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Review Article

A REVIEW ON AGRICULTURE, FOOD SECURITY AND CLIMATE CHANGE

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Abstract: The increase in greenhouse gas emissions is raising the earth's temperature and the consequences include varying precipitation, extreme weather events (droughts and floods) and shifting of seasons. The rapid pace at which climate change is taking place, combined with the increase in global population and slow income growth, threatens food security globally. Agriculture has proved to be extremely vulnerable to climate change as seen by the drastic decline in food production over the past decades. High temperatures that are being experienced in most parts of the globe will eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Rural communities face increased risks including recurrent crop failure, loss of livestock and reduced availability of fisheries and forest products. Changing temperatures and weather patterns furthermore create conditions for the emergence of new pests and diseases that affect animals, trees and crops. This has direct effects on the quality and quantity of yields as well as the availability and price of food, feed and fiber. In other way Climate change would affect all four dimensions of food security: availability, accessibility, stability, and utilization. However Agriculture has the potential to make a significant contribution to mitigating climate change. To make agriculture GHG efficient and climate-resilient, landscape and farming systems need to change in order to actively absorb and store carbon in soils and vegetation; reduce emissions of methane from rice production, livestock and burning; and decrease nitrous oxide emissions from inorganic fertilizers and enhance the resilience of production systems and ecosystem services to climate change.

Key Words: Greenhouse, agriculture, climate change.

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Introduction: Agriculture is one of the most climate-sensitive industries, with outdoor production processes that depend on particular levels of temperature and precipitation. Although only a small part of the world economy, it has always played a large role in estimates of overall economic impacts of climate change (Ackerman and Stanton, 2013).

Similarly Tsegaye (2014) stated that Agriculture is inherently sensitive to climatic conditions and it is vulnerable to current and anticipated global climate change. Consequently, livelihood of the people leading agriculture dependent life is highly vulnerable to climatic shocks. Developing countries particularly the poorest people are the most vulnerable to the adverse impacts of climate variability and ongoing and projected climate change. Their economies depend heavily on climate-sensitive sectors such as agriculture, forestry, fisheries, a reliable water supply, and other natural resources (World Bank, 2008). In line with the above ideas FAO (2011) revealed that Agriculture is among the most vulnerable sectors to the effects of climate change because changes in temperatures and rainfall, more frequent weather extremes, and the growing presence of carbon dioxide (CO_2) in the atmosphere have mostly negative effects on productivity. Also UNCTAD (2009) stated that Agriculture is one of the sectors whose production is most vulnerable to the effects of climate change while the magnitude of effects remains uncertain including changes in temperature and water availability, weather extremes and flooding and changing CO_2 levels in the atmosphere. Climate change, which is largely a result of burning fossil fuels, is already affecting the Earth's temperature, precipitation, and hydrological cycles. Continued changes in the frequency and intensity of precipitation, heat waves, and other extreme events are likely, all which will impact agricultural production. Furthermore, compounded climate factors can decrease plant productivity, resulting in price increases for many important agricultural crops (Rosenzweig, 2002).

