepal and Bangladesh (UNHCR, 2005). Nevertheless, aid donors routinely fail to provide all of the resources called for in UN humanitarian aid appeals (Figure 5). The UN Office for the Coordination of Humanitarian Affairs reports that in 2007, donors provided just 72 percent of the amount requested for all sectors in its consolidated appeal for complex emergencies (those due to conflict and related causes) and flash appeals for natural disasters. Although the food aid response was somewhat better at 88 percent, neither water and sanitation nor health appeals (both nutrition-related) garnered even 50 percent of the requested funds (OCHA, 2008). In April 2008, the WFP informed donors that it would immediately need an additional $755 million just to maintain current commitments, due to skyrocketing food prices (Sullivan, 2008).

Figure 5
UN Humanitarian Appeals and Donor Response (US$)



Source: OCHA.

Unacceptably Slow Progress in Reducing Hunger and Malnutrition

The world is not making sufficient progress toward meeting the 1996 World Food Summit goal of halving the *number* of undernourished people (i.e., those with calorie deficient diets) from 1990 levels by 2015 and progress on the MDG target of cutting the proportion of people living in hunger to half of the 1990 level by that same year is uneven. The UN Millennium Project has adopted two indicators to measure progress toward the MDG target: the prevalence of underweight[2] among children under five years of age and the undernourished proportion of the total population.

Although the number of undernourished people slowly but steadily declined between 1970 and 1990, since 1995, the number has actually *increased* (Figure 6). As a result, the total number of undernourished people in developing countries was only marginally changed from 1990 levels by 2003, the last year for which data are available (820 million people vs. 823 million). In contrast, the proportion of undernourished people in the total population of developing countries declined during the same period from 20 to 17 percent (FAO, 2006a).

[2] See HTTP://WWW.UNMILLENNIUMPROJECT.ORG/GOALS/GTI.HTM#GOAL1. "Underweight" means children with lower weights than expected for their age. Unlike stunting and wasting, it does not distinguish between the effects of chronic and acute malnutrition.

As Figure 7 indicates, these disappointing aggregate figures mask substantial progress against hunger in some regions and understate the alarming increases in the number of undernourished people in others. Tens of millions of people in China achieved freedom from hunger during 1990-2003, while Southeast Asia and South America also recorded substantial gains. However, large increases in the undernourished populations of South Asia outside India, Eastern Africa and the Near East, plus a doubling of the ranks of the hungry in Central Africa (driven by war and political chaos in the Democratic Republic of the Congo) offset these gains (FAO, 2006a).

Figure 6

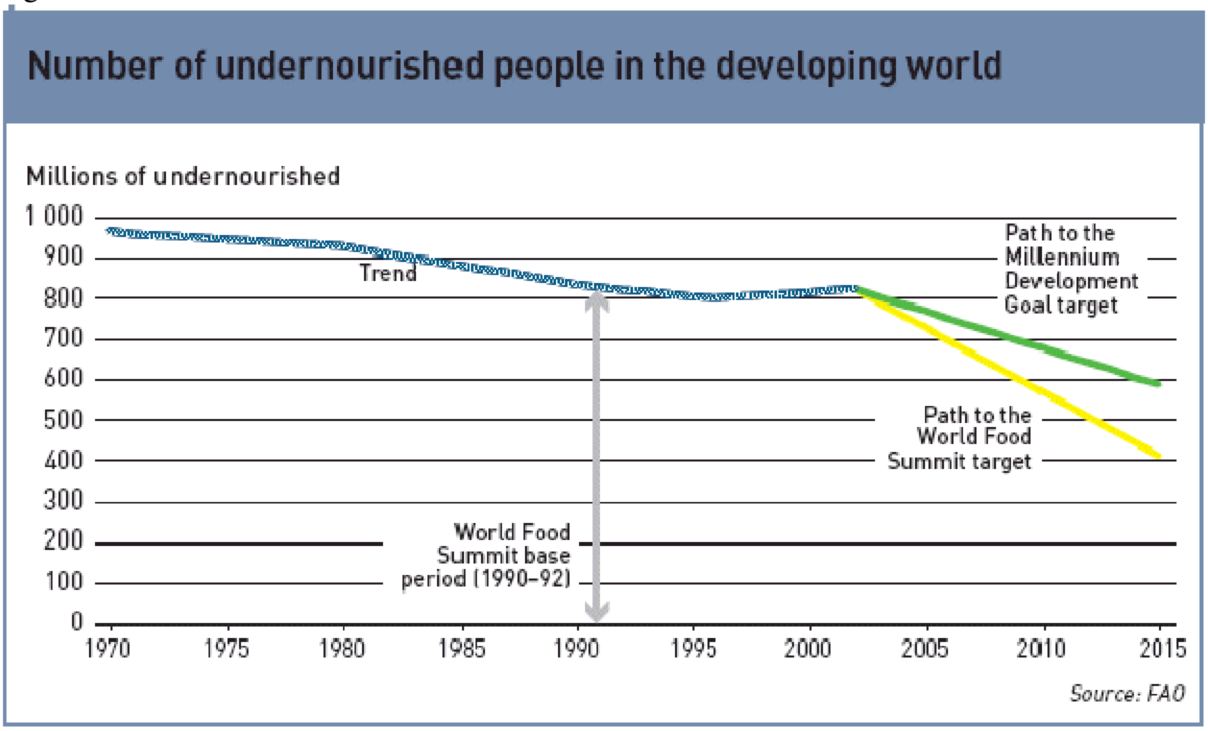
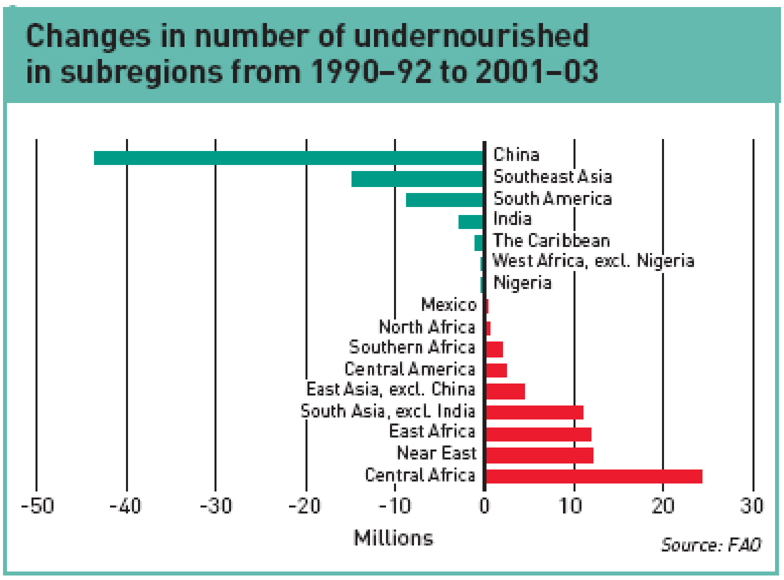


Figure 7



The Food and Agriculture Organization of the United Nations projects that the developing world as a whole and most of its regions will fall short of the World Food Summit hunger reduction goal in 2015 and that more people will be undernourished than in 1990 in Sub-Saharan Africa and the Near East. However, East and Southeast Asia will succeed in cutting their undernourished populations beyond the target, due to policies emphasizing growth with equity in many countries of the region. The developing world is projected to meet the MDG target on cutting the undernourished proportion of its population, reducing the level by a bit more than half, with Latin America and the greater Asia-Pacific region on target and Sub-Saharan Africa and the Near East falling short (Table 1).

Between 1990 and 2005, the prevalence of underweight among children under the age of 5 in developing countries fell from 30 percent to 23 percent. That rate of reduction is inadequate to achieve the MDG target of halving the prevalence from 1990 levels by 2015. Moreover, child malnutrition increased in Sub-Saharan Africa while it declined in the rest of the developing world. Again, however, both the number of malnourished children (67 million) and the prevalence of child malnutrition (37 percent) in South and Central Asia exceeded the levels for all of Africa (34.5 million and 25 percent) (SCN, 2004). This disparity is known as the "Asian enigma," because on most indicators of human wellbeing (access to safe water, school enrolment, food availability per person, income per person, degree of democratic governance), people in South Asia are better-off than those in Africa. But the female-to-male life expectancy ratio – a measure of women's social status relative to that of men – is higher in Africa than in South Asia. Also, South Asia has less favourable climate and population density (Smith and Haddad, 2000).

Causations and Linkages: Conceptual and Analytical Frameworks

An understanding of the causes and consequences of malnutrition is essential for formulating appropriate policies to improve nutrition as strategies need to be tailored to local conditions. For example, low food production caused by insufficient agricultural productivity is a primary reason for hunger in tropical Africa and remote parts of Asia and Latin America, whereas poverty is more likely the primary reason for hunger in South and East Asia, Latin America, Central Asia and the Middle East. The rights-based approach to food security provides the framework for a more effective and complete analysis of the underlying causes of hunger and malnutrition by, for example, requiring the assessment of existing policies, laws and institutions and the identification of the most vulnerable to food insecurity and malnutrition. The costs of inaction are considerable, so efforts to accelerate progress against malnutrition in all its forms should have a high place on the global policy agenda.

As Table 1 indicates, inadequate dietary intake is one of the main immediate causes of malnutrition, along with disease. The two interact in a vicious downward spiral. Inadequate food consumption heightens vulnerability to infectious diseases. In turn, infections, particularly malaria, measles, persistent diarrhoea and pneumonia, can keep the body from absorbing adequate food (WHO, 1997). These immediate causes stem from a complex set of underlying causes at the household level: insufficient access to food – one aspect of food insecurity – poor maternal and child caring practices and inadequate access to clean drinking water, safe sanitation and health services. Ultimately, these factors are embedded in the larger political, economic, social and cultural environment in which households find themselves.

Food insecurity, ill health and sub-optimal caring practices are all closely related to poverty. The one billion people who live in extreme poverty – on the equivalent of less than US$1 per day – generally also consume fewer than 2,100 calories per day. The world's 163 million ultra poor people, whose incomes are less than half that level, on average consume less than 1,600 calories a day (Ahmed *et al.*, 2007). Moreover, in all regions of the developing world, lower-income households experience significantly higher rates of preschooler stunting than better-off families (Van de Poel *et al.*, 2008). Poverty assessments in Bangladesh, Viet Nam and Guatemala similarly indicate a higher incidence of illness in poor households than among better-off families (Ahmed *et al.*, 2007). With regard to caring practices, even when exclusive breastfeeding for the first six months of life is widely practiced, poor households often engage in sub-optimal complementary feeding practices once children reach six months of age. Poor families cannot afford to purchase animal source foods that are rich in protein and bioavailable micronutrients (Black *et al.*, 2008).

