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Addressing the challenges of climate change and biofuel production for food and nutrition security

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ABSTRACT

More than one billion people are suffering hunger and malnutrition in 2009. Food security has deteriorated since 1995 and reductions in child malnutrition are proceeding too slowly to meet the Millennium Development Goal (MDG) target of halving hunger by 2015. Three major challenges threaten current and future efforts to overcome food insecurity and malnutrition: climate and global environmental change and the consequent loss of ecosystems' services, the growing use of food crops as a source of fuel and the food and financial crises. This paper reviews and analyses the current and projected effects of climate change and bioenergy on nutrition and proposes policy recommendations to address these challenges. The first section of the review lays out the public health and socio-economic consequences of malnutrition and explores causes and costs. The paper then analyses the implications of climate and global environmental change and biofuel production for food security and nutrition, addressing strategies for adaptation and mitigation. This analysis includes a number of important socio-economic factors, besides climate change and biofuel production, that are currently impacting food and nutrition security, and that will likely contribute to future effects. The paper concludes with a series of policy proposals and recommendations to adapt to and mitigate the impacts of climate and global environmental change placing human rights in the centre of decision making. These proposals include a number of options for improving sustainability and food and nutrition security while addressing the links between climate change and bioenergy demand.

1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) estimates than more than one billion people are undernourished worldwide in 2009; this is about 100 million people more than in 2008, around one-sixth of all humanity (FAO, 2009a).

Despite a dozen years of solemn pledges by global leaders to take action to drastically decrease world hunger, promises made at the World Food Summit in 1996, the Millennium Summit of 2000 and high-level follow-up meetings held during the course of the present decade, food security in the world has deteriorated since 1995. This has contributed to the unacceptably slow pace for achieving the Millennium Development Goals (MDGs) of cutting the prevalence of malnutrition and reducing hunger by half by 2015. Between 1990 and 2005, prevalence of underweight children in the developing world only fell from 30% to 23% (United Nations Standing Committee on Nutrition, 2004). At that rate, it will not be possible to meet the MDG targets.

Three major challenges have arisen that threaten to drastically complicate efforts to overcome food insecurity and malnutrition: climate change, the growing use of food crops as a source of biofuel and soaring food prices. As a result of climate and global environmental changes such as land degradation and changes in hydrological resources, essential ecosystems' services, agricultural production systems and access to food are likely to decline drastically particularly in Sub-Saharan Africa and South Asia (Easterling et al., 2007). This will increase the risk of hunger and malnutrition in the two regions that are home to three of every five undernourished people. Furthermore, climate change is expected to exacerbate undernutrition through its effects on illnesses, such as diarrhoea and other infectious diseases (Confalonieri et al., 2007). Projected increases in the frequency and intensity of droughts and floods and their potential impact on crops and livestock losses are especially worrisome (FAO, 2008b).

Rising bioenergy demand is likely to affect nutrition through a number of pathways. Production of staple food crops, particularly maize, for biofuel markets can have a negative impact on the availability of grain for direct consumption as food and for use as feed

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for livestock to produce meat and milk. As demand for biofuels is likely to remain high and to be met with food crops for the foreseeable future, this may lead to the clearing of biodiverse-rich land for cultivation, including tropical forests and wetlands. Slash and burn methods will mean additional emissions of the greenhouse gases (GHGs) that cause global warming. Intensified production of energy crops such as sugarcane, as well as increased cereal production to meet competing demand for food, feed, fibre and fuel, may mean excessive or poorly managed use of water and farm chemicals, causing illnesses and deterioration in environmental health, with negative implications for nutrition.

In addition, bioenergy demand is a significant driver of recent dramatic increases in food prices. According to an analysis by the International Food Policy Research Institute (IFPRI), it accounted for 30% of the escalation in global cereal prices between 2000 and 2007 and for nearly 40% of the increase in the real global price of maize (Rosegrant, 2008). Increased food prices are likely to result in calorie deficits and even more importantly they are likely to cause micronutrient malnutrition, as diets of low-income people shift from consumption of micronutrient-rich foods such as animal products, fruit and vegetables, towards consumption of less expensive staple foods. The growing use of food crops to produce biofuels has been considered by the former Special Rapporteur on the Right to Food of the UN Human Rights Council as: "*A crime against humanity*" (Ferrett, 2007).

Nevertheless growing demand for bioenergy can also offer opportunities to smallholder farmers. If the right policies are in place, these farmers may be able to boost their incomes and take advantage of technological spillovers to improve food crop production alongside their energy crops. This could have positive implications for both food availability and access, key inputs for good nutrition.

This paper examines the consequences of climate change and rising bioenergy demand for sustainable development, food and nutrition security and proposes policy recommendations to address these challenges.

2. Methods

In preparation for the June 2008 High-Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy, the Food and Agriculture Organization of the United Nations (FAO) organized several expert consultations on the impacts of climate change on diverse issues related to food security. FAO also commissioned background policy papers on the impacts of climate change and bioenergy on nutrition, food safety and human health. This paper reviews and analyzes the outcomes of these FAO expert consultations; the results of systematic bibliographic searches on the effects of climate change and bioenergy on food security, health and nutrition; and the outcomes of consultations with researchers in the field of food and nutrition security.

The analysis of the impacts of climate change on food and nutrition security follows the four-dimensional food security framework defined by FAO: (1) food availability which includes food production and trade; (2) stability of food supply; (3) access to adequate quantities and varieties of safe, good quality food and (4) food utilization which refers to food safety and nutrition (FAO, 2000; Schmidhuber & Tubiello, 2007). Food security is a key factor in good nutrition, along with health, sanitation and care practices.

The recommendations of this paper follow the human rights-based approach applied to address ethical issues on agriculture and sustainability (Von Braun & Brown, 2003). The human right-based approach provides a conceptual framework that is normatively based on international human rights standards and operationally directed to promoting and protecting human rights. This approach can provide the tools for balancing many factors, reaching easier consensus and conducting a more effective and complete analysis, as well as a more authoritative basis for advocacy and for claims on resources. The human rights framework also offers the opportunity to embrace environmental concerns more explicitly and is thus highly relevant to assessing the challenges of climate change and bioenergy for nutrition.

Definitions of terms related to food insecurity, malnutrition, undernourishment, nutritional status, stunting etc. correspond to the FAO Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) Glossary (FAO FIVIMS, 2010). According to FAO, food insecurity is a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life.

Undernourishment measures aspects of food security and exists when energy intake is below the minimum dietary energy requirement which is the amount of energy needed for light activity and a minimum acceptable weight for attained height. Although undernourishment is based on national level data, it may be used as a proxy for food consumption in contexts where regional or household level data are unavailable or unreliable. It varies by country and from year to year depending on the gender and age structure of the population. Malnutrition is a broad term that refers to all forms of poor nutrition. Malnutrition is caused by a complex array of factors including dietary inadequacy (deficiencies, excesses or imbalances in energy, protein and micronutrients), infections and socio-cultural factors. Malnutrition includes undernutrition as well as overweight and obesity. Definitions of the terms related to climate such as climate change and variability, vulnerability, adaptation and mitigation strategies correspond to those included in the Glossary of the Intergovernmental Panel for Climate Change (Baede, 2007). According to the IPCC, climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate variability refers to variations in the mean state and other statistics (such as standard deviations and the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events (Baede, 2007).

3. Food and nutrition security: reasons for action

World hunger reached a historic high in 2009, with more than one billion people living in chronic hunger (FAO, 2009a). During the World Summit on Food Security in 2009, FAO's director general called it to the world's attention that "*every six seconds a child dies of hunger in the world*" and called on countries to agree on immediate action to reverse the situation and to end the scourge of hunger and malnutrition (FAO, 2009b). However, unless substantial and sustained remedial actions are taken immediately, such as development of policies and programmes for improving food and nutrition security and adoption of adaptation and mitigation strategies for climate change, the World Food Summit target of halving the number of hungry people in the world by half by 2015 will not be reached (FAO, 2009a).