The bigger parts of the global population who are victims of food and nutrition insecurity (75-80 %) live in rural areas in the southern hemisphere and are directly or indirectly dependent on agriculture for their livelihoods (WFP, 2010). In most countries where agricultural productivity is already low and the means of coping with adverse events are limited, climate change is expected to reduce productivity to even lower levels and make production more erratic. Long term changes in the patterns of temperature and precipitation, that are part of climate change, are expected to shift production seasons, pest and disease patterns, and modify the set of feasible crops affecting production, prices, incomes and ultimately, livelihoods and lives (Edame *et al*, 2011). Conversely Projections to 2050 suggest both an increase in global mean temperatures and increased weather variability, with implications for the type and distribution of agricultural production worldwide (Shaw et al, 2007). Wherever the problem resides, climate change directly affects food security and nutrition everywhere in the world. It undermines current efforts to protect the lives and livelihoods and end the suffering of the over 1 billion food insecure people and will increase the risk of hunger and malnutrition by an unprecedented scale within the next decades (IASC, 2009). According to (Bhutta et al, 2008) under nutrition is already the single largest contributor to the global burden of disease, killing 3.5 million people every year, almost all of them are children in developing countries. Manyeruke *et al* (2013) also argued that Climate change has posed a serious threat on food security in developing countries in Africa. This has led developing countries to heavily rely on foreign aid in the form of food hand-outs to avert hunger. The shift in climatic conditions over the sub-Saharan region towards semi-arid to arid conditions has stemmed up a lot of concern as to whether Africa can feed itself .Similarly, Arendal et al. (2009) assures that climate change poses a threat to country food security in northern regions because it influences animal availability, human ability to access wildlife, and the safety and quality of wildlife for consumption. Agriculture is important for food security in two ways: it produces the food people eat; and (perhaps even more important) it provides the primary source of livelihood for 36 percent of the world's total workforce. In the heavily populated countries of Asia and the Pacific, this share ranges from 40 to 50 percent, and in sub-Saharan Africa, two-thirds of the working population still make their living from agriculture. If agricultural production in the low-income developing countries of Asia and Africa is adversely affected by climate change, the livelihoods of large numbers of the rural poor will be put at risk and their vulnerability to food insecurity increased (ILO, 2007).

Agriculture also has the potential to make a significant contribution to mitigating climate change. A full assessment of the GHG emissions due to agriculture is still in the making. What is clear is that modern industrialized agriculture from developed economies is a major source of GHG emissions; but the extent and magnitude have not yet been established. In developing countries, major agricultural production systems also contribute to the cumulative GHG emission from agriculture. However, as agriculture represents the main income-earning activity in many of these same countries, mitigation actions must also be designed to help ensure food security and alleviate poverty reduction (Elbehri, 2011). This review mainly aimed at focusing on the impact of climate change on agriculture in general and food security in particular.

Climate change, water and agriculture: Research on climate and agriculture has reached less definite global conclusions, but it has an increasing local importance. As the world warms, precipitation patterns will change, with some areas becoming wetter, but some leading agricultural areas becoming drier. These patterns are difficult to forecast; climate model predictions are more uncertain for precipitation than for temperature, and "downscaling" global models to yield regional projections is only beginning to be feasible. Yet recent droughts in many parts of the world underscore the crucial role of changes in rainfall. Even if total annual precipitation is unchanged, agriculture may be harmed by changes in the seasonality or intensity of rainfall (Min et al. 2011). Overall, warming is increasing the atmosphere's capacity to hold water, resulting in increases in extreme precipitation events. According to Sanderson et al. (2011) observational data and modeling projections show that with climate change wet regions will generally (but not universally) become wetter, and dry regions will become drier. Perceptible changes in annual precipitation are likely to appear in many areas within this century. While different climate models disagree about some parts of the world, there is general agreement that boreal (far-northern) areas will become wetter, and the Mediterranean will become drier (Mahlstein et al. 2012). With 2°C of warming, dry-season precipitation is expected to decrease by 20 percent in northern Africa, southern Europe, and western Australia, and by 10 percent in the southwestern United States and Mexico, eastern South America, and northern Africa by 2100 (Giorgi and Bi 2009).

In the Sahel area of Africa, the timing of critical rains will shift, shortening the growing season (Biasutti and Sobel 2009), and more extensive periods of drought may result as temperatures rise (Lu 2009).In the Haihe River basin of northern China, projections call for less total rainfall but more extreme weather events (Chu et al. 2009). Indian monsoon rainfall has already become less frequent but more intense, part of a pattern of climate change that is reducing wet-season rice yields (Auffhammer et al. 2011). The relationship of crop yields to precipitation is markedly different in irrigated areas than in rain-fed farming; it has even been suggested that mistakes in analysis of irrigation may have accounted for some of the optimism about climate and agriculture in the 1990s literature (Schlenker et al. 2005). In California, by far the leading agricultural state in the United States, the availability of water for irrigation is crucial to yields; variations in temperature and precipitation are much less important, as long as access to irrigation can be assumed (Schlenker et al. 2007). Yet there is a growing scarcity of water and competition over available supplies in the state, leading some researchers to project a drop in irrigated acreage and a shift toward higher-value, less-water-intensive crops (Howitt et al. 2009). An analysis of potential water scarcity due to climate change in California estimates that there will be substantial costs in dry years, in the form of both higher water prices and supply shortfalls, to California's Central Valley agriculture (Hanemann et al. 2006).