Table 1

Projected undernourishment in the developing world

	Number of undernourished people *(millions)*			Prevalence of undernourishment *(percentage of population)*		
	1990–92*	2015	WFS target	1990–92*	2015	MDG target
Developing countries	823	582	412	20.3	10.1	10.2
Sub-Saharan Africa	170	179	85	35.7	21.1	17.9
Near East and North Africa	24	36	12	7.6	7.0	3.8
Latin America and the Caribbean	60	41	30	13.4	6.6	6.7
South Asia	291	203	146	25.9	12.1	13.0
East Asia**	277	123	139	16.5	5.8	8.3

Notes
The base period for projections is 1999–2001 and not 2001–03. Some small countries have also been excluded from the projections.
* Data for 1990–92 may differ slightly from numbers reported elsewhere in the report as the projections are based on undernourishment estimates that do not include the latest revisions.
** Includes Southeast Asia.

Source: FAO

A high percentage of the world's extremely poor people live in South Asia. However, ultra poverty is heavily concentrated in Sub-Saharan Africa. While South Asia made progress against the deepest poverty during the 1990s and the first years of the present decade, both extreme poverty and ultra poverty increased in Sub-Saharan Africa (Ahmed *et al.*, 2007).

Discrimination, geography and environmental factors also play a role in poverty, food insecurity and malnutrition. In both South Asia and Latin America, indigenous people, members of ethnic minority groups and socially excluded people, such as members of "secluded" and "backward" castes in India, are over-represented among poor people and especially among ultra poor people. In Guatemala, the proportion of indigenous preschoolers who are stunted is more than double the rate for non-indigenous children. Gender discrimination also influences malnutrition: in South Asia, there is evidence that women consume less food and lower quality diets than men, mainly as a result of food distribution within households (Ahmed *et al.*, 2007).

Poverty rates tend to be higher in more remote areas with difficult access to roads, markets, communications infrastructure, schools and health services (Ahmed *et al.*, 2007). Such areas are often “less-favoured” in terms of their natural resource endowments as well as in socio-economic and political terms. Most of the rural poor people in developing countries (who account for the vast majority of all poor people) live in such resource-poor areas (Pender and Hazell, 2000).

Costs of Malnutrition

Taken together, stunting, severe wasting, low birthweights due to intrauterine growth restriction, sub-optimal breastfeeding (non-exclusive for six months and discontinued before one to two years) and deficiencies of vitamin A, zinc and iron lead to the deaths of 3.6 million children under five years of age each year (Black *et al.*, 2008). Moreover, these forms of malnutrition together account for 35 percent of all preschooler deaths and 11 percent of the global burden of disease, i.e., the total gap between current global health status and an ideal situation where everyone lives into old age in full health (Black *et al.*, 2008). Thus, malnutrition is a calamity that deprives humanity of countless scientists, creative artists, community and national leaders and productive workers who die prematurely or grow up without reaching their full potential.

Malnutrition puts heavy charges on the economies of developing countries. Difficult pregnancies and the illnesses that malnourished mothers and their children experience cost an estimated $30 billion annually. Lost productivity and income due to early deaths, poor school performance, disability and absenteeism likely raise the yearly total into the hundreds of billions of dollars (Victora *et al.*, 2008; Behrman, Alderman and Hoddinott, 2006; FAO, 2004). Lost income due to iron deficiency alone reduces gross domestic product by as much as 8 percent in Bangladesh and a still significant 2 percent in Honduras (SCN, 2004). Not only is malnutrition a significant drain on economic growth, but it also reflects and contributes to inequity, as it disproportionately affects poor, marginalized and extremely vulnerable groups. While the policies and programmes needed to address malnutrition will require substantial resources, it is essential to recognize that the costs of *not* tackling malnutrition are considerable.

Future Challenges and Major Issues and Risks

Chapters 4 and 5 examine the effects of climate change and rising bioenergy demand on nutrition. However, some additional factors will constrain efforts to reduce malnutrition in the coming years:

- demographic forces;
- widespread land degradation and scarcity of fresh water resources, resulting from both bad management practices, inappropriate land uses for a certain land class and impacts from climate change and extreme climate variations;
- structural shifts in the food and agricultural system;
- transboundary movement of diseases;
- environmental and energy forces.

Demographic Forces

According to UN population data, between 2007 and 2050, world population will increase by 37 percent, from 6.7 billion to 9.2 billion people, with the net increase equivalent to the total global population in 1950. Africa will have the highest rate of population growth of any region during this period, 1.7 percent per year (UN Population Division 2007, 2008).

Population growth alone will mean increased demand for food, requiring a 50 percent increase in production. Anticipated economic growth of 6 percent per year in developing countries during the next few years will lead to additional increases in demand, as will rapid urbanization (von Braun, 2007a).

Virtually all global population growth between 2007 and 2050 will occur in the cities of the developing world. Indeed, the net increase in urban population during that period will exceed the net growth in overall population, as cities will also absorb migrants from rural areas. The world's urban population will nearly double during this period, rising from 3.3. billion to 6.4 billion people. By 2019, a majority of the developing world's populace will live in cities and towns (UN Population Division, 2008). These trends have implications for food demand and nutrition. People in cities and towns have fewer opportunities than rural people to produce their own food and so must rely on purchases and the cash economy to eat. A sharp increase in food prices will have a large impact on people who rely almost entirely on cash income, especially the poor. Urban women have higher opportunity costs on their time, so they cannot spend as much time as their rural sisters do on purchasing and preparing food. As a result, city folk tend to shift their consumption to foods that are easier to prepare (e.g., from sorghum, millet, maize and root crops to rice and wheat) and to more meat, milk, fruit, vegetables and processed foods (Garrett and Ruel, 2000).

Street foods are a significant contributor of urban dwellers' daily energy and nutrient intakes and play a particularly prominent role in food access by the urban poor. Street foods provide cheap sources of often nutritious food and are a good source of income for informal food sector workers, most of whom are women and more likely than men to invest that income in the wellbeing of their children. In Nigeria, city dwellers spend as much as half their food budgets on street foods. In Bamako, Mali, street foods provided 134-417 kcal/person per day (Ag Bendech *et al.*, 2000). With rising costs for food and cooking fuel, the use of street foods tends to increase as prices in this informal sector are inclined to rise slower due to the economies of scale of production. Lack of infrastructure (i.e. water, sanitation), lack of basic training in food hygiene of vendors and weak or arbitrary enforcement of the legal framework (if street foods-specific regulations do exist at all) are all factors contributing to the variable and sometimes poor safety of these foods. However, the contribution of street foods to food security (ensuring cheap, nutritious and easily available food to urban dwellers), as well as to poverty reduction, is such that high priority should be given by local authorities (for example, municipalities) to reduce the threats to food safety. In particular, emphasis should be given to training of street foods' vendors in food hygiene, insisting on an adequate and consistent enforcement of local food regulations and improving basic infrastructure to the vendors allowing them to respect the most basic principles for hygienic food preparation.

Structural Changes in the Food and Agricultural System

Productivity growth in cereals, the main staple food crops, declined dramatically in the 1990s and continues to decline for maize (which is important as a source of feed and fuel as well as food) (Figure 8). A major reason for this is underinvestment in agriculture. Growth of public agricultural research expenditures slowed in the 1990s and in 2000, developing countries excluding China and India accounted for only a small share of that spending. Funding for the international agricultural research centres supported by the Consultative Group on

International Agricultural Research (CGIAR) has stagnated (Pardey *et al.*, 2006). Public research is essential for addressing the problems of poor farmers and consumers in developing countries, as private firms are unlikely to do so.

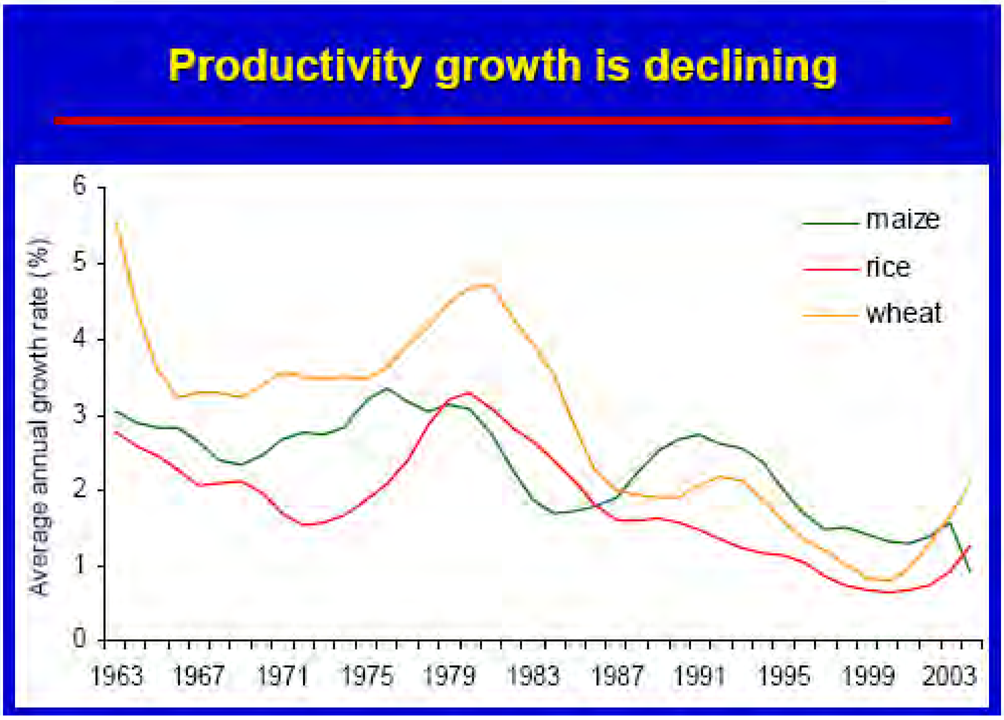
Increasingly, the preferences of affluent consumers in high- and middle-income countries are shaping global food and agricultural systems. Production and value chains no longer respond simply to price signals. Such concerns as quality, food safety, convenience and choice have become decisive. For example, developed-country consumers seek pre-washed, pre-cut and bagged salads that are ready to eat, rather than just the raw materials for making a salad. The mad cow, foot-and-mouth and highly pathogenic avian influenza scares in Europe and North America over the past 10 years have also heightened attention to food safety and quality, health and environmental issues. Consumers demand to know where food came from and how it was produced. Animal welfare is also increasingly an issue in food marketing. There are standards organizations that award products labels indicating their status as organic, fair trade, environment-friendly and cruelty-free. This new situation offers smallholders opportunities and niche markets among high-income buyers. But being able to produce up to the standards to get the appropriate label and undergoing periodic audits may require investment in knowledge and equipment and also has high transaction costs that may be too heavy for low-income farmers (Hazell *et al.*, 2007). This will constrain their ability to earn income and has implications for food security.