3.1. Public health consequences of malnutrition

Malnutrition is defined as an abnormal physiological condition caused by deficiencies, excesses or imbalances in energy, protein and/or other nutrients (FIVIMS, 2009). Appropriate intake of calories does not guarantee adequate intake of essential micronutrients. Micronutrient malnutrition, sometimes referred to as "hidden hunger", has serious public health consequences. For example, over one billion people consume diets deficient in iron. Iron deficiency is responsible for roughly half of the global prevalence of anaemia. Iron deficiency anaemia causes 20% of global maternal mortality, can impair children's health and development and has been shown to reduce adult work performance and labour productivity (Trowbridge & Martorell, 2002). Another common micronutrient disorder, Vitamin A deficiency, affects 40 million people worldwide. Vitamin A deficiency is associated with immunological impairment, increased risk of morbidity and mortality, and is a direct cause of blindness (WHO, 2001). It is also entirely preventable if intake is adequately diversified and sufficient in beta and other carotenes.

In addition to micronutrient deficiencies, chronic malnutrition and poor quality diets are endemic in many poor countries. Stunting is defined as low height for age, reflecting a sustained past episode or episodes of undernutrition (FAO FIVIMS, 2010). It is measured as two or more standard deviations below the international reference population, and can be qualified as mild, moderate or severe. Stunting is a common indicator of chronic undernutrition in children. A stunted child is likely to have experienced a long-term deficit in overall caloric intake, sometimes beginning in utero. Stunted children also often suffer from specific micronutrient deficiencies. One in three developing-country children under the age of five – 178 million children – suffer from mild, moderate or severe stunting due to chronic undernutrition and poor quality diets. Eighty percent of these children live in just 20 African and Asian countries. Even mild stunting is associated with higher rates of illness and death, impaired cognitive function and reduced school performance in children (Black et al., 2008).

Chronic malnutrition during the first 2 years of life usually results in irreversible harm. Furthermore, at each stage in the lifecycle, malnutrition has consequences for each successive stage and/or the next generation. For example, the 15–30 million children a year are born with low birth weights (LBW) (i.e., less than 2.5 kg) as a result of inadequate maternal nutrition before and during pregnancy. LBW babies have higher morbidity and mortality rates than normal weight babies. Moreover, those LBW babies who manage to survive infancy remain susceptible to underweight and infection in childhood, thus increasing risk of compromised cognitive function and physical development. LBW babies who are female often grow up to be undernourished women who then give birth to their own LBW babies (UNICEF, 2009).

In addition to the direct effects of malnutrition on health, malnutrition also interacts with many infectious diseases increasing severity of symptoms and raising mortality rates. For example, HIV/AIDS interacts negatively with malnutrition. Poor nutrition can accelerate the spread of HIV, both by increasing people's vulnerability 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. In addition, HIV impairs the immune system and so can lead to additional infections (Gillespie & Kadiyala, 2005).

3.2. Socio-economic consequences of malnutrition

Taking action to reduce malnutrition is not only a moral imperative; it is also integral to sustained economic growth and national development. The economic costs of hunger include: (1) direct costs of lost productivity, lost earnings and the medical care required to treat those suffering from malnutrition and associated diseases and (2) indirect costs due to compromised cognitive and physical development. For example, individual productivity losses of up to 8% have been attributed to malnutrition in countries worst affected in South Asia such as Bangladesh (Alderman, 2005). This forfeit in lifetime earnings is equivalent to a decrease in gross domestic product (GDP) of up to 3% (World Bank, 2008). Further, a 2004 FAO report attributed up to 14% in reduced productivity and earnings to stunting in children (FAO, 2004). This figure is especially pertinent in terms of *future* development goals, since nearly one-third of all children in the developing world are currently stunted. Decelerated economic growth and compromised human capital are negative externalities associated with each cohort of children whose physical development is stunted and whose cognitive function is impaired.

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. Food insecurity, ill health and sub-optimal caring practices are all closely related to poverty. Malnutrition reflects and contributes to inequity, disproportionately affecting poor, marginalized and extremely vulnerable groups. Poor people generally consume fewer than 2100 kcal per day. Low-income households experience significantly higher rates of pre-schooler stunting and illness and are less able to adopt health promoting caring practices than better-off families.

Taken together, chronic and acute child malnutrition, low birth weights, sub-optimal breastfeeding and micronutrient deficiencies lead to the deaths of 3.6 million mothers and preschool children each year, accounting for 35% of all pre-schooler deaths and 11% of the global disease burden (Black et al., 2008). Difficult pregnancies and illnesses due to malnutrition cost developing countries $30 billion annually (FAO, 2004). Lost productivity and income resulting from early deaths, poor school performance, disability and absenteeism raise the yearly total into the hundreds of billions of dollars (FAO, 2004). While the policies and programmes needed to address malnutrition will require substantial resources, the costs of not tackling malnutrition are higher. Furthermore, food insecurity and malnutrition infringe on the human right to adequate food.

4. Climate change challenges for food and nutrition security

Climate change and variability and the consequent global environmental changes and loss of ecosystem services will have significant impacts on food and water security and eventually on malnutrition, particularly in developing countries in the Sub-Sahara and in South East Asia (Confalonieri et al., 2007).

4.1. Climate change trends and projections relevant to water, food and nutrition

Heat waves, droughts and heavy precipitation events are expected to continue to be more frequent and future tropical cyclones will become more intense (Meehl et al., 2007). It is primarily via these impacts on the ecosystem services and in water and agriculture systems that climate and global environmental change will have negative effects on water, food and nutrition security, particularly in vulnerable and poor populations.

Total temperature increases of 0.76 °C have been reported during the 20th century (Trenberth et al., 2007). 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). Recent studies on trends and sources of carbon sinks show that these estimations are much worse than expected (Le Quéré et al., 2009). According to the 4th Technical Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2007, among the Special Report on Emissions Scenarios (SRES), the best estimate for the projected low scenario is an increase of 1.8 °C and the best estimate for the high SRES scenario is 4.0 °C by 2100 (Meehl et al., 2007).

A science statement of the UK Met Office, the UK Natural Environment Research Council and the UK Royal Society at the end of 2009 reveals that current projections are much worse than those estimated by the IPCC in 2007 and the evidence for dangerous, long-term and potentially irreversible climate change has strengthened (Slingo, Thorpe, & Rees, 2009).

Climate change and variability will lead to more intense and longer droughts particularly in the tropics and sub-tropics (Trenberth et al., 2007). Droughts and water scarcity threaten food security, increasing risk of reduced energy intake as well as compromising dietary diversity. This may lead to malnutrition problems including, inadequate energy intake and/or micronutrient deficiencies.

Global mean sea surface temperatures have risen about 0.6 °C since 1950 and sea surface temperatures are estimated to have risen significantly (Bindoff et al., 2007; Nicholls et al., 2007). There is also evidence of ocean acidification due to increased atmospheric CO_2 (The Royal Society, 2005). Ocean warming, acidification and changes in salinity and precipitation affect biochemical water properties, water microflora, fisheries distribution and availability and seafood safety (FAO, 2008a).

Mountain glaciers and snow cover have declined on average in both hemispheres. During the 21st 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 et al., 2007). Decreases in glaciers and ice caps have contributed to sea-level rise (Lemke et al., 2007). According to the 4th IPCC report's estimations for unmitigated emissions, the sea-level will rise by 40 cm by the 2080s, with 60% of this increase occurring in South Asia and 20% in South East Asia (Nicholls et al., 2007). The risk of flooding of human settlements will therefore 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 contaminated food and water and diarrhoeal and other infectious diseases thus lowering their capacity to utilize food nutrients effectively.

4.2. Climate change impacts on water and food systems

The impacts of global climate change on food and water security are of great concern, particularly for developing countries. According to the IPCC, by 2080, it is estimated that 1.1–3.2 billion people will be experiencing water scarcity per year (depending on the Special Report on Emissions Scenarios of socio-economic development); 200–600 million will suffer hunger; and 2–7 million more people per year will be affected by coastal flooding (Yohe et al., 2007).

4.2.1. Climate change stress on freshwater systems

Current and future 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).