It was found that climate change is worsening the already unsustainable pattern of water use in agriculture (Ackerman and Stanton 2011). Nearly four-fifths of the region's water is used for agriculture, often to grow surprisingly water-intensive, low-value crops; a tangled system of legal restrictions and entitlements prevents operation of a market in water. Lu (2009) notes that there is significant uncertainty regarding future Sahel drying, because it is influenced by 1) sea-surface temperature changes over all the world's oceans; and 2) the radiative effects of greenhouse gas forcing on increased land warming, which can lead to monsoon-like conditions. A number of countries in sub-Saharan Africa (SSA) already experience considerable water stress as a result of insufficient and unreliable rainfall, changing rainfall patterns or flooding. The impacts of climate change – including predicted increases in extremes – are likely to add to this stress, leading to additional pressure on water availability, accessibility, supply and demand. For Africa, it is estimated that 25% of the population (approximately 200 million people) currently experience water stress, with more countries expected to face high risks in the future (Ludi, 2009)

Agriculture is among the most vulnerable sectors to the effects of climate change because changes in temperatures and rainfall, more frequent weather extremes, and the growing presence of carbon dioxide (CO_2) in the atmosphere have mostly negative effects on productivity. Yet, the projected increase in world population during the next 40 years, which should reach 9.1 billion in 2050, calls for agriculture to significantly step up its productivity and production levels. Agricultural activities also account for a substantial share of total greenhouse gas (GHG) emissions and these are expected to increase in the future due to a variety of drivers, including population and income increases, diet changes and technological change. Together, these factors demonstrate the urgency of implementing measures that favor actions and policies that simultaneously address climate change mitigation and adaptation in agriculture while supporting development objectives and ensuring food security. (**Elbehri, 2011)**

Predicted Changes for Agricultural Production Systems across Regions

Table 1: estimated impact of climate change on agricultural production across region

	Sub Saharan Africa	**Latin America**	**South Asia**	**South East Asia**
Temperature	Temperatures to increase by 3–7° C by 2080–2099.	Temperatures to increase by 1–7.5° C by 2070–2099.	Temperatures to increase by 2.3–4.5° C By 2070–2099.	Temperatures to increase by 2–3.8° C by 2070–2099.
Precipitation	Precipitation to decrease by up to 30–40% in most parts of southern Africa, but to increase by 7% in tropical and eastern regions by 2080–2099.	Precipitation to change by up to -40% to +12% by 2080.	Precipitation to Increase by 10–17% by 2070–2099.	Precipitation to Increase by 3–8% by 2070–2099.
Agriculture	Rain-fed cereal (wheat, maize,rice) production to decrease by 12% (net loss) by 2080, with Great regional variations	Overall grain yields to change by between -30% to +5% by 2080. For example, rain-fed wheat production is to decrease By 12–27% by 2080.	Net cereal production to decrease by at least 4–10%. For example, rain-fed wheat production is to decrease by 20–75% by 2080.	Overall cereal production to increase by up to 30%, but rain-fed wheat production is to decrease By 10–95% by 2080.

Adapted from McCarl (2007).