The global food system now has a dualistic structure. On the one hand, the vast majority of farms (85 percent) remain smallholder operations, of less than two hectares in size, that are home to more than 2 billion people (Hazell *et al.*, 2007). In many countries, small farmers account for a considerable share of output. In India, they grow more than 40 percent of the cereal grains, own the majority of the livestock and account for most dairy production. In Sub-Saharan Africa, smallholders account for 90 percent of all agricultural production (IFPRI, 2005). On the other hand, the 0.5 percent of the world's farms that exceed 100 hectares in size claim a disproportionate share of global farm income, enjoy privileged access to policy makers and, particularly in developed countries, receive the lion's share of tens of billions of dollars in subsidies each year (OECD, 2007).

Moreover, outside of farming, growing concentration and consolidation characterizes the global food system. At the top of the food chain, the 10 leading food retailers enjoy a 24 percent share of the $3.5 billion global market and grocery stores have expanded their operations in developing countries at a rapid pace (ETC Group, 2005, 2007). Between 2004 and 2006, the sales of agricultural input firms grew 8 percent, the revenues of food processors and traders jumped 13 percent and retail food sales grew by a whopping 40 percent (von Braun, 2007a). At the end of February 2008, the giant agricultural input and grain trading firm Cargill announced a nearly 100 percent increase in revenues over a year earlier due to rising cereal prices (*Washington Post* Staff and Wire Reports, 2008).

Thus, buying power is increasingly concentrated in the hands of supermarkets and other powerful corporate actors, especially in Latin America, Southeast Asia and China. Small farmers often find themselves at a disadvantage. The buyers increasingly have stringent demands regarding quality, timeliness and conditions of production and it is not clear that small farmers will be able to comply with all these requirements (Hazell *et al.*, 2007). Even if they can, their ability to bargain for a fair share of the value of their produce may be limited.

Figure 8



Source: World Bank (2008a).

Transboundary Pests and Diseases

Agricultural intensification, rapid growth in international trade and more frequent international travel offer opportunities to bolster rural livelihoods through productivity gains, entry into export markets, earnings from ecotourism and the ability to purchase a wider array of affordable goods and services. However, there are also substantial risks from the spread of plant and plant pests, animal diseases and invasive species across international borders and climate change will heighten these risks. This threatens ecosystems, water and biodiversity (World Bank, 2008a). For example, the wind-borne Ug99 wheat rust fungus has spread from Uganda to Kenya, Ethiopia, Yemen and Iran and threatens crops in South and Central Asia. It has devastated entire fields and in 2007 caused substantial losses in both Kenya and Ethiopia. Up to 80 percent of African and Asian wheat varieties are susceptible to wheat stem rust, so the disease has the potential to help drive further escalation of wheat price inflation and severely harm rural livelihoods, with negative implications for nutrition (FAO, 2008a). Also, some trans-boundary animal diseases pose serious and costly threats not only to rural livelihoods, but to human health as well, e.g., highly pathogenic avian influenza (bird flu) (World Bank, 2008a).

Environmental and Energy Pressures

Many key ecosystem services provided by biodiversity, such as nutrient cycling in soils, pest regulation and pollination, sustain intensive agricultural productivity. Promoting the healthy functioning of ecosystems ensures the resilience of agriculture as it intensifies to meet the stress of growing demands for food production.

For the past 40 years or more, efforts to intensify agricultural production have helped boost food output, but some agricultural practices have taken a toll on the natural resource base on which agriculture depends. Some 1.4 billion people live in river basins where water use exceeds recharge rates (UNDP, 2006). Poor management of irrigation systems has contributed to land degradation, causing salination and waterlogging of soils. Overgrazing and deforestation also contribute to land degradation and climate change (UNDP-Global Environmental Facility, 2004; Scherr, 1999). In Sub-Saharan Africa, where farmers apply an average of 9 kilograms of fertilizer per hectare (compared to 142 kilograms in South-east Asia), insufficient fertilizer use (rather than overuse) leads to degradation, as the cultivation and harvesting of products lead to a net loss of soil nutrients. Agricultural practices (such as failure to maintain soil cover or obstruct water run-off) can contribute to soil erosion. Degraded soils reduce agricultural productivity and eventually become unable to produce crops (Scherr, 1999). Large-scale livestock operations and inappropriate management of farm chemicals have contributed to degradation of freshwater ecosystems, causing pollution that can threaten the health of humans and livestock (Millennium Ecosystem Assessment, 2005). Crop genetic diversity is essential for food security, as it is the basis of both farmers' livelihoods and agricultural innovation. However, repeated planting of a limited number or even a single variety can erode genetic diversity (Bioversity International, 2008).

Without the wider utilization of effective and efficient existing technologies and in the absence of a technological breakthrough that will boost yields on existing farmland, increases in food production to meet growing demand will have to come from the expansion of agriculture into new areas. This would likely put more fragile marginal land under cultivation, as well as destroy forests and wildlife habitat, cause loss of biodiversity and increase GHG emissions from burning, decomposition of organic matter and loss of carbon sinks. We need to examine the efficiency of the constraints that are facing existing farmland productivity, otherwise we may only aggravate the environmental pressure. An additional serious constraint, especially in fast-growing Asia, is the rapid conversion of farmland to such other uses as residential, commercial and industrial (Reuters, 2008; Ding, 2004). Furthermore, food and agricultural production faces growing competition for water for home and industrial use, although agriculture continues to account for over 80 percent of water use (FAO, 2008b; UNDP, 2006). All of these factors constrain food availability.

According to the UN Office for the Coordination of Humanitarian Affairs (OCHA), the number of natural disasters has increased, due to more frequent extreme weather events, such as hurricanes, cyclones, droughts and floods. In 2007, OCHA appealed for nearly $400 million in food and other emergency aid for people affected by 14 such calamities in developing countries (OCHA, 2007). While these disasters stem from natural events, human activity – frequently related to agriculture, fisheries, or forestry – often magnifies their impact. Logging, forest clearing for agricultural development and destruction of mangroves for aquaculture development dismantle natural barriers to storms and floods, creating "unnatural disasters." The devastating effects of the recent cyclone in Myanmar are a prime example: clear-cutting of mangroves heightened the vulnerability of coastal lands. Deforestation on the hillsides of Honduras meant large-scale mudslides when Hurricane Mitch hit in 1998. Total losses exceeded the combined national incomes of Honduras and Nicaragua, the two most severely affected countries. Natural disasters in the 1990s caused losses of over $600 billion, more than those of the previous four decades (Abramovitz, 2001).

With regard to energy, by April 2008, crude petroleum prices reached an all-time high of US$120 per barrel (Lazo, 2008) and helped to raise demand for biofuels as an alternative source of energy. Energy costs are likely to remain high for the foreseeable future, due to war and political instability in the Middle East, the supply-constraining policies of the

Organisation of Petroleum Exporting Countries and the growing consolidation of the petroleum industry into transnational megafirms that are using windfall profits to repurchase shares and pay dividends instead of aggressively exploring for new reserves (Science Daily, 2007). These costs have a direct bearing on food production and rural livelihoods, as they mean increased costs for operating farm machinery, inputs and transportation of both inputs and farm products (von Braun, 2008). In addition, the price of fertilizer, a by-product of fossil fuels, increased 150 percent over the past five years. However, according to the World Bank, higher energy and fertilizer costs account for only about 15 percent of recent increases in food prices (World Bank, 2008b).

4. Climate Change, Food Security and Nutrition

Overview of Climate Change - Evidence for and Potential Effects

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC),[3] climate change and variability will have significant impacts on food security and malnutrition.

Climate change will lead to more intense and longer droughts than have been observed over wider areas since the 1970s, particularly in the tropics and subtropics (Trenberth *et al.*, 2007). In addition, the frequency of heavy precipitation events has increased over most land areas. It is very likely that heat waves and heavy precipitation events will continue to become more frequent and that future tropical cyclones (typhoons and hurricanes) will become more intense (Meehl *et al.*, 2007; Trenberth *et al.*, 2007). It is primarily via these impacts that climate change will have negative effects on food security and nutrition.

Droughts and water scarcity diminish dietary diversity and reduce overall food consumption and this may lead to malnutrition problems including undernutrition, protein-energy malnutrition and/or micronutrient deficiencies. The risk of flooding of human settlements may increase, from both sea-level rise and increased heavy precipitation in coastal areas. This is likely to result in an increase in the number of people exposed to diarrhoeal and other infectious diseases, thus lowering their capacity to utilise food effectively.

Global atmospheric concentrations of greenhouse gases (GHGs), carbon dioxide (CO_2), methane and nitrous oxide have increased markedly since 1750 as a result of human activities. By 2005, the global atmospheric concentration of CO_2 far exceeded the natural range of the preceding 650,000 years (Forster *et al.*, 2007). Total temperature increases during the 20th century have been 0.76°C (Trenberth *et al.*, 2007). Average arctic temperatures increased at almost twice the global average rate during the past 100 years.

Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century (Meehl *et al.*, 2007). The best estimate for the low scenario, among the Special Report on Emissions Scenarios (SRES)[4] projected by the 4th IPCC assessment, is an increase of 1.8°C and the best estimate for the high SRES scenario is 4.0°C (Meehl *et al.*, 2007).

Mountain glaciers and snow cover have declined on average in both hemispheres (Lemke, 2007). During the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges; these regions are home to more than one-sixth of the world's population (Kundzewicz, 2007).

Widespread decreases in glaciers and ice caps have contributed to sea-level rise (Lemke, 2007). According to the 4th IPCC report's estimations for unmitigated emissions, the sea-level

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[3] IPCC is a scientific intergovernmental body set up by the UN World Meteorological Organization and the UN Environment Programme to provide decision-makers and others with objective information about climate change. The scientific community generally regards its reports as authoritative (Sample 2007).
[4] See Appendix 1 for details on these scenarios.

will rise by 40 centimetres by the 2080s, with 60 percent of this increase occurring in South Asia and 20 percent in South East Asia (Meehl *et al.*, 2007).