Populations in water-scarce regions are likely to face decreased water availability. In other areas, flooding, increased precipitation and higher temperatures are likely to increase the incidence of infectious and diarrhoeal diseases. And as climate change is projected to increase the burden of diarrhoeal diseases in low-income regions by approximately 2–5% by 2020 (McMichael et al., 2004) a concomitant rise in malnutrition is to be expected.

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, 2005). Water scarcity may lead to multiple adverse health outcomes, including sanitation problems, water-borne diarrhoeal diseases, exposure to chemicals, vector-borne diseases associated with water-storage systems such as dengue or malaria and malnutrition.

Water insecurity constitutes a serious constraint to sustainable development, particularly in savannah regions which cover approximately 40% of the world's land area (Rockstrom, 2003). This has a profound impact on the fulfillment of human rights, in particular on the right to water which is closely linked to the right to food.

4.2.2. Climate change impacts on food systems and food and nutrition security: pathways

The pathways through which climate change may impact food security, food safety and nutrition are complex and comprise biological, physical and socio-economic systems which are also affected by climate change. These pathways include:

- Increased frequency and intensity of extreme climatic events such as heat waves, droughts, storms, cyclones, hurricanes, and floods.
- Decrease of fresh water resources.
- Sea-level rise and flooding of coastal lands, leading to salination and or contamination of water, agricultural lands and food.
- Water and food hygiene and sanitation problems.
- Impacts of temperature increase and water scarcity on plant or animal physiology.
- Beneficial effects to crop production through CO_2 "fertilization".
- Influence on plant and livestock diseases and pest species and livestock diseases.
- Damage to forestry, livestock, fisheries and aquaculture.
- Impaired sustainability.

In addition, multiple socio-economic and environmental stresses, such as loss of biodiversity, limited availability of water and land resources, loss of ecosystem services, the HIV/AIDS pandemic and political armed conflict, demographic changes and globalization are further increasing sensitivity to climate change and reducing agricultural resilience particularly in certain regions of Africa such as the Sahel.

4.3. Climate change and global environmental change

Climate change and variability have irreversible impacts on the global environment by changing hydrological systems and freshwater supplies, land degradation, loss of biodiversity, food production systems and ecosystem services and social disruption (WHO, 2005). These factors are closely interrelated since deforestation, agriculture and livestock production systems further accelerate climate change.

The regions likely to be adversely affected are those already most vulnerable to food insecurity and malnutrition, notably Sub-Saharan Africa and South Asia. The numbers of people affected will be largest in areas of the mega-deltas of Asia and Africa with high rates of population growth and natural resource degradation. In seasonally dry and tropical regions, crop productivity is projected to decrease with even small local temperature increases (Easterling et al., 2007). In Africa, by 2020, 75–250 million people will be exposed to increased water stress due to climate change (Boko et al., 2007).

Coastal areas, especially heavily-populated mega-delta regions in South, East and South East Asia, will be at greatest risk due to increased flooding (Cruz et al., 2007). Sea-level rise is projected to extend areas of salination of groundwater and estuaries, resulting in a decrease of coastal freshwater availability for humans, ecosystems and agriculture systems. Small islands are especially vulnerable to the effects of climate change, sea-level rise and extreme events. Deterioration in coastal conditions through erosion of beaches and coral bleaching is expected to affect local resources (e.g. fisheries) with consequent socio-economical impacts such as the reduction of the value of these destinations for tourism (Mimura et al., 2007).

In the Arctic regions there are projected reductions in thickness and extent of glaciers and ice sheets and changes in natural ecosystems with detrimental effects on fisheries, migratory birds, mammals and predators high in the food chain and thus affecting the traditional food supply of native populations (Arctic Climate Impact Assessment, 2005). Indigenous circumpolar communities rely on their natural resources for the provision of traditional foods, fuel, and medicines, and will be particularly affected by the socio-economic impacts of climate change.

4.4. Climate change and the four dimensions of food security: food availability, food stability, food access and food utilization

Climate and environmental 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 (Schmidhuber & Tubiello, 2007). In addition food security depends not only on climate, environmental and socio-economic impacts, but also and crucially so, on changes to trade flows, stocks and food-aid policy. Fig. 1 shows FAO's *Food Insecurity and Vulnerability Information and Mapping Systems* (FIVIMS) framework, which describes the relationships between the four dimensions of food security.

4.4.1. Climate change impacts on food availability – production and trade

Agricultural output in developing countries is expected to decline by 10–20% by 2080, depending on whether there are beneficial effects from CO_2 fertilization (Easterling et al., 2007). Climate change and variability impacts on food production will be mixed and vary regionally. 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 range, food production is projected to decrease in all regions.

Evidence from models from the 4th IPCC assessment suggests that moderate local increases in temperature (1–3 °C), along with associated CO_2 increase and rainfall changes, can have small beneficial impacts on the production of major rain-fed crops (maize, wheat, rice) and pastures in mid- to high latitude regions. However, in seasonally dry and tropical regions, even slight warming (1–2 °C) reduces yield. Further warming (above a range of 1–3 °C) has increasingly negative impacts on global food production in all regions (Easterling et al., 2007).

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).

Fisheries and aquaculture production are affected by sea water warming, change of salinity and water acidification. Increases in sea-water temperature are leading to changes in the distribution of marine fisheries and community interactions (Parry, Rosenzweig, & Livermore, 2005). Brackish water species from delicate estuarine ecosystems are particularly sensitive to temperature and salinity changes. 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, which affects calcification processes, coral reefs' bleaching and the balance of the food web. 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).

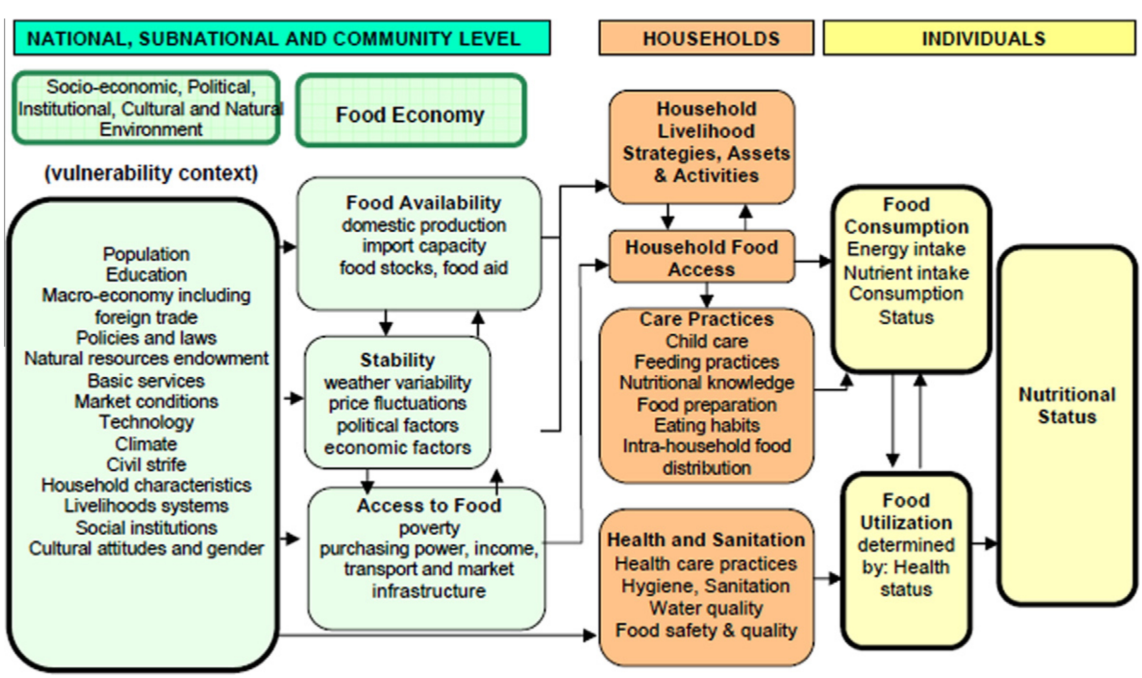

Fig. 1. FAO/FIVIMS Framework: linkages between the overall development context, the food economy, households and individual measures of wellbeing (adapted from FAO FIVIMS 2010).