Most agricultural producers located in low income and less developed countries are typically operating well below their potential productive capacity. As noted by the FAO (2007) the developing world already contends with chronic food problems. Estimates suggest that this situation could worsen: around 11 percent of arable land in developing countries could be affected by climate change, including a reduction of cereal production in up to 65 countries, and loss of up to 16 percent of GDP in some cases. Tables 1 summarize some of the general impacts of a range of climate change scenarios

Agricultural production and temperature change: A study of five leading food crops in sub-Saharan Africa found strong relationships of yields to temperatures (Schlenker and Lobell 2010). By mid-century, under the climate scenario, yields are projected to drop by 17 to 22 percent for maize, sorghum, millet, and groundnuts (peanuts) and by 8 percent for cassava. These estimates exclude carbon fertilization, but maize, sorghum, and millet are C4 crops, while cassava has a negative response to increased CO2, as noted above. Negative impacts are expected for a number of crops in developing countries by 2030. Among the crops most vulnerable to temperature increases are millet, groundnut, and rapeseed in South Asia; sorghum in the Sahel; and maize in Southern Africa (Lobell et al. 2008). Other crops exhibit different, but related, patterns of temperature dependence; some perennials require a certain amount of "chill time," or annual hours below a low temperature threshold such as 7°C. In a study of the projected loss of winter chilling conditions in California, Germany, and Oman, fruit and nut trees showed large decreases in yield due to climate change (Luedeling et al. 2011). In this case, as with high temperature yield losses, the relevant temperature variable is measured in terms of threshold effects, not year-round or even seasonal averages. Small changes in averages can imply large changes in the hours above or below thresholds, and hence large agricultural impacts.

The contribution of agriculture for climate change: Agriculture accounts for about 13–15 per cent of global GHG emissions (as agriculture's share in global GDP is just about 4 per cent, this suggests that agriculture is very GHG intensive (Lybbert and Sumner, 2010). The GHG share of agriculture rises to approximately 30–32 percent if land-use changes, land degradation and deforestation are included. Agricultural emissions of methane and nitrous oxide grew by 17 percent in the period 1990–2005 (IPCC, 2007), roughly proportionate, for instance, to the increase in global cereals' production volume, but about three times as fast as productivity increased in global cereals' production. These GHG emissions are predicted to rise by 35–60 percent by 2030 in response to population growth and changing diets in developing countries, in particular towards greater consumption of ruminant meats and dairy products, as well as the further spread of industrial and factory farming in developed and developing countries (ibid, 2007).

Major Sources of Direct Agricultural Green House Gas Emissions

Emissions from agriculture come from four principal subsectors: agricultural soils, livestock and manure management, rice cultivation, and the burning of agricultural residues and savanna for land clearing.

Agricultural soils: Nitrous oxide (N_2O) is the largest source of GHG emissions from agriculture, accounting for 38 percent of the global total. N_2O is produced naturally in soils through the processes of nitrification and de-nitrification. Agricultural activity may add nitrogen to soils either directly or indirectly. Direct additions occur through nitrogen fertilizer usage, application of managed livestock manure and sewage sludge, production of nitrogen-fixing crops and forages, retention of crop residues, and cultivation of soils with high organic matter content. Indirect additions occur through volatilization and subsequent atmospheric deposition of applied nitrogen, as well as through surface runoff and leaching of applied nitrogen into groundwater and surface water (USEPA, 2006).The land area which is suitable for the production of food, feed, fuel, wood and other products provides a massive carbon store, but is also a source of GHG emissions (FAO, 2009)

Rice cultivation: The agricultural sector is, for example, the second largest contributor of CH_4 in the United States, with approximately 70 percent of agricultural CH_4 emissions coming from enteric fermentation, 25 percent from the decomposition of manure, and 5 percent from rice cultivation (FAO, 2009).Flooded rice fields are the third largest source of agricultural emissions, contributing to 11 percent in the form of methane arising from anaerobic decomposition of organic matter. China and South-East Asian countries produce the lion's share of methane emissions from rice, accounting for over 90 percent in 1990. Due to population increases in these countries, emissions are expected to increase by 36 percent in South-East Asia and by 10 percent in China by 2020 (USEPA, 2006).