Climate Change Impacts on the Human and the Global Environment

Global environmental hazards to human health, environment and sustainability include climate change, stratospheric ozone depletion, loss of biodiversity, changes in hydrological systems and the supplies of freshwater, land degradation and stresses on food-producing systems (WHO, 2005a). These factors are closely interrelated. For example deforestation, agriculture and livestock production systems further accelerate climate change. Vulnerability to adverse effects from climate change differs by region, ecosystem, population group and gender.

Vulnerable Regions

The regions likely to be adversely affected by climate change are those already most vulnerable to food insecurity and malnutrition, notably Sub-Saharan Africa, which may lose substantial agricultural land. The numbers of people affected will be largest in the mega-deltas of Asia and Africa, while small islands are especially vulnerable (Nicholls *et al.*, 2007). It should be noted that IPCC assessments do not provide much information on a regional or national basis.

In seasonally dry and tropical regions, crop productivity is projected to decrease with even small local temperature increases (1-2°C), which would increase the risk of hunger due to reduced food availability (Easterling *et al.*, 2007). In Africa, by 2020, between 75 million and 250 million people are projected to be exposed to increased water stress due to climate change. If coupled with increased demand, this will adversely affect livelihoods and exacerbate water-related problems (Boko *et al.*, 2007; Kundzewicz *et al.*, 2007). In much of Africa, agricultural production and access to food are projected to be severely compromised by climate variability and change. This would further adversely affect food security and exacerbate malnutrition on the continent.

Coastal areas, especially heavily-populated mega-delta regions in South, East and South-east Asia, will be at greatest risk due to increased flooding from the sea and, in some mega-deltas, flooding from the rivers (Cruz *et al.*, 2007). Sea-level rise will extend areas of salination of groundwater and estuaries, resulting in a decrease in coastal freshwater availability for humans and ecosystems (Kundzewicz *et al.*, 2007). Small islands, whether located in the tropics or higher latitudes, are especially vulnerable to the effects of climate change, sea-level rise and extreme events (Mimura *et al.* 2007). Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources, e.g., fisheries and reduce the value of these destinations for tourism (Mimura *et al.*, 2007).

In the Polar Regions, the main projected biophysical effects are reductions in thickness and extent of glaciers and ice sheets and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators (Anisimov *et al.,* 2007).

Vulnerable Ecosystems

The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification) and other global change drivers (e.g., land use change, pollution, overexploitation of resources) (Fischlin *et al.*, 2007). Examples of delicate ecosystems that are already being affected include the tundra, boreal forests, mountains and the Mediterranean region. Approximately 20-30 percent of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C (Fischlin *et al.*, 2006).

Vulnerable Populations

The most vulnerable people will suffer earliest and most from climate change. Climate change therefore should be addressed in a way that is fair and just, cognizant of the needs and risks faced by the vulnerable groups and adherent to the human rights principles of non-discrimination and equality. Any sustainable solution to climate change must take into account its human impact and the needs of all communities in a holistic manner.

Humans are exposed to climate change directly through changing weather patterns and indirectly through changes in water, air, food quality and quantity, ecosystems, agriculture and economies. Climate change during 1970-2000 is estimated to have caused at least 160,000 deaths and 5 million disability-adjusted life years from only four factors: malaria, diarrhoea, malnutrition and flooding (McMichael, 2004). Projected climate-change related exposures are likely to affect the health status of millions of people, particularly those with low adaptive capacity, through:

- increased deaths, disease and injury due to heat-waves, floods, storms, fires and droughts;
- increases in malnutrition and consequent disorders, with implications for child growth and development;
- increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone related to climate change;
- altered spatial distribution of some infectious-disease vectors; and
- increased burden of diarrhoeal diseases, which will affect nutrient absorption and food utilization.

Due to the very large number of people that may be affected, malnutrition, linked to extreme climatic events, may be one of the most important consequences of climate change Confalonieri *et al.*, 2007).

Populations at greater risk from food insecurity, including smallholder and subsistence farmers, pastoralists, traditional societies, indigenous people, coastal populations and artisanal fisherfolk, will suffer complex, localized impacts of climate change. These groups, whose adaptive capacity is constrained, will experience the negative effects on yields of low-latitude crops, combined with a high vulnerability to extreme events. Indigenous people who rely on their natural resources for the provision of traditional foods will be particularly affected. Box 4.1 presents an example of the impacts of climate change in the ecosystems and the traditional food systems of indigenous peoples of the circumpolar regions.

In the longer term, there will be additional negative impacts of other climate-related processes such as snow-pack decrease, sea-level rise and spread in prevalence of human diseases affecting agricultural labour supply such as malaria, tick-borne diseases, cholera and other diarrhoeal diseases.

Gender Vulnerability

Men and women are affected differently in all phases of climate-related extreme weather events, from exposure to risk and risk perception; to preparedness behaviour, warning communication and response; physical, psychological, social and economic impacts; emergency response; and ultimately to recovery and reconstruction (Fothergill, 1998). Many of the world's poorest people are women living in rural areas in developing countries who are currently dependent on subsistence agriculture to feed their families and who are disproportionately affected by the lack of modern fuels and power sources for farming, household maintenance and productive enterprises (Lambrou and Piana, 2006). Climate change could add to water and food insecurity and increase these women's work levels, particularly in Africa and Asia (Parikh and Denton, 2002).

Box 4.1: Impacts on traditional food systems of indigenous peoples in polar regions

Indigenous peoples rely on their natural resources for the provision of traditional foods, fuel and medicines and will be particularly affected by the impacts of climate change on ecosystems and the environment. Traditional food systems are also threatened because of increasing loss of indigenous peoples' traditional territories due to climate change mitigation measures such as carbon sinks and renewable energy projects.

Indigenous peoples are often the most marginalized and disadvantaged groups in terms of receiving the resources needed for wellbeing, including food and health care. Extreme poverty and food insecurity often characterizes these groups, who rely on the intact environment for harvesting their traditional foods and medicines (Kuhnlein, 2003). The traditional food systems of indigenous peoples contain a wealth of micronutrients.

The approximately 10 percent of the circumpolar population that is indigenous is particularly vulnerable to climate change (ACIA, 2005). The traditional diet of populations in circumpolar regions is likely to be negatively affected by changes in animal migrations and distribution and human access to them (Confalonieri, 2007). Persistent contaminants are present in Inuit Arctic traditional food species in areas very distant from industrial emissions, with dietary exposure of some contaminants exceeding federal tolerance levels in Canada (Kuhnlein *et al.*, 2002). Further, increasing temperatures may indirectly influence human exposure to environmental contaminants in some foods (e.g. fish and marine mammal fats).

Impacts on the Four Food Security Dimensions: Availability, Stability, Access and Utilization

Climate change will affect all four dimensions of food security, namely food availability (i.e., production and trade), stability of food supplies, access to food and food utilization (FAO, 2003a). Food security depends not only on climate and socio-economic impacts, but also and crucially so, on changes to trade flows, stocks and food-aid policy.

Climate Change Impacts on Food Availability – Production and Trade

Pasture, Crops, Livestock Production

Agricultural output in developing countries is expected to decline by 10-20 percent by 2080, depending on whether there are beneficial effects from CO_2 fertilization. Technological change over the next decade is unlikely to be sufficient, which underlines the need for the wider utilization of effective and efficient existing technologies to alleviate the losses or to increase yields enough to keep pace with growing food demand (Cline, 2007).

Climate change and variability impacts on food production (food availability) will be mixed and vary regionally (FAO, 2003b, 2005b). Recurrent severe droughts in several countries in Africa over the past three decades illustrate the potentially large effects of local and/or regional climate variability on crops and livestock. A reduction in the production potential of tropical developing countries, many of which have poor land and water resources and are already faced with serious food insecurity, may add to the burden of these countries (Hitz and Smith, 2004; Fischer *et al.*, 2005; Parry *et al.*, 2005).

Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this it is projected to decrease.

Evidence from models from the 4th IPCC assessment suggests that moderate local increases in temperature (1-3ºC), along with associated CO_2 increase and rainfall changes, can have small beneficial impacts on major rain-fed crops (maize, wheat, rice) and pastures in mid- to high-latitude regions. In seasonally dry and tropical regions, even slight warming (1-2ºC) reduces yield. Further warming (above a range of 1-3ºC) has increasingly negative impacts on global food production in all regions.

Fisheries and Aquaculture Production

Increases in temperature are leading to changes in the distribution of marine fisheries and community interactions (Parry *et al.*, 2005). Brackish water species from delicate estuarine eco-systems are particularly sensitive to temperature and salinity changes. Water temperature increases lead to mortalities of crustacean and shrimp postlarvae (Tirado *et al.*, 1993). Regional changes in the distribution and productivity of particular fish species are expected due to continued warming and local extinctions will occur at the edges of ranges, particularly in freshwater and diadromous species such as salmon or sturgeon (Easterling *et al.*, 2007). Increases in atmospheric CO_2 are raising ocean acidity (The Royal Society, 2005), which affects calcification processes, coral reefs' bleaching and the balance of the food web.

In relation to aquaculture production, increases in seawater temperature have been associated with increased densities of *Vibrio* spp in shellfish and algal blooms in the aquaculture industry, which are major causes of diarrhoea and food toxicity, respectively.

Global warming will confound the impact of natural variation on fishing activity and complicate management. The sustainability of the fishing industries of many countries will depend on increasing flexibility in bilateral and multilateral fishing agreements, coupled with international stock assessments and management plans (Easterling *et al.*, 2007).

Trade of Crops, Livestock and Forestry

Trade in cereal crops, livestock and forestry products is projected to increase in response to climate change, with increased dependence on food imports for most developing countries. Exports of temperate zone food products to tropical countries will rise, while the reverse may take place in forestry in the short-term (Easterling *et al.*, 2007).

Climate Change Impacts on Food Availability, Stability, and Access

Changes in the patterns of extreme weather events will affect the stability of, as well as access to, food supplies. Recent modelling studies suggest that increasing frequency of crop loss due to these extreme events may overcome positive effects of moderate temperature increases (Easterling *et al.*, 2007). For forests, elevated risks of fires, insect outbreaks, wind damage and other forest-disturbance events are projected. This change in frequency of extreme events is likely to disproportionately impact smallholder farmers and artisanal fishers (Easterling *et al.*, 2007). Food insecurity and loss of livelihood would be further exacerbated by the loss of cultivated land and nursery areas for fisheries through inundation and coastal erosion in low-lying areas (FAO, 2003c).

Climate-related animal and plant pests and diseases and alien invasive aquatic species will reduce the availability of quantities of food, influence the stability of the production system and reduce food access through reduction of income from animal production, reduction of yields of food and cash crops, lowered forest productivity and changes in aquatic populations, as well as increased costs of control (FAO, 2008c).