4.4.2. Climate change impacts on food stability and access

Changes in the patterns of extreme weather events such as floods, cyclones, hurricanes 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 any 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, such as floods, is likely to disproportionately impact food stability and access particularly for smallholder farmers and artisanal fishers (Easterling et al., 2007). Food insecurity and loss of core livelihood strategies may be further exacerbated by the loss of cultivated land and nursery areas for fisheries through inundation and coastal erosion in low-lying areas affecting food stability and access to food (FAO, 2003).

Climate-related animal and plant diseases and pests such as blue tongue and rift valley fever in cattle or soy bean rust and corn root worm (Diabrotica) in crops and alien invasive aquatic species such as mollusks, algae or trematodes will reduce the stability of the production system and the stability of food stocks (FAO, 2008a). Food access will be affected 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, 2008a). Climate change and variability influences the contamination of food with non-infectious hazards such as biotoxins (e.g. mycotoxins or marine toxins) and chemicals and environmental contaminants such as dioxins or heavy metals which may have an impact on food and animal feed stability and access. For example droughts, floods, and higher temperatures impact crop susceptibility to fungal attack which facilitates mycotoxin contamination of animal and human food crops and reduces the stability of food and animal feed stocks.

Climate change impacts on the stability of primary production affect food manufacturing and trade. Emerging hazards in primary production could influence the design of the safety management systems required to effectively control those hazards and ensure the safety of the final product. In addition, rising average temperatures could increase hygiene risks associated with storage and distribution of food commodities affecting food stability and access.

Food prices impact food access of households, *inter-alia* 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). Temperature increases of more than 3 °C may cause prices to increase by up to 40% (Easterling et al., 2007).

4.4.3. Climate change and food utilization

Food utilization refers to the ability to absorb and use food nutrients and is related to individual health status, water and food sanitation, and food and water safety among other factors.

Climate change may affect health outcomes and food utilization with additional malnutrition consequences. 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.

Climate change plays an important role in the spatial and temporal distribution of vector-borne diseases such as malaria. Malaria affects food availability (e.g. compromised labour productivity in the agriculture sector, livestock productivity), access and utilization of humans as well as of livestock.

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 for example around the Sahel and in South East Africa. Elsewhere, the geographical range of malaria will expand and the transmission season may change for example into highland and upland areas in Africa (Confalonieri et al., 2007). It is estimated that in Africa climate change will increase the number of person-months of exposure to malaria by 16–28% by 2100 (McMichael et al., 2004).

Most of the projected climate-related disease burden will result from increases in diarrhoeal diseases and malnutrition. Diarrhoeal diseases 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% for each degree of temperature increase (Checkley et al., 2000). Climate change is projected to increase the burden of diarrhoeal diseases in low-income regions by approximately 2–5% in 2020 and will impact low-income populations already experiencing a large burden of disease (Campbell-Lendrum, Pruss-Ustun, & Corvalan, 2003). Diarrhoeal food-borne diseases such as *Salmonellosis* have been found to increase by 12% for each degree increase in weekly or monthly temperature above 6 °C ambient temperature (Kovats et al., 2004). Increased ocean temperatures are leading to increased densities of *Vibrio* spp. in shellfish and have been linked with large outbreaks of diarrhoea (Paz, Bisharat, Paz, Kidar, & Cohen, 2007; Zimmerman et al., 2007).

Climate change and variability influences food contamination with biotoxins such as mycotoxins and marine toxins which affect food and animal feed utilization. Increased sea-water temperature and other climate related changes exacerbate eutrophication, causing phytoplankton growth, and increases frequencies of harmful algal blooms (HABs). Accumulation of marine toxins by filter feeders and the subsequent consumption of these products by humans have serious health implications. Higher temperature and humidity conditions favour fungal growth and facilitate mycotoxin contamination of animal and human food crops (FAO, 2008a). Some mycotoxins such as aflatoxins are carcinogenic and are a public health concern.

Floods, droughts and other climate related transport mechanisms for chemical contaminants such as Persistent Organic Pollutants (POPs) and dioxins, contribute to the dispersion and/or accumulation of chemical contaminants on soils, crops, animal feeds and foods. Increase in sea-water temperature facilitates methylation of mercury and subsequent uptake by fish (Booth & Zeller, 2005). 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.

4.5. Populations at risk of hunger and malnutrition

A majority of the large and expanding populations in developing countries derive their livelihoods from agriculture and will, therefore, be especially vulnerable to climate change. Vulnerability to global climate and environmental change differs by region, ecosystem, population group and gender.

Projected climate change related exposures are likely to affect the health status of millions of people, particularly those with low adaptive capacity, through: (1) increases in malnutrition; (2) increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts; (3) increased frequency of cardio-respiratory diseases; (4) altered spatial distribution of some infectious-disease vectors; and (5) increased burden of diarrhoeal disease (Confalonieri et al., 2007).

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, and will dramatically affect children growth and development in affected countries (Confalonieri et al., 2007). Populations at greater risk of food insecurity include smallholder and subsistence farmers, pastoralists, traditional societies and artisanal fisherfolk which will suffer complex, localised impacts of climate change (Easterling et al., 2007). Indigenous people who rely on their natural resources for the provision of traditional foods will be particularly affected.

The most vulnerable people will suffer earliest and most, therefore climate change should be addressed in a way that is fair and just and adherent to the human rights principles of non-discrimination and equality. Men and women are affected differently in all phases of climate-related extreme weather 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 (Confalonieri et al., 2007). Many of the world's poorest people are rural women and children in developing countries who depend on subsistence agriculture (family farms) 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 & Piana, 2006). Climate change could add to water and food insecurity, increase women's work levels and child labour particularly in Africa and Asia and reduce opportunities for education. In this case the right to food and the right to education get in conflict with each other leading to ethical questions on tradeoffs of human rights (Von Braun & Brown, 2003). In areas threatened with drought and desertification, women's increased responsibilities to access food could significantly reduce their opportunities to engage in income-generating activities (Masika, 2002).

4.5.1. Estimations of risk of hunger due to climate change

Overall, climate change is projected to increase the number of people at risk of hunger (FAO, 2005). For example, climate change is projected to increase the percentage of the population at risk of hunger in Mali from 34% to between 64% and 72% by the 2050s, though this could be substantially reduced by the effective implementation of a range of adaptive strategies (Butt, McCarl, Angerer, Dyke, & Stuth, 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 in 2000, 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) 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 (740–1300 million under A2). Climate and socio-economic changes combine to alter the regional distribution of hunger, with large negative effects on Sub-Saharan Africa (Easterling et al., 2007).

Estimates of people at risk of hunger do not consider malnutrition as an outcome. There is a need for methodologies to convert estimated losses in regional yields into estimates of changes in numbers of malnourished people.

4.5.2. The complex linkages between climate change and malnutrition

Attribution of current and future climate change related malnutrition burdens is problematic because the determinants of malnutrition are complex and there are many confounders. Both acute and chronic nutritional problems are associated with climate variability and change and malnutrition is also a result of socio-economic and development factors.

Research and information on the links between climate change related food and water insecurity and malnutrition are hence necessary. 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 diarrhoea (Aziz et al., 1990). Children in poor rural and urban slum areas are at high risk of diarrhoeal disease morbidity and mortality. 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.

There is an ongoing effort to develop a new model for estimating the burden of malnutrition attributable to climate change (Kovats et al., 2009). In this model stunting has been estimated as a function of undernourishment (food-causes) and a GDP-derived development indicator (non-food causes). The model outcome measures are the proportion of population that is stunted in five world regions under 4 SRES emissions scenarios. Malnutrition burdens were estimated under three scenarios of improvements in agricultural technology. Although the models indicate the burden of malnutrition is likely to increase under climate change, such estimates are very sensitive to model assumptions, and incorporate a large range of uncertainty from both the climate and socio-economic inputs and assumptions (Kovats et al., 2009).

While stunting is an indicator of malnutrition, its use as an indicator of the impacts of climate change and variability on malnutrition has limitations. Stunting in geographical regions affected by long term famines such as those in the Sub-Sahara, is also associated with long term inter-generational stunting. Stunting is used as an indicator of chronic undernutrition among young children and does not necessarily reflect the impacts of acute malnutrition during child development windows of vulnerability. Nutritional, developmental and cognitive problems may result from acute undernourishment following natural disasters or associated with social conflict, wars and displacement to refugee camps (UN High Commission for Refugees, 2005). The consequences of acute nutritional problems associated with increased frequency and intensity of climate related natural disasters, armed conflict and displacement need to be addressed.

4.6. Social dimension of climate change and food insecurity

4.6.1. Social conflict and displacement

Conflict could emerge as a result of climate change environmentally induced migration. 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

(FAO, 2006a). 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). Political refugees from violent regions are more likely to become involved in militant activities (Gleditsch, Ragnhild, & Salehyan, 2007).

In Sub-Saharan Africa, where cropping and grazing are often practiced 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, Switzer, & Crawford, 2005). According to the United Nations Environmental Programme, 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 (United Nations Environmental Programme, 2007).

In 2008, the United Nations appealed for humanitarian assistance for over 100 million people in two dozen countries affected by conflict and political and economic breakdown. Displaced people are susceptible to malnutrition because they frequently depend on food aid that may for a variety of reasons be inadequate in both quantity and quality. Aid donors routinely fail to provide all of the resources requested through UN humanitarian appeals.

4.6.2. 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 disease 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, migration and dependency on food relief; with 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 in India (Confalonieri et al., 2007).

4.7. Strategies to reduce negative impact of climate change on food and nutrition security

4.7.1. Food security adaptation strategies to climate change

Adaptation strategies to climate change for food security can 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.

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. 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 agricultural 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).

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 the nutritional quality of the introduced crops may be less than of the crops they replace. Efforts to breed micronutrient-dense staple crops should be integrated with climate change adaptations such as breeding drought- and water-tolerant varieties. Adaptation strategies promoting more heat-tolerant native livestock breeds have to consider while native breeds are more resistant they often have lower levels of productivity.

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, often by changing the decision-making environment under which autonomous adaptation activities occur (Easterling et al., 2007). 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).

4.7.2. Opportunities for mitigation in the agriculture and livestock sectors

Agriculture, land use and waste account for some 35% of the GHG emissions that contribute to climate change (Stern, 2006). The expansion of livestock and biofuel sectors plays a major role in deforestation and land degradation and thereby contributes to climate change. Improved agricultural practices can make a significant contribution at low-cost to increasing soil carbon sinks and to GHG emission reductions. 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 techniques and livestock and manure management to reduce methane emissions and improved nitrogen fertilizer management to reduce nitrous oxide emissions in some agricultural systems (Metz, Davidson, Bosch, Dave, & Meyer, 2007).

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 potential to capture significant amounts of carbon and other GHGs and, at the same time, to contribute to poverty reduction (Consultative Group on International Agricultural Research, 2008). Cultivation of productive forage grasses that sequester carbon can be combined with tree planting in silvopastoral systems of cultivation (mixed herding and tree cultivation). Agroforestry of tree species such as *Faidherbia albida* in Africa, contributes carbon sequestration and helps maintain soil health through nitrogen fixation and uses of cuttings as fertilizer and mulch. Agroforestry also provides fodder, fruit, timber, fuel, medicines and resins. This can help improve nutrition in farmers' households through higher incomes and by directly adding diversity to diets.

Agricultural research can help create new technologies that will facilitate agriculture-based mitigation strategies. For example, research is underway at Consultative Group on International Agricultural Research-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. The International Assessment of Agricultural Knowledge, Science and Technology for Development report (IAASTD) recommended to reverse top-down transfer of technology and replace them with bottom-up, participatory, farmer-oriented innovations (International Assessment of Agricultural Knowledge, Science and Technology for Development, 2008).

The livestock sector is a major player in climate change, responsible for 18% of GHG emissions measured in CO_2 equivalent. Livestock production 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 also be the leading player in the reduction of biodiversity, since it is a 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 (FAO, 2006a).

There are measures that can help reduce these negative impacts 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. 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 Livestock and Environment and Development Initiative (LEAD) 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 levels (FAO, 2006a). LEAD proposes using the Kyoto Protocol's Clean Development Mechanism to finance the spread of biogas and silvopastoral 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 (FAO, 2006b).

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. In order to meet the MDGs, it would be necessary to balance competition for land for agriculture, livestock, forestry and biofuels production.

5. Biofuel production challenges for water, food and nutrition security

By April 2008, crude petroleum prices reached an all-time high of US$120 per barrel and helped to raise demand for biofuels. This increases costs of fertilizer, operating farm machinery and transportation of both inputs and outputs (Lazo, 2008). Rising petrol prices have made new biofuels, such as ethanol and biodiesel, an attractive alternative energy source, and technological development has made them more cost-effective and energy-efficient. But biofuels offer only a very small gain in energy efficiency and their production only minimally reduces GHG emissions. Moreover, the production of biofuels made from food crops (e.g. maize, sugarcane) has been criticized for a number of food-security related reasons, (see following sections). Research is underway to develop cellulosic biofuels from low value non-food crops, such as grasses or wood, in order to avoid tradeoffs between food and fuel, but these substances are more difficult to process than starch or sugar crops and it is not clear that their production will expand significantly in the near future (FAO, 2008c).

5.1. Biofuel production and impacts on food and nutrition security

Biofuel production can have negative impacts on nutrition through increased GHG emissions that may result from burning forests to clear land for crop cultivation, as well as through direct effects on health and sanitation and reduced food availability and associated price effects. One major problem is diversion of food and feed crops to biofuel production, as returns to biofuel production are often greater than the returns a farmer might get were the same crops sold for food, or for non-biofuel crops (Trostle, 2008). Such practices can reduce food availability and may consign food and feed production to less productive land, thus reducing yields and food security, and raising food prices. In relation to such effects, the International Food Policy Research Institute (IFPRI) estimates that rising bioenergy demand accounted for 30% of the increase in weighted average grain prices between 2000 and 2007. The impact was 39% of the real increase in maize prices (Rosegrant, 2008). Furthermore, a FAO analysis found global expenditures on imported foodstuffs in 2007 rose by about 29% above the record of the previous year. The bulk of the increase was accounted for by rising prices of imported cereals and vegetable oils – commodity groups that feature heavily in biofuel production (FAO, 2008d). Beyond such studies based on modelling and projections, it is essential to have more empirical evidence on actual effects than is presently available. The impact of higher commodity prices on national economies depends on country-specific circumstances. Higher commodity prices will have negative consequences for net food-importers. And for low income food deficit countries, food import bills will rise, precipitously in some cases. In addition, even for countries that are net food-exporters, many smallholders and agricultural labourers are net purchasers of food. For example, empirical evidence from a number of Sub-Saharan African countries in no case finds a majority of farmers or rural households to be net food sellers (FAO, 2008d).

A rise in the food bill for households that are net buyers of food may lead to the substitution of starchy staples for micronutrient-rich animal source foods, legumes, processed foods, fruits and vegetables. Extremely poor people will experience decreased calorie consumption (FAO, 2008e). 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 (FAO, 2008e). IFPRI projects that in 2020, if biofuel production proceeds at or exceeds its current pace, calorie availability will decline and child malnutrition will increase substantially, particularly in Sub-Saharan Africa (Rosegrant, Zhu, Msangi, & Sulser, 2008).

5.2. Biofuel production, water security and environmental health

Growth of the biofuel sector may also lead to water shortages and contamination. For example, sugarcane cultivation, one of the most popular biofuel feedstocks, is particularly water-intensive. As mentioned above, water scarcity in developing countries is a cause of concern for agricultural productivity, health and sanitation. Poorly managed input use in energy crop cultivation (or cultivation for food or feed use, for that matter) could pollute drinking water, adversely affecting human and animal health.