Food prices may have an impact on food access of households, by limiting the acquisition of appropriate foods for a nutritious diet and the purchasing power of food aid programmes. Climate variability and change will likely contribute substantially to rising food prices (Cline, 2007; von Braun, 2007a). Temperature increases of more than 3°C may cause prices to increase by up to 40 percent (Easterling *et al.*, 2007).

Climate Change Impacts on Health and Food Utilization

Climate change may affect health outcomes and food utilization with additional malnutrition consequences. For example, populations in water-scarce regions are likely to face decreased water availability, particularly in the sub-tropics, with implications for the consumption of safe food and drinking water. Flooding and increased precipitation are likely to contribute to increased incidence of infectious and diarrhoeal diseases. The risk of emerging zoonosis may increase due to changes in the survival of pathogens in the environment, changes in migration pathways, carriers and vectors and changes in the natural ecosystems. The increased livestock population in new areas with concomitant disease threats need to be addressed.

Vector-borne Diseases

Climate change plays an important role in the spatial and temporal distribution of vector-borne diseases such as malaria. Climate change will have mixed effects on malaria distribution. In the long term, in some areas the geographical range will contract due to the lack of the necessary humidity and water for mosquito breeding.[5] Elsewhere, the geographical

[5] The northern limit of *Plasmodium falciparum* malaria in Africa is the Sahel, where rainfall is an important limiting factor in disease transmission

range of malaria will expand and the transmission season may be changed. It is estimated that in Africa climate change will increase the number of person-months of exposure to malaria by 16-28 percent by 2100 (McMichael, 2004). Malaria affects food availability, access and utilization of humans as well as of livestock.

Diarrhoeal Diseases

Most of the projected climate-related disease burden will result from increases in diarrhoeal diseases and malnutrition. Diarrhoeal diseases particularly affect nutrient absorption and food utilization. Associations between monthly temperature and diarrhoeal episodes and between extreme rainfall events and monthly reports of outbreaks of water-borne disease have been reported worldwide. Higher temperatures have been associated with increased episodes of diarrhoeal disease in adults and children in Peru, where diarrhoeal reports increased 8 percent for each degree of temperature increase (Checkley *et al.*, 2000). Diarrhoeal food-borne diseases such as *Salmonellosis* have been found to increase by 12 percent for each degree increase in weekly or monthly temperature above 6ºC ambient temperature (Kovats *et al.*, 2004). Increased ocean temperatures are leading to increased densities of *Vibrio* spp. (diarrhoeal agent) in shellfish (Zimmerman *et al.*, 2007).

Climate change is projected to increase the burden of diarrhoeal diseases in low-income regions by approximately 2-5 percent in 2020 and will impact low-income populations already experiencing a large burden of disease (Campbell-Lendrum *et al.*, 2003; McMichael, 2004). Countries with an annual GDP *per capita* of US$6,000 or more are assumed to have no additional risk of diarrhoea.

Food Contamination

Climate change and variability influences food contamination with non-infectious hazards such as biotoxins (e.g. mycotoxins or marine toxins) and chemicals, which may have an impact on food and animal feed stability, access and/or utilization.

Chemical food contamination may lead to recommendations to limit consumption of locally produced food in order to protect human health, thus reducing the dietary options of rural communities and indigenous peoples and compromising their traditional diets. For example, high contamination with dioxins associated with severe droughts in Central Asia have led to recommendations that poor rural communities limit the consumption of locally produced foods (Mountean *et al.*, 2003). Higher ocean temperatures are leading to increased levels of methyl mercury in fish and marine mammals, prompting recommendations to limit the intake of fish and marine fats by pregnant women and indigenous people in the polar regions (Kuhnlein *et al.*, 2002; Booth and Zeller, 2005).

Global Climate Change Impacts on Food and Water Security, Hunger and Nutrition

The impacts of global climate change on food and water security and safety and on nutrition are a great concern, particularly for developing countries. These changes, in sum, will have a profound impact on the fulfilment of human rights, in particular on the right to water which is closely linked to the right to food. By 2080, it is estimated that 1.1 to 3.2 billion people will be experiencing water scarcity (depending on the Special Report on Emissions Scenarios of socio-economic development); 200 to 600 million, hunger; and 2 to 7 million more per year, coastal flooding (Yohe *et al.*, 2007).

There are many pathways through which global climate change and variability may impact food and water security and safety and nutrition, including:

- increased frequency of extreme climatic events;
- sea-level rise and flooding of coastal lands, leading to salination and/or contamination of water and agricultural lands;
- impacts of temperature increase and water scarcity on plant or animal physiology;
- beneficial effects to crop production through CO_2 "fertilization;"
- influence on plant diseases and pest species and livestock diseases including zoonosis, leading to crop and animal losses;
- damage to forestry, livestock, fisheries and aquaculture; and
- impaired sustainability: socio-economic, political/armed conflict and demographic impacts.

Multiple socio-economic and environmental stresses, such as globalization, limited availability of water resources, loss of biodiversity, the HIV/AIDS pandemic and social and armed conflicts, are further increasing sensitivity to climate change and reducing resilience in the agricultural sector (FAO, 2003a). For example, health stressors such as HIV/AIDS, particularly in Southern Africa, are impacting agriculture through mass deaths of prime-age adults, which divert labour resources to caring, erode household assets, disrupt intergenerational transmission of agricultural knowledge and weaken the capacity of agricultural service providers, reducing resilience of smallholder agriculture to climate change.

Water Insecurity

Access to safe water remains an extremely important global health issue. More than 2 billion people live in the dry regions of the world and suffer disproportionately from malnutrition, infant mortality and diseases related to contaminated or insufficient water (WHO, 2005a).

The impacts of climate change on freshwater systems and their management are mainly due to observed and projected increases in temperature, sea-level and precipitation variability. Climate change is likely to exacerbate declining reliability of irrigation water supplies leading to increased competition for water for industrial, household, agricultural and ecosystem uses. In coastal areas, sea-level rise will extend areas of salination of groundwater, resulting in a decrease in freshwater availability (Kundzewicz *et al.*, 2007).

Water insecurity constitutes a serious constraint to sustainable development, particularly in savannah regions which cover approximately 40 percent of the world's land area (Rockstrom, 2003). Water scarcity may lead to multiple adverse health outcomes, including water-borne diseases, exposure to chemicals, vector-borne diseases associated with water-storage systems and malnutrition.

Links to Malnutrition

Attribution of current and future climate-change-related malnutrition burdens is problematic because the determinants of malnutrition are complex. Both acute and chronic nutritional problems are associated with climate variability and change.

Research and information on the links between climate-change-related food and water insecurity and malnutrition are necessary. There is also a need for methodologies to convert estimated losses in regional yields into estimates of changes in numbers of malnourished people. This has been recognized as one of the critical research needs by the 4th IPCC assessment report.

Drought and water scarcity can lead to negative effects on nutrition through increased infections, mortality and reduced food availability (in terms of both quantity and quality). In Gujarat, India, during the 2000 drought, diets were found to be deficient in energy and several vitamins. In this population, serious effects of drought on anthropometric indices may have been prevented by public-health measures (Hari Kumar *et al.*, 2005). The HIV/AIDS epidemic may have further amplified the effect of drought on nutrition in countries such as those in Southern Africa (Mason *et al.*, 2005). On the other hand, malnutrition increases the risk both of acquiring and of dying from an infectious disease. For example in Bangladesh both the impacts of drought and lack of food are associated with an increased risk of mortality from a diarrhoeal illness (Aziz *et al.*, 1990).

Children in poor rural and urban slum areas are at high risk of diarrhoeal disease mortality and morbidity. Childhood mortality due to diarrhoea in low-income countries, especially in sub-Saharan Africa, remains high and child malnutrition is projected to persist in regions of low-income countries. Children may survive the acute illness but may later die due to persistent diarrhoea or malnutrition.

People at Risk of Hunger

Overall, climate change is projected to increase the number of people at risk of hunger (FAO, 2005a). For example, climate change is projected to increase the percentage of the Malian population at risk of hunger from 34 percent to between 64 and 72 percent by the 2050s, although this could be substantially reduced by the effective implementation of a range of adaptive strategies (Butt *et al.*, 2005).

The increase in the number of people at risk of hunger due to climate change must be viewed within the overall large reductions due to socio-economic development. Compared to 820 million undernourished today, the IPCC Special Report on Emissions Scenarios (SRES) scenarios of socio-economic development *without* climate change project a reduction to 100-230 million (range is over A1, B1, B2 SRES scenarios[6]) undernourished by 2080 (or 770 million under the A2 SRES scenario) (Easterling *et al.*, 2007).

IPCC SRES scenarios *with* climate change project 100-380 million (range includes with and without CO_2 effects and A1, B1, B2 SRES scenarios) undernourished by 2080 (740-1,300 million under A2). Climate and socio-economic changes combine to alter the regional

[6] See Appendix 1 for an explanation of these IPCC scenarios.

distribution of hunger, with large negative effects on Sub-Saharan Africa (Easterling *et al.*, 2007).

Climate Change and Sustainable Development

Sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. On the other hand, climate change can slow the pace of progress towards sustainable development, either directly through increased exposure to adverse impact or indirectly through erosion of the capacity to adapt (Yohe et. al., 2007). Degradation of ecosystem services poses a barrier to achieving sustainable development and to meeting the MDGs (Millennium Ecosystem Assessment, 2005).

In order to meet the MDGs, it would be necessary to balance competition for land for agriculture, livestock, forestry and biofuels production. The expansion of livestock and biofuel sectors has a major role in deforestation and land degradation and thereby contributes to climate change.

Livestock's Long Shadow

The Livestock, Environment and Development (LEAD) Initiative has identified the livestock sector as a major player in climate change, responsible for 18 percent of GHG emissions measured in CO_2 equivalent. The livestock sector is a key player in increasing water use, accounting for over 8 percent of global human water use, mostly for the irrigation of feedcrops. It is probably the largest sectoral source of water pollution, contributing to eutrophication, human health problems, emergence of antibiotic resistance and many other problems. This sector may be the leading player in the reduction of biodiversity, since it is the major driver of deforestation, as well as one of the leading drivers of land degradation, pollution, climate change, sedimentation of coastal areas and facilitation of invasions by alien species (LEAD, 2006).

There are measures that can help reduce the overall impact of livestock production. Among them, sustainable intensification can reduce effects on deforestation, pasture degradation, wildlife biodiversity and resource use. Intensification should be addressed through technologies and policies that can enhance the overall sustainability of livestock production (Delgado *et al.*, 1999). Emissions can be reduced through improved diets to reduce fermentation in ruminants' digestive systems and improved manure and biogas management. Water pollution and land degradation can be tackled through better irrigation systems, better management of waste and improved diets that increase nutrient absorption.