Likewise, the scarcity of water in developing countries is a concern for agricultural productivity and for health and sanitation, even in the absence of expanding production of bioenergy crops. In underdeveloped rural areas, there is very high demand for access to water for irrigation, cooking, and drinking, and there is evidence to suggest that energy crop production could divert water from these and other needs (United Nations Energy, 2007). IFPRI modelled the possible effects of continued development of biofuels and found that stress on regional water supplies increased only marginally (Rosegrant et al., 2008). However, a significant acceleration of biofuels expansion in areas requiring additional irrigation water from already depleted aquifers could cause much greater water scarcity problems and further push up cereal prices (United Nations Energy, 2007). Strategic land-use planning could help ensure that adequate land and water resources are available for food and feed crop production, as well as that adequate water is allocated for household use.

5.3. Strategies to reduce the negative impact of biofuel production on food and nutrition security

Appropriate policies can make bioenergy development more pro-poor and environmentally sustainable. For example, poor farmers might be able to grow energy crops on degraded or marginal land not suitable for food production. Further investment is needed in developing technologies to convert cellulose to energy, which could provide smallholders with a market for crop residues. Biofuel production is labour-intensive, offering new job opportunities (Von Braun & Pachauri, 2006). Organizing groups of smallholders through contract farming schemes to grow and market biomass may well be more pro-poor than plantation production. Technologies, institutional arrangements and bioenergy crop choice are important to determining impacts on poverty and the environment. Outgrower schemes could allow for technology spillovers to food crops, meaning additional growth and poverty reduction benefits, as well as increased food availability (Arndt, Benfica, Thurlow, & Uaiene, 2008). It is important to note that there may be barriers to female farmers taking advantage of opportunities, as they have less access than men to land, water, credit, inputs and services. Contract farming schemes targeted at female farmers, and female farmer cooperatives might be options to reduce gender inequities within the biofuel production context (Lambrou & Piana, 2006).

In addition, codes of conduct have been developed that could constrain excessive exuberance on cultivating biofuels, as with fair trade guidelines, or ensure that cultivation occurs in a sustainable manner. For instance the Roundtable on Sustainable Biofuels (2009) has developed a third-party certification system for biofuels sustainability standards, encompassing environmental, social and economic principles and criteria for which biofuels producers can apply.

6. Additional challenges to food and nutrition security

A number of important factors besides climate change and biofuel production are currently impacting food and nutrition security, and will likely contribute to future effects. They include the food and financial crises, and other underlying drivers such as demographic forces, structural shifts in food and agriculture systems, globalization and international land deals.

6.1. Food and financial crises

According to FAO the most recent increase in hunger has been caused by the world economic crisis that has resulted in lower incomes and increased unemployment. This has reduced access to food by the poor (FAO, 2009c). The current global economic slowdown, which follows and partly overlaps with the food and fuel crisis, is at the core of the sharp increase in world hunger. It has reduced incomes and employment opportunities of the poor and significantly lowered their access to food. The increase in undernourishment is not a result of limited international food supplies. Recent figures of the FAO Food Outlook indicate a strong world cereal production in 2009, which will only modestly fall short of last year's record output level of 2287 million tones (FAO, 2009d).

With lower incomes, the poor are less able to purchase food, especially where prices on domestic markets are still stubbornly high. While world food prices have retreated from their mid- 2008 highs, they are still high by historical standards. Also prices have been slower to fall locally in many developing countries. At the end of 2008, domestic staple foods still cost on average 24% more in real terms than 2 years earlier; a finding that was true across a range of important foodstuffs. The incidence of both lower incomes due to the economic crisis and persistent high food prices has proved to be a devastating combination for the world's most vulnerable populations (FAO, 2009c).

High food prices in recent years have been driven by a host of factors. These include income and population growth, increased demand for animal source foods and subsequent increased demand for animal feed, low global cereal stocks, rising energy prices, consistent underinvestment in rural infrastructure, weather disruptions, speculation in commodities markets and increased demand for biofuels. The 2008 financial crisis had a compounding effect on the already fragile markets; repercussions include decreased trade, reduced remittance streams, capital flight and contraction of credit and foreign aid. Taken together, the two crises constitute a serious threat to macroeconomic stability and subsequently, to food and nutrition security in the developing world (Von Braun, 2008).

6.2. Other underlying drivers of food insecurity

There are other emerging and underlying drivers of food insecurity which have substantial socio-economic, social and environmental consequences.

Demographic forces are important determinants of food security. World population is projected to increase by 37%, to 9.2 billion people by 2050 (United Nations Population Division, 2008). Anticipated economic growth of 6% per year in developing countries during the next few years and rapid urbanization will also lead to increases in global food demand and structural shifts in diets (Von Braun, 2007).

Structural shifts in food and agriculture systems are important factors for food security. The global agriculture production system has a dualistic structure. The vast majority of the world's farms (85%) are small-scale operations of less than two hectares. The 0.5% of farms that exceed 100 hectares capture a disproportionate share of global farm income, enjoy privileged access to policy-makers and, particularly in developed countries, receive generous subsidies (Organisation for Economic Co-operation and Development, 2007). Buying power is increasingly concentrated in the hands of agribusiness and other powerful corporate actors.

Emerging international water and farm land deals, if unregulated, will further contribute to water and food insecurity and increasing poverty and inequity in developing countries. Unregulated farm land deals, often referred to as farm land grabs, can impinge on the fundamental right to food. Government-backed farm land deals can be driven by food insecurity in investor countries but also by investment opportunities rather than food security concerns. Food supply uncertainties are created by constraints in agricultural production due to climate-related limited availability of water and arable land and by the expansion of biofuel production. In addition, global demand for biofuels and other non-food agricultural commodities, expectations of rising rates of return to agriculture and land values, and policy measures in home and host countries are key factors driving new patterns of land investment (Cotula, Vermeulen, Leonard, & Keeley, 2009). There is a need to develop a code of conduct for land acquisition to protect developing countries to guard against possible exploitation and perpetuating food insecurity in the poorest countries.

Most of the underlying drivers of food insecurity, such as changing demographics or emerging international farm land deals are also affected by climate change. These complex interactions make assessing the impacts of climate change on food systems difficult and increase the existing uncertainties. Therefore it is necessary to develop robust decision-making tools to facilitate the development of adaptation and mitigation strategies under deep uncertainty.

7. Approaches for responding to the challenges of climate change and biofuel production to food and nutrition security

A combination of adaptation and mitigation measures, sustainable development and research to enhance both adaptation and mitigation can diminish the threats to nutrition from climate change. Changes in policies and institutions will be needed to facilitate adaptation. Adaptation measures should be integrated with development strategies and programmes.

7.1. Priorities for responding to climate change and biofuel production

The development of adaptation strategies should consider that adaptation capacity depends on geographical situation, economic development, natural resources, social context, institutions, governance and technology. For example, on average, cereal cropping system adaptations such as changing varieties and planting times enable avoidance of a 10–15% reduction in yield corresponding to a 1–2 °C local temperature increase. The benefits of adaptation tend to increase with the degree of climate change up to a 3 °C temperature increase, at which point adaptive capacity in low latitudes is exceeded, and mitigation strategies are required (Easterling et al., 2007).

With regard to mitigation, financial incentives can help promote improved land management, maintenance of soil carbon content and efficient use of fertilizers and irrigation. These incentives could encourage synergy with sustainable development practices and efforts to reduce vulnerability. In addition, incentives to improved waste management, as well as stronger regulation, would improve the sanitary environment and increase returns to health-based interventions (Metz et al., 2007).

Agriculture, food and nutrition issues need to be placed onto national and international climate change agendas, in order to devise effective and pro-poor policies. The expiration of the Kyoto Protocol in 2012 offers an opportunity to bring these issues to the table. International organizations should assist countries to assess their capacity building needs. Promoting successful adaptive and mitigation strategies will require adopting a human rights' perspective when tackling the challenge of climate change.

There are multiple ways food and nutrition security can be protected from climate change and the adverse effects of biofuel production. Biofuel production in developing countries should be carefully designed, so as not to crowd out other development investments. Policies should ensure that smallholders, including women farmers, have access to resources so that they can participate in biofuel production on a fair basis. Policies also need to examine and regulate the environmental consequences of biofuel development. Further, increased investment in agricultural productivity will help developing countries increase their own food production and participate in the biofuel market. Global cooperation is needed on R&D to bring technologies on line that will allow production of biofuels from non-food crops. Developed-country governments should remove trade barriers to developing-country biofuel exports and, along with international organizations such as FAO and the international financial institutions, provide financial and technical assistance to pro-poor, sustainable biofuel projects in developing countries. Finally, developing-country governments need to conduct food and nutrition security impact assessments before launching biofuel projects.