The LEAD Initiative emphasizes the need to approach these problems using economic tools such as removing damaging subsidies and establishing correct pricing of water, grazing and waste, as well as payment for environmental services. LEAD proposes using the Kyoto Protocol's Clean Development Mechanism to finance the spread of biogas and silvopastoral (mixed herding and tree cultivation) initiatives involving afforestation and reforestation. In order to properly address all these issues, there is a need to develop suitable institutional and policy frameworks at the local, national and international levels (LEAD, 2006).

Social Impacts of Climate Change

Implications for Rural and Urban Populations

Climate change could adversely impact rural populations' food security through reduced crop yields, geographical shifts in optimum crop-growing conditions, reduced water resources for agriculture and human consumption, loss of cropping land and yields through floods, droughts and sea-level rise and increased rates of adverse health outcomes, including diarrhoeal diseases and malnutrition (Confalonieri *et al.*, 2007).

Smallholder and subsistence farming households in the dryland tropics are particularly vulnerable to increasing frequency and severity of droughts. These may lead to a higher likelihood of crop failure; increased diseases and mortality of livestock, indebtedness, out-migration and dependency on food relief; and impacts on human development indicators such as health, nutrition and education (Easterling *et al.*, 2007).

Drought and the consequent loss of livelihoods is also a major trigger for population movements, particularly rural to urban migration. Population displacement to urban slums can lead to increases in diarrhoeal and other communicable diseases and poor nutritional status resulting from overcrowding and a lack of safe water, food and shelter. Recently, rural to urban migration has been implicated as a driver of HIV transmission and unplanned urbanization has contributed to the spread of *Plasmodium vivax* malaria and dengue fever in urban slums (Confalonieri *et al.*, 2007).

Environmental Refugees and Social Conflict

The UN projects that there will be up to 50 million people escaping the effects of environmental deterioration by 2020. The spectrum of associated health risks includes food and water emergencies and infectious, nutritional and mental diseases. By increasing the scarcity of basic food and water resources, environmental degradation increases the likelihood of violent conflict (LEAD, 2006). The Southern African Millennium Ecosystem Assessment suggests a bidirectional causal link between ecological stress and social conflict: conflict may cause environmental degradation but the latter may also trigger conflict (Biggs *et al.*, 2004). Conflict could emerge as a result of climate change environmentally induced migration. Political refugees from violent regions are more likely to become involved in militant activities. (Gleditsch *et al.*, 2007).

In sub-Saharan Africa, where cropping and grazing are often practised by different ethnic groups, the advance of crops into pasture land often results in conflict, as shown by major disturbances in the Senegal river basin between Mauritania and Senegal and in North-east Kenya, between the Boran and the Somalis (Nori *et al*,. 2005). According to UNEP, the conflict in Darfur has been driven in part by climate change and environmental degradation, which threaten to trigger a succession of new wars across Africa (UNEP, 2007) (see Box 4.2).

Adaptation and Mitigation Strategies

Adaptation Strategies

Adaptation strategies to climate change for food security could be autonomous or planned. Autonomous adaptation is the ongoing implementation of existing knowledge and technology in response to the changes in climate experienced. Planned adaptation is the increase in adaptive capacity by mobilizing institutions and policies to establish or strengthen conditions favourable for effective adaptation and investment in new technologies and infrastructure.

Autonomous Adaptation

Many of the autonomous adaptation options are extensions or intensifications of existing risk-management or production-enhancement activities for cropping systems, livestock, forestry and fisheries production (Easterling *et al.*, 2007).

While autonomous adaptations have the potential for limiting damage from climate changes, there has been little evaluation of how effective and widely adopted these adaptations may actually be, given the complex nature of agriculture decision-making, the diversity of responses within regions and the possible interactions between different adaptation options and economic, institutional, human and environmental health and cultural barriers to change among others (Easterling *et al.*, 2007).

Box 4.2: Climate Change and Conflict in Sudan (UNEP 2007)

Environmental issues and competition over agricultural land use are important causative factors in the instigation and perpetuation of conflict in Sudan. Resource-based conflicts between traditional farmers and nomadic herders have been present in Sudan throughout recorded history. The introduction of mechanized rain-fed agriculture systems that compete for resources has been found to exacerbate and trigger conflict.

A UNEP post-conflict environmental assessment indicates that there is a very strong link between land degradation, desertification and the conflict in Darfur. Tensions between farmers and herders over disappearing pasture and evaporating water holes threaten to reignite other long-standing conflicts within Sudan. The southern Nuba tribe, for example, has warned it could re-start the war as Arab nomads, pushed southwards into their territory by drought, are cutting down trees to feed their camels.

The assessment reveals that in the past 30 years, rainfall has dropped by 16 percent in southern Darfur and 34 percent in northern Darfur; the desert climate in Sudan has advanced southwards by 100 km over 40 years; deforestation has been accelerated while underground aquifers are being drained; and yields of the local staple, sorghum, could drop by 70 percent by 2060.

At the same time the Darfur conflict has exacerbated Sudan's environmental degradation, forcing more than two million people into refugee camps. Currently, Sudan has the world's largest population of displaced persons, with over five million internally displaced persons and international refugees. This massive population displacement has led to human rights abuses, conflicts over resources, food insecurity and a high prevalence of severe malnutrition.

Adaptation strategies to climate change for food security and nutrition are particularly complex and often have limitations. For example, shifts to drought-resistant and less labour-intensive crops such as cassava or sweet potatoes in African countries that are severely affected by droughts or HIV/AIDS should take into consideration that these crops could be less nutritious. Efforts to breed micronutrient-dense staple crops should be integrated with climate change adaptations such as breeding drought- and water-tolerant varieties. Similarly, more heat-tolerant native livestock breeds often have lower levels of productivity.

Planned Adaptation

Autonomous adaptations may not be fully adequate for coping with climate change, thus necessitating deliberate, planned measures. Many options for policy-based adaptation to climate change have been identified for agriculture, forests and fisheries. These can either involve adaptation activities such as developing infrastructure or building the capacity to adapt in the broader user community and institutions, often by changing the decision-making environment under which management-level, autonomous adaptation activities occur. Policy-based adaptations to climate change will interact with, depend on, or perhaps even be just a subset of policies on natural resource management, human and animal health, governance and human rights, among many others (Yohe *et al.*, 2007).

Mitigation Strategies

Agriculture, land use and waste account for some 35 percent of the GHG emissions that contribute to climate change (Stern, 2006). At the same time, improved agricultural practices can make a significant contribution at low cost to increasing soil carbon sinks and to GHG emission reductions (Metz *et al.*, 2007). Key mitigation strategies in the agriculture sector include: improved crop and grazing land management to increase soil carbon sequestration, restoration of degraded lands, improved rice cultivation and livestock and manure management to reduce methane emissions and improved nitrogen fertilizer management to reduce nitrous oxide emissions in some agricultural systems (Metz *et al.*, 2007).[7]

Improved management of tropical land offers a promising agriculture-based mitigation strategy. Reduced deforestation, more sustainable forest management and adoption of agroforestry (integration of tree and crop cultivation) have particularly good potential to capture significant amounts of carbon and other GHGs and, at the same time, to contribute to poverty reduction (CGIAR, 2008). Cultivation of productive forage grasses that sequester carbon can be combined with tree planting in silvopastoral systems of cultivation. Agroforestry not only captures carbon and helps maintain soil health through nitrogen fixation and use of cuttings as fertilizer and mulch, but it also provides fodder, fruit, timber, fuel, medicines and resins. This can help improve nutrition in cultivator households through higher incomes and by directly adding diversity to diets (CGIAR, 2008).

Agricultural research can help create new technologies that will facilitate agriculture-based mitigation strategies. For example, research is underway at CGIAR-supported international agricultural research centres to breed new, drought-tolerant varieties of sorghum that will provide food, feed and fuel all from a single plant, without current tradeoffs among uses.

[7] Ordinarily, nitrogen fertilizer tends to break down into nitrous oxide, a greenhouse gas that also contributes to ozone depletion and nitrate, which aids crop growth, but also contaminates streams and groundwater, thereby threatening health and nutrition.

In the waste management sector, existing technologies for mitigation are available that can contribute to improved public health as an input into good nutrition. These include waste incineration with energy recovery, composting of organic waste, controlled waste water treatment and recycling to minimize waste (Metz *et al.*, 2007).

5. Nutrition and Bioenergy

Overview

Bioenergy is energy produced from organic matter, or biomass. Biofuels are energy carriers derived from biomass. A wide range of biomass sources can be used to produce energy. Some have been used for millennia, such as fuelwood, charcoal and animal dung. Newer sources include ethanol, biodiesel and biogas. These new sources depend on natural vegetation, crops grown specifically for energy, or agricultural or other biological forms of wastes and residues. Processing makes these biofuels cleaner and more efficient than traditional biofuels and if they are produced in a way that reduces net carbon emissions, they could contribute to mitigating climate change. Ethanol, for instance, can be made from sugars (e.g., sugar beets, sugarcane and sweet sorghum), grains (such as maize and wheat), root crops (such as cassava), cellulose and waste products. Biodiesel is made from vegetable oils or animal fats. Bioethanol production is mostly concentrated in Brazil and the United States, while the European Union produces most biodiesel (FAO, 2008d, 2008e; von Braun, 2007b).

Rising petrol prices have made the new biofuels an attractive alternative energy source. Technological development has recently made them more cost-effective and energy-efficient. Nevertheless, biofuels offer only a very small gain in energy efficiency over petrol and their production only minimally reduces GHG emissions. Research is underway to develop cellulosic biofuels from low value non-food crops, such as grasses or wood. These feedstocks are, however, more difficult to process than starch or sugar crops and it is not clear that their production will expand significantly in the near future (von Braun, 2007b; FAO, 2008e).

Nutrition Impacts

Biofuel production can have negative impacts on nutrition through three main pathways: increased GHG emissions, direct effects on health and sanitation and reduced food availability and associated price effects. To the extent that biofuel production exacerbates climate change, for example, because of burning of forests to clear land for production of bioenergy crops (UN-Energy, 2007; Easterling *et al.*, 2007), that will indirectly contribute to malnutrition, as explained in Chapter 4.

Growth of the biofuel sector may lead to water shortages and water contamination. Use of sugarcane as a feedstock, as in Brazil, is particularly water-intensive. The availability of water in developing countries is a cause of concern for agricultural productivity and for health and sanitation. In underdeveloped rural areas, where there is very high demand for access to water for irrigation, cooking and drinking, bioenergy crop production would compete for scarce water supplies. An acceleration of biofuel expansion in areas requiring additional irrigation water from already depleted aquifers could cause much greater water scarcity problems and further push up cereal prices. Poorly managed use of inputs to cultivate energy crops could pollute drinking water, adversely affecting human and animal health (UN-Energy, 2007; Easterling *et al.*, 2007; Rosegrant *et al.*, 2006).

Diversion of Food and Feed to Fuel and Rising Food Prices

Biofuel demand puts additional pressure on limited land and water resources. Increasing prices are leading to the diversion of food and feed crops to biofuel production, with some 24 percent of the 2008 U.S. maize crop projected to go into ethanol production (Trostle, 2008). In developing countries, there is intense pressure on farm land from current food crop needs, but expanded bioenergy crop production could divert land away from foods crops.

Diverting cereal from food and feed to fuel use has the potential to reduce food availability. In addition, there is a risk that food and feed production will be consigned to less productive land, which may result in lower yields, while the most fertile hectares support high-value fuel crops.

Related to such effects, IFPRI estimates that rising bioenergy demand contributed significantly to the jump in global food prices between 2000 and 2007. Increased biofuel demand, compared with previous historical rates of growth, is estimated in IFPRI's analysis to have accounted for 30 percent of the increase in weighted average grain prices. The impact was even higher for maize prices, for which growing biofuel demand is estimated to have accounted for 39 percent of the real increase. The figures are 21 percent for rice, 22 percent for wheat prices (Rosegrant, 2008).

A rise in the food bill for households that are net buyers of food will tend to result in reduced demand for foods of higher value and increased demand for staples within a given set of taste and food preferences. Bennett's Law describes this relationship between income and the share of starchy staples in the diet (Bennett, 1941). In many situations, depending upon local market conditions, food price increases may lead not only to a reduction in the average number of meals and the amount of food consumed but also to the substitution of cereals, root crops and cheaper cuts for higher value foods such as animal products, legumes, processed foods, fruits and vegetables. For rural communities, greater reliance upon gathered seasonal wild foods may occur. As prices continue to rise, poor people will experience a worsening of dietary quality and micronutrient intake and extremely poor people will experience an additional decrease in food energy consumption. Decreased overall food consumption in terms of calories, as well as of other essential nutrients including protein, fat and micronutrients, can lead to weight loss; impaired developmental, mental and physical growth in children; and either sub-clinical or clinical micronutrient deficiency in all age groups. For adults, prolonged periods of inadequate nutrition reduce productivity through reduction in the physical ability to do work both by increasing the number of days taken by sick leave and reducing the rate and the amount of work that can be accomplished (Geissler and Powers, 2005). As *The Economist* magazine (2008) recently editorialized, this can have devastating effects on nutrition, poverty and political stability:

"Famine traditionally means mass starvation. The measures of today's crisis are misery and malnutrition. The middle classes in poor countries are giving up health care and cutting out meat so they can eat three meals a day. The middle poor, those on $2 a day, are pulling children out of school and cutting back on vegetables so they can afford rice. Those on $1 a day are cutting back on meat, vegetables and one or two meals, so they can afford one bowl. The desperate – those on 50 cents a day – face disaster.

Roughly a billion people live on $1 a day. If, on a conservative estimate, the cost of their food rises 20% (and in some places, it has risen a lot more), 100 million people could be forced *back to absolute poverty. In some countries, that would undo all the gains in poverty reduction they have made during the past decade of growth. Because food markets are in turmoil, civil strife is growing; and because trade and openness itself could be undermined, the food crisis of 2008 may become a challenge to globalisation.*"

We can examine the impact of increased food prices using the price elasticities of different food groups. For example, we can compare South Africa and Malawi: South Africa is a middle-income, net-maize exporting country. Though clearly not all households within South Africa are middle-income and food-secure, we can get an impression of food security status from the country's aggregate food balance sheet data. Malawi, in contrast, is a net maize importer with high prevalence of food insecurity and malnutrition. Figure 9 shows the different effects in the two countries of a 30 percent price increase for all food groups (a modest escalation compared to the actual price rises of 2006 to early 2008). Food and calorie data are taken from FAO country food balance sheets.[8] Elasticites were estimated using IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).[9] In this figure, own-price elasticities by country and specific food groups are used.

The baseline data for Malawi in 2003 estimate *per capita* calorie consumption to be just above the 2,100 kilocalorie daily minimum required for an adult. Though we see slivers of consumption of fruit, dairy and meat, the bulk of calories come from cereals and other starchy staples and pulses, indicating a lack of dietary diversity. The price increase squeezes consumption in all food groups, worsening dietary diversity. The largest drop is seen in cereals and starchy roots, significantly decreasing calorie consumption well below the required minimum.

On the other hand, South Africa starts out well above the minimum daily calorie requirements, with much higher consumption of meat as well as dairy and eggs, though still limited consumption of fruits and vegetables. With the price increase, calorie consumption is shown to decrease in South Africa as well; however, the higher status at baseline of food energy consumption and dietary diversity mean that the impacts are not as damaging for nutrition status; calorie consumption remains close to the minimum required level and meat and dairy products still form a substantial part of the diet.

Figure 9 gives a revealing snapshot of how food price increases will have different effects on nutrition and food security depending on the baseline consumption basket. However, actual household food budgeting is more complex than a simple response to own-price elasticity. Furthermore, price changes due to rising biofuel demand and other factors are not equal across all foods. Thus the changes in price of one food may impact spending on another food, as households maximize utility according to budget and preferences. For instance, when the price of maize rises, rather than simply decreasing consumption of starchy staples, a household may substitute another less preferred staple. Figure 10 compares the impact on calorie intake from higher prices using own-price and cross-price elasticities. Cross-price elasticities show the impact of consumers substituting other starchy staples for maize when its price increases by 30 percent. Note how calories from the cereals and starchy roots food group increase slightly when cross-price elasticities are used to allow for substitution.

[8] These data can be accessed at HTTP://FAOSTAT.FAO.ORG/SITE/345/DEFAULT.ASPX.

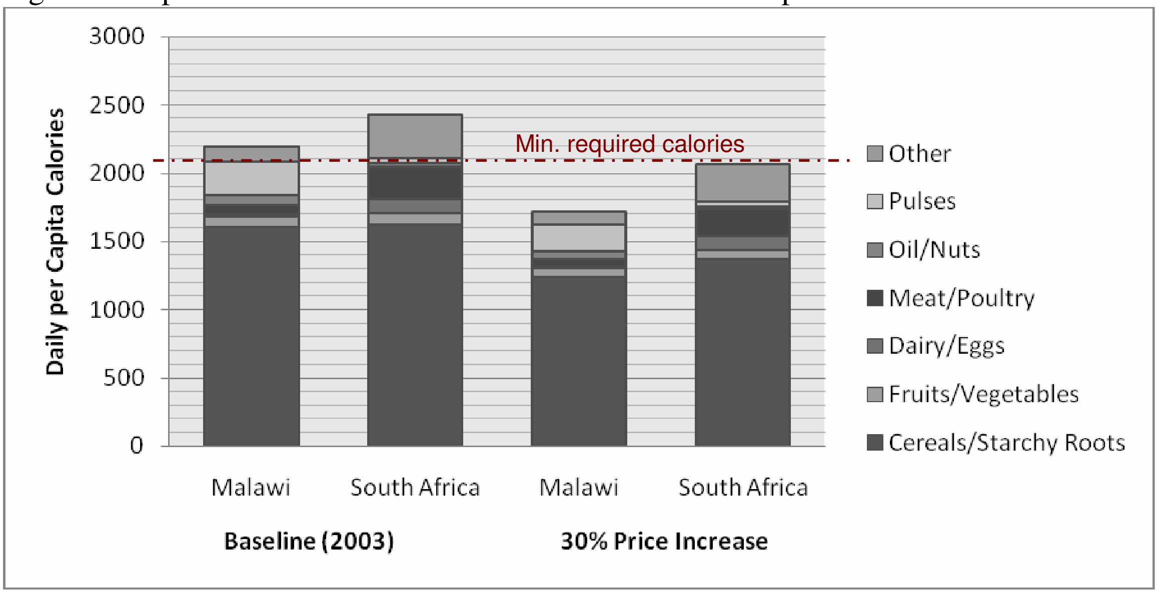
[9] For details on IMPACT, see Appendix 2.

Looking ahead, Figures 11 and 12 report IMPACT projections of the effects of two different scenarios of biofuel demand on calorie availability and underweight preschool children in 2020 (as compared to 2000). The first scenario is based on actual biofuel investment plans, with assumed biofuel expansion in countries that have not specified plans. The second scenario assumes a doubled rate of biofuel expansion (von Braun, 2007a).

Mitigation of Negative Impacts of Biofuels

Appropriate policies can make bioenergy development more pro-poor and environmentally sustainable. Poor farmers might be able to grow energy crops on degraded or marginal land not suitable for food production, but appropriate soil and fertilizer management practices will have to be tailored to soil type and climatic conditions, otherwise bioenergy production may aggravate land degradation, generate GHG emissions and cause environmental problems through soil erosion and degradation of water quality. Also, further investment is needed in developing technologies to convert cellulose to energy. This could provide developing-country farmers, including smallholders, with a use for crop residues like stalks and leaves, which would be converted into ethanol for electricity, thereby benefiting both poor farmers with additional income and also poor consumers with cheaper energy. This has positive food security implications because it has the potential to improve access to food and it would also

Figure 9: Impact of Food Price Increases on Calorie Consumption



Source: Authors' calculations using FAOSTAT database and IFPRI IMPACT model.

reduce the impact of biofuel production on food systems and prices (von Braun and Pachauri, 2006). However, if the valuation of crop residues for biofuel increases significantly, this might reduce the availability of green manure for fertilizer.