7.2. Policies and programmes for improving food and nutrition security

The ultimate causes of food insecurity and malnutrition are social, economic, cultural and political. Therefore, it is essential that efforts to improve food security and good nutrition address these causes.

At regional and national levels, developing countries have issued national policies and plans of action for nutrition, but in practice, these strategies often do not assure adequate budgetary allocations, or incorporate the appropriate specific actions to address nutrition problems on the ground. For example, in a recent review of poverty reduction strategies in countries facing serious malnutrition, while over 70% identified malnutrition as a development problem, only 35% included budget allocations for explicit nutrition activities (Shekar & Lee, 2006). This finding corroborates the perception that, while nutrition is beginning to receive attention as a serious problem, few countries are choosing, or are able, to follow-up with programmes on the ground.

Accelerated progress against food insecurity and malnutrition requires that governments put appropriate policy responses much higher on their agendas, with adequate resources provided. One example of a country where this has happened is Brazil. Brazil's Zero Hunger (*Fome Zero*) programme shows the tremendous difference it makes when governments make food security and nutrition high priorities. In addition to providing direct welfare and food aid to persistently poor families, *Fome Zero* provides conditional cash transfers to low-income families throughout Brazil on the condition that children attend school and receive routine vaccinations, and that pregnant women receive pre-natal care and nutrition education. Through this combination of basic welfare grants and conditional cash transfers, *Fome Zero* attempts to: (1) reduce immediate poverty through direct welfare grants, (2) break the inter-generational transmission of poverty with the transfer conditionalities designed to increase human capital via improved health and education outcomes, and (3) empower beneficiary families by linking them to complementary services. *Fome Zero* thus addresses the more distal socio-economic causes of food insecurity as well as providing direct food aid to beneficiaries.

In order for programmes like *Fome Zero* to work, donors must provide technical and financial support, and within the context of climate change and bioenergy demand, the urgency for action increases. Harmonised, large-scale, multi-component programmes are required to make a difference and should include the following steps:

- create an enabling environment to promote peace, eradicate poverty and reduce gender inequality;
- promote a fair and market-oriented world trade system;
- increase investments in human resources, sustainable food production systems and rural development;
- implement policies to improve physical and economic access to sufficient, nutritionally adequate and safe food and its effective utilization;

- focus on participatory and sustainable agriculture;
- use a "nutrition lens" to direct multi-sectoral actions to improve food and nutrition security at the household level; improve food quality and safety; prevent, control and manage infectious diseases and micronutrient deficiencies; promote appropriate diets, including breastfeeding and healthy lifestyles; provide care for the vulnerable, including people living with HIV/AIDS; introduce productive safety nets; and provide direct assistance;
- prevent and prepare for emergencies; and
- build anti-hunger alliances: a broad global coalition of food producers and consumers, international organizations, scientists, academics, religious groups, NGOs, donors, policy-makers and all those concerned about the problem of world hunger.

7.2.1. Governance issues

A number of governance issues have considerable bearing on food and nutrition security. Both food security and nutrition are multi-sectoral issues, and determinants can include health, education and agricultural pathways. Hence a comprehensive national food and nutrition strategy requires cross-sectoral collaboration. But developing-country governments are composed of sectoral ministries that frequently view budgetary allocation as a zero-sum game. Since each sector is competing with others for funding to carry out its own mandate, and since improved nutrition outcomes are not typically used as performance indicators for most ministries, it can be hard to provide incentives for nutrition-based mandates across a multiplicity of ministries. For example, most country leaders will not judge the effectiveness of their Ministry of Education based on reductions of iodine deficiency among schoolchildren. Nor do senior decision-makers always recognize the costs of undernutrition. As long as nutrition is perceived primarily as an output, rather than an input, to growth and development, it will not receive adequate recognition or funding. In addition, determinants of nutritional status are often poorly understood by policy-makers and politicians. Further, many developing countries lack adequate human resources to implement nutrition-based agendas (Benson, 2008).

In addition to these country-level problems, a fragmented and incoherent international nutrition system complicates the picture. Resources for nutrition are inadequate. Annual donor funding runs at less than US$300 million, compared to US$2.2 billion for HIV/AIDS and several billion dollars in food aid (Morris, Cogill, & Uauy, 2008). In real terms, aid to agriculture is about half the level of 25 years ago (FAO, 2006b). Governments of low-income countries devote 19% of their budgets to military expenditures, compared to less than 5% for agriculture. Military expenditures account for 2.6% of GDP in low-income countries, compared to 1% for public health (World Bank, 2007). However, there are some indications that priorities are changing. The African Union seeks to boost agriculture to 10% of member budgets and bring agricultural growth to 6% per year, and the World Bank is putting renewed stress on both nutrition and agriculture (World Bank, 2006, 2008).

7.2.2. A revitalized twin-track approach

At the International Conference on Financing for Development held in 2002, the Food and Agriculture Organization (FAO), the International Fund for Agricultural Development (IFAD) and the World Food Programme (WFP) agreed upon a "twin-track approach" for combating hunger and poverty: strengthening the productivity and incomes of hungry and poor people, targeting the rural areas; and direct and immediate access to food by hungry people and social safety nets. This includes food transfers, conditional and unconditional cash transfers and public works programmes, and may be targeted or universal (FAO, 2008e).

Examples of the "twin-track approach" include introducing improved water management, use of green manures, agroforestry and other low-cost, simple technologies designed to strengthen rural infrastructure. These methods not only enhance the productivity and incomes of small farmers, but also empower them in their role as stewards of natural resources. Investing in rural infrastructure can also reduce the lethal impact of water-borne illnesses, improve access to health care, prevent thousands of needless child and maternal deaths and open links to markets where farmers can sell surplus produce and acquire fertilizer and other inputs at reasonable prices.

High food prices exacerbate food insecurity and create social tensions, but high agricultural commodity prices also present a potential opportunity for reversing the decline in public investment in agriculture. More food needs to be produced where it is urgently needed to contain the impact of soaring prices on poor consumers and simultaneously maximize production to create more income and employment opportunities for rural poor people. The "twin-track approach" increases smallholder farmers' access to resources, infrastructure and services so they are better equipped to increase their supply response to higher prices. Agricultural growth will also stimulate growth in other sectors. Appropriate policies and institutions, such as organization and collective action, can help facilitate smallholder participation in value chains on a fair basis.

Agricultural and rural development strategies must recognize the important roles that women play in food security and nutrition. Hence the "twin-track approach" also includes measures to provide direct access to food for the neediest families such as feeding programmes for mothers and infants. These programmes target the hub of the vicious cycle of hunger and malnutrition that undermines maternal health, stunts children's physical and cognitive growth, impairs school performance and impedes progress towards gender equality and the empowerment of women.

7.2.3. Direct nutrition interventions

Good nutrition makes an essential contribution to the fight against poverty. It protects and promotes health; reduces mortality, especially among mothers and children; encourages and enables children to attend and benefit from school; and enhances productivity and incomes in adulthood. The increased participation of poor and vulnerable people and of women in the development process that may arise from effective community nutrition programmes will likely lead to more effective demands for improved services and to better use of existing resources.

With regard to pre-schooler malnutrition, the crucial "window of opportunity" is from conception through the first 18–24 months of a child's life. Effective interventions targeting infants and young children include improving food consumption and nutrient intakes through improved complementary feeding and dietary diversity, breastfeeding promotion, salt iodisation, vitamin A and zinc supplementation, vitamin A fortification, hand-washing and hygiene interventions and treatment of severe acute malnutrition. Interventions should not neglect other age groups, other family members, or low-income childless households who may equally be in need of support. For example, the care of adolescent girls and pregnant women is vital for protecting their own health and that of their future children (Bhutta et al., 2008).