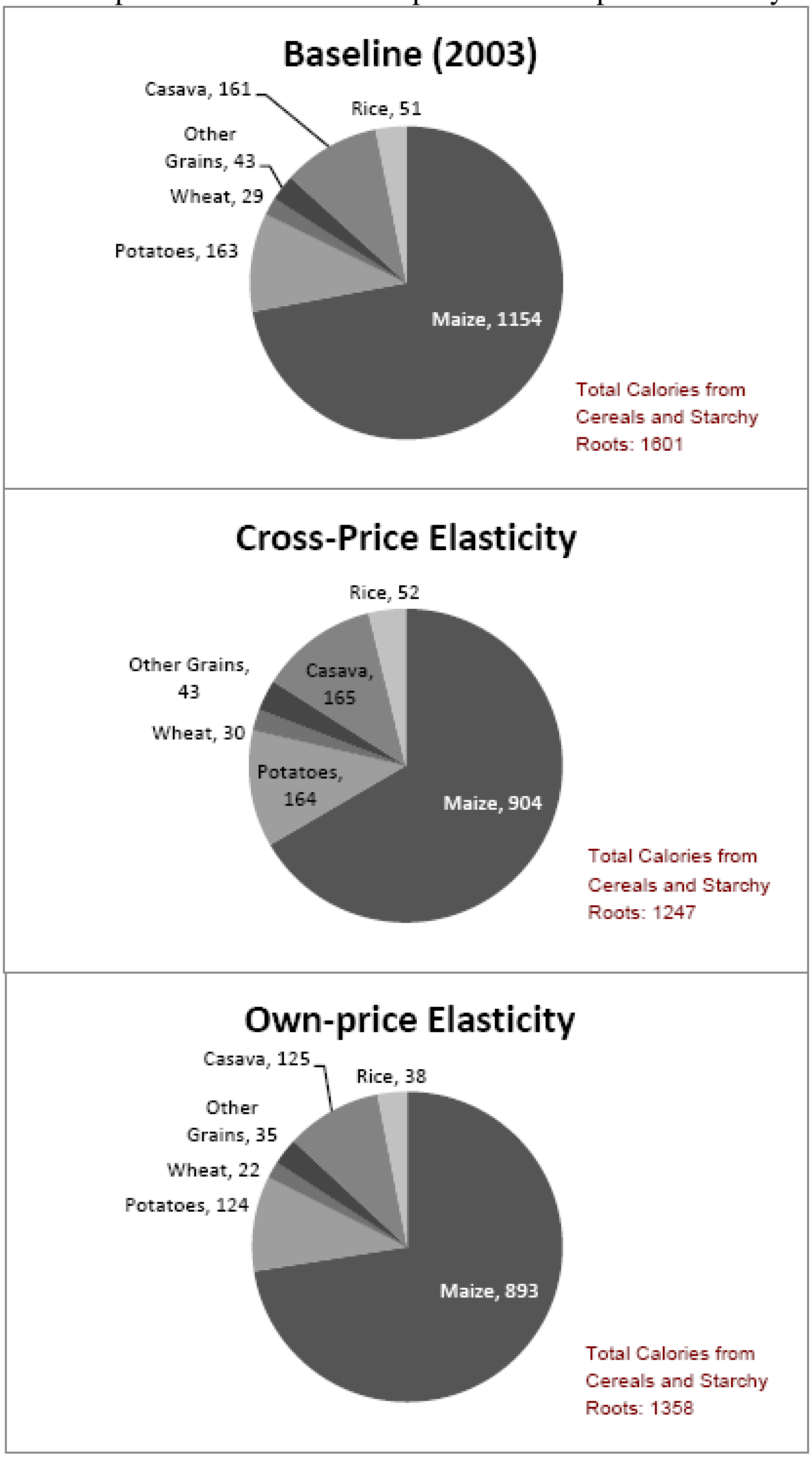
Because biofuel production is labour-intensive, it could be a boon to rural areas with abundant labour. In Brazil, one study showed that in 1997, the ethanol sector employed about one million people. Thirty-five percent of these jobs were temporary harvesting jobs employing many poor migrant labourers from the northeast (Brazil's poorest region), but 65 percent were permanent (von Braun and Pachauri, 2006). This also has positive food-security implications.

Smaller-scale and rural-based production will open up opportunities for biofuel to be pro-poor. Organizing groups of smallholders through contract farming schemes to grow and market biomass to processing plants may be most effective for this (Hazel, 2006). For example, substantial investments in biofuels are currently in process in Mozambique. Some 6 million hectares are already planted to biofuel crops and the government has received requests for use rights (as all land is state-owned) for more than 12 million additional hectares for this purpose. Preliminary results from an IFPRI macroeconomic analysis suggest that expansion via either plantation production of sugarcane for ethanol or outgrower cultivation of an oil-bearing crop called *Jatropha curcas* for biodiesel will lead to increased welfare and reduced poverty, due to income-earning opportunities, with positive implications for food security (Arndt *et al.*, 2008).

However, technologies and institutional arrangements are important to determining the impact on poverty. The outgrower scheme is considerably more pro-poor, as it uses more unskilled labour and permits smallholders, rather than plantation owners, to reap land rents. Moreover, such schemes have the potential for technology to spill over to other crops, including food crops, with additional growth and poverty reduction benefits resulting, as well as increased food availability. Jatropha also is more environment-friendly than sugarcane, as it requires far less water, grows in infertile soil, even in drought conditions, animals do not graze on it and it produces non-polluting biodiesel (Arndt *et al.*, 2008).

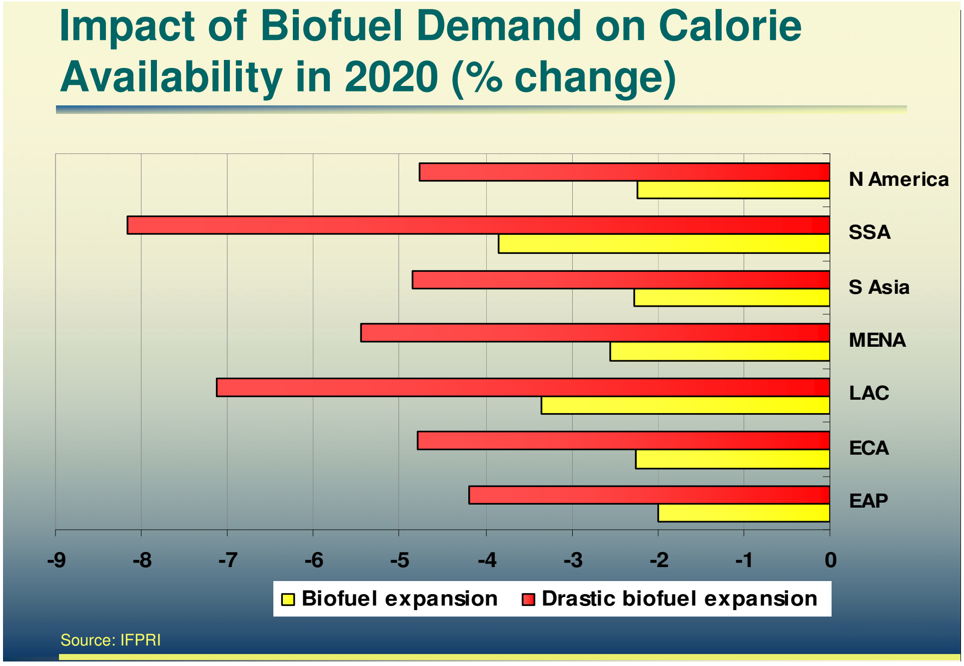
A considerable body of research indicates that women are more likely than men to use income for the wellbeing of children, including nutrition (Quisumbing, 2003). There may be barriers to female farmers taking advantage of opportunities created by biofuel demand. Women often have less access than men to land, water, credit, inputs and services, even when they are responsible for much of the agricultural work. In Cameroon, for instance, women provide 75 percent of the agricultural labour, but own less than 10 percent of the land. In Brazil, women own 11 percent of the land. These disparities make it difficult for women and especially female heads of household, to benefit from energy crop production. Even use of marginal lands for biofuel crops may work against women. Such land is often considered common property and in both South Asia and West Africa, women and children are responsible for gathering on and use of common property resources, but women often do not have decision-making authority over such resources. Thus, expansion of bioenergy crop production on such land could adversely affect women's ability to produce food (Rossi and Lambrou, 2008).

Figure 10: Impact of Price Increase on Root and Grain Consumption in Malawi: Cross-price vs. Own-price Elasticity



Source: Authors' calculations.

Figure 11


Impact of Biofuel Demand on Calorie Availability in 2020 (% change)
N America
SSA
S Asia
MENA
LAC
ECA
EAP
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
Biofuel expansion
Drastic biofuel expansion
Source: IFPRI

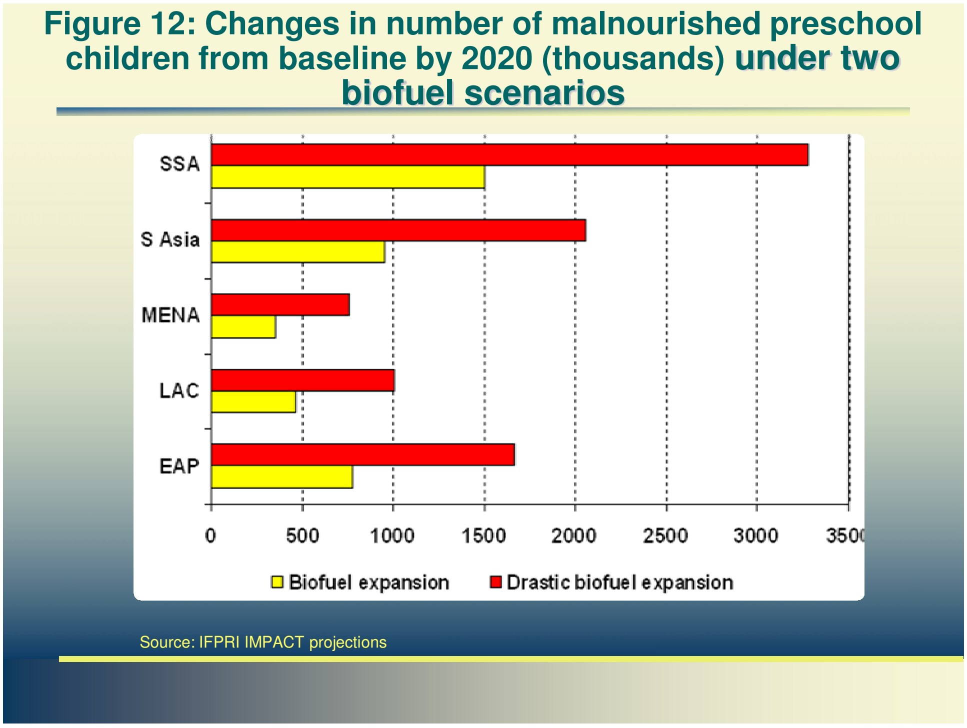


Figure 12: Changes in number of malnourished preschool children from baseline by 2020 (thousands) under two biofuel scenarios
SSA
S Asia
MENA
LAC
EAP
0
500
1000
1500
2000
2500
3000
Biofuel expansion
Drastic biofuel expansion
Source: IFPRI IMPACT projections