A new approach to tackling micronutrient malnutrition in infants, children and adults is through "biofortification," which involves developing micronutrient-dense crop varieties. A number of biofortified varietals are also being developed with agronomically desirable traits, such as increased resistance to pests and disease. In the long run, biofortification may be more sustainable than supplementation or fortification, as it has lower recurrent costs (HarvestPlus, 2007).

IFPRI research has shown that improvements in girls' education (relative to other interventions) had the biggest impact on reducing child malnutrition in developing countries during 1970–1995

(Smith & Haddad, 2000). But at present, 100 million primary school-aged children are not enrolled and 57% of these children are girls (United Nations Educational, Scientific and Cultural Organization, 2008). School meals and food-for-education programs can help achieve full enrollments, educational gender equality and improved food security.

8. Conclusions

Efforts to improve food security and nutrition in the face of current challenges, including climate change and rising bioenergy demand, must continue to place the achievement of the MDGs, as internationally agreed-upon development targets, at the centre of human endeavour. In particular, it remains essential to accelerate progress in reducing poverty, hunger and malnutrition while mitigating risk and protecting the environment. A rights-based approach engages affected stakeholders – particularly smallholder farmers, including women and poor rural and urban consumers – as active participants in this process. Civil society organizations have a key role to play.

8.1. Responding to climate change

Climate change is projected to affect the health status of millions of people, particularly those with low adaptive capacity, through increases in malnutrition and consequent disorders, with implications for child growth and development, as well as through an increase in diarrhoeal disease. The 4th IPCC assessment report has concluded that, 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 health consequences of climate change.

Agricultural production, including access to food, is projected to be severely compromised by climate variability and change in many African countries and South East Asia. This would further adversely affect food security and exacerbate malnutrition. Agriculture, food and nutrition issues need to be placed onto national and international climate change agendas, in order to devise effective and pro-poor policies. The expiration of the Kyoto Protocol in 2012 offers an opportunity to bring these issues to the table as a new agreement is negotiated.

Sustainable economic development and poverty reduction remain top priorities for developing countries. Climate change could exacerbate climate-sensitive impediments to sustainable development faced by developing countries. To address this challenge requires integrated approaches for adaptation, mitigation and sustainable development. Strategies should include measures that would simultaneously reduce pressures on biodiversity and food security and contribute to carbon sequestration.

Adaptation is a key factor to address the impacts climate change will have on food production and food insecurity. Early impacts of climate change can be effectively addressed through adaptation; however, options for successful adaptation diminish and associated costs increase, with increasing climate change impacts. Prioritization of investment needs aimed at improving adaptation of food security to climate change is crucial. The development of adaptation strategies should consider that adaptation capacity depends on geographical situation, economic development, natural resources, social context, institutions, governance and technology of the countries.

Sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. Plans for sustainable development should promote adaptive and mitigation strategies, for example, by including adaptation and mitigation measures in land-use planning and infrastructure design or by including measures to reduce vulnerability in existing disaster risk reduction plans.

Mitigation in agriculture has a significant potential and can use available technologies which can be implemented immediately. Agricultural mitigation measures often have synergy with sustainable development policies and many influence social, economic and environmental aspects of sustainability. In order to improve the mitigation potential in this sector, synergies between climate change policies, sustainable development and improvement of environmental quality should be promoted.

Adaptation and mitigation measures should be developed as part of overall and country specific development programmes such as Poverty Reduction Strategy Papers, pro-poor strategies and national Food and Nutrition Action Plans. In this framework international organizations should assist countries to assess their capacity building needs for the development of integrated adaptation, mitigation and sustainable development strategies to address food security and nutrition challenges from climate change and biofuel demand.

Adopting a human rights' perspective when tackling the challenge of climate change puts people at the centre of attention of decision-making. Sustaining and protecting the environment against degradation will be enhanced through the protection and promotion of human rights. At the same time, human rights cannot be fully realized without securing the environmental dimensions of ecosystem services essential to the right to life, the right to food and all other human rights.

Priority research needs for the assessment of climate change impacts on food, fibre, forestry and fisheries have been identified in the 4th IPCC assessment report. Attribution of current and future climate change-related malnutrition burdens is problematic because the determinants of malnutrition are complex. Research and information on the links between climate change-related food insecurity and malnutrition are necessary.

8.2. Assuring pro-poor and sustainable biofuel development

In order to assure that biofuel development is pro-poor, environmentally friendly and supports food security and nutrition, a number of steps must be taken. These include:

- developed-country governments should remove trade barriers to developing-country biofuel exports;
- developed-country governments, international organizations and the international financial institutions should provide financial and technical assistance to pro-poor, sustainable biofuel projects in developing countries;
- developing-country governments need to conduct food and nutrition security impact assessments before launching biofuel development projects;
- developing-country government policies should make opportunities available to smallholders, including women farmers, to participate in biofuel production, such as incentives to encourage outgrower schemes and labour-intensive processing plants;
- policies should also encourage technology spillovers from biofuel production that can enhance food crop production;
- research is needed on non-food crop sources of bioenergy, e.g., cellulosic biofuels, to minimize food-feed-fuel tradeoffs; and
- policies should favour production of biofuel crops with a small environmental footprint that can contribute to climate change adaptation and mitigation strategies.

8.3. Making nutrition a development priority

Direct nutrition improvement programmes have a unique, essential role to play in efforts to reach the MDGs. Good nutrition makes an essential contribution to the fight against poverty. It protects and promotes health; reduces mortality, especially among mothers and children; encourages and enables children to attend and benefit from school; and enhances productivity and incomes in adulthood. By indirectly strengthening communities and local economies, good nutrition contributes to the achievement of other development objectives which, in turn, impact upon the MDGs. For example, the increased participation of poor and vulnerable people and of women in the development process that may arise from effective community nutrition programmes will likely lead to more effective demands for improved services and to better use of existing resources. The use of nutritional goals and indicators and of participatory community nutrition approaches to design and monitor interventions would facilitate the development and implementation of such interventions. It is also essential to recognize and address the social, economic, cultural and political determinants of undernutrition. National nutrition data should be disaggregated with regard to groups presumed to be vulnerable, in order to establish whether and to what extent nutritional discrepancies exist and to inform policies towards realizing the right to food and the highest attainable standard of health.

Developing-country governments should give high priority to implementing proven nutrition interventions on a national scale. Donors should substantially increase support for efforts to improve nutrition. Improved policy coherence and international cooperation are required to eradicate malnutrition in all its forms (Easterling et al., 2007). Key elements of an intervention strategy for making nutrition a development priority include:

- setting targets, agreeing on coordinated actions in each country and mobilizing resources;
- using participatory approaches that build local institutions and skills, strengthen legal rights and access to resources and empower women, indigenous people and other vulnerable groups;
- giving priority to "hot spots" where a high proportion of the population suffers from malnutrition, hunger and extreme poverty and often also from illiteracy, disease, social marginalization and high rates of child and maternal mortality;
- using food assistance to develop and enhance skills or to create physical assets, such as food storage facilities or soil and water conservation structures that will help communities weather crises and build the foundation for longer-term development;
- focusing on people-centred policies and investments in rural areas and on agriculture in ways that promote sustainable use of natural resources, improve rural infrastructure, facilitate the functioning of markets and enhance rural institutions;
- supporting dynamic rural growth by improving the productivity of smallholder agriculture and by diversifying into rural non-farm activities and strengthening micro-enterprises in which rural women play a major role;
- strengthening poor urban livelihoods with an urban twin-track approach that combines pro-poor employment and asset generation programmes with measures to help the poor meet their basic needs for food, shelter, water, health and education; and
- accelerating progress towards an open and fair international trading system, with special attention to improving market access and reducing export subsidies and trade distorting domestic support in agriculture (FAO, 2005).

All of these approaches are proven, practical and affordable. All can be effectively adapted and applied to meet local requirements, monitored to ensure that they are effective and scaled up as they prove successful and sufficient resources are mobilized. If developing countries intensify their efforts to revitalize agricultural and rural development and ensure that hungry people have access to food and if donor countries fulfil their pledges to increase development assistance substantially, we can reach the World Food Summit and MDG hunger reduction targets and progress towards reaching all of the other MDGs.

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