Livestock production: Enteric fermentation or the natural digestive processes in ruminants, such as cattle and sheep, accounts for the majority of methane production in this category. It is the second largest source of total emissions from agriculture, with a 34 percent global share. Other domesticated animals, such as swine, poultry and horses, also emit methane as a by-product of enteric fermentation. Manure management includes the handling, storage and treatment of manure, and accounts for 7 percent of agricultural emissions. Methane is produced by the anaerobic breakdown of manure, while nitrous oxide results from handling manure aerobically (nitrification) and then an aerobically (de-nitrification), and is often enhanced when available nitrogen exceeds plant requirements. By 2020, over 60 percent of meat and milk consumption is expected to take place in the developing world, As a result, methane emissions from enteric fermentation are projected to increase by 32 percent by 2020, with China, Brazil, India, the U.S. and Pakistan being the likely top sources (USEPA, 2006).

CO_2 from fossil fuel consumption: These emissions are primarily from combustion of gasoline and diesel to fuel farm equipment, including tractors, combines, irrigation pumps, grain dryers, etc., but also include emissions related to the production of fertilizers, pesticides and herbicides, which are primarily derived from fossil fuels (Kleinschmit,2009)

Overview of impact of Climate Change on agriculture and food security: Climate change, agriculture and food security is now a subject of global concern (Edame, 2011). Climate change can influence agricultural production in a number of ways. For instance Temperature affects plants, animals, pests, and water supplies. Temperature alterations directly affect crop growth rates, livestock performance and appetite, pest incidence, and water supplies in soil and reservoirs. In other way Precipitation alters, for example, the water directly available to crops, the drought-stress that crops are placed under, and the supply of forage for animals, animal production conditions, irrigation water supplies, aquaculture production conditions, and river flows supporting barge transport. Also Changes in atmospheric CO_2 influence the growth of crop plants and weeds by altering one of the basic inputs for photosynthesis. Finally Sea level rise due to climate change influences the suitability of ports and waterborne transport, inundates producing lands, and may alter aquaculture production conditions. **(Jodie Keane *eta al*, 2009).** According to FAO (2007) Climate change impacts crops, pasture, forests and livestock (quantity, quality); Changes in land use, soil and water resources (quantity, quality); increased weed and pest challenges; shifts in spatial and temporal distribution of impacts; rise in Sea level, changes to ocean salinity; Sea temperature rise causing fish to inhabit different ranges. Additionally the socio economic impacts of climate change subsumes Decline in yields and production; reduced marginal GDP from agriculture; Fluctuations in world market prices; changes in geographical distribution of trade regimes; increased number of people at risk of hunger and food insecurity; Migration and civil unrest

Increased intensity and frequency of storms, drought and flooding, altered hydrological cycles and precipitation variance have implications for future food availability. The potential impacts on rain fed agriculture *vis-à-vis* irrigated systems are still not well understood (FAO, 2007). The developing world already contends with chronic food problems. Climate change presents yet another significant challenge to be met. While overall food production may not be threatened, those least able to cope will likely bear additional adverse impacts (WRI, 2005). The estimate for Africa is that 25–42 percent of species habitats could be lost, affecting both food and non-food crops. Habitat change is already underway in some areas, leading to species range shifts, changes in plant diversity which includes indigenous foods and plant-based medicines (McClean, Colin *et al*., 2005). In developing countries, 11 percent of arable land could be affected by climate change, including a reduction of cereal production in up to 65 countries, about 16 percent of agricultural GDP (FAO Committee on Food Security, Report of 31st Session, 2005). Changes in ocean circulation patterns, such as the Atlantic conveyer belt, may affect fish populations and the aquatic food web as species seek conditions suitable for their lifecycle. Higher ocean acidity (resulting from carbon dioxide absorption from the atmosphere) could affect the marine environment through deficiency in calcium carbonate, affecting shelled organisms and coral reefs.

The claims made by non-agricultural development on scarce land and water are set to increase. These will tend to exacerbate the insecurity of tenure which the poor already face in relation to land and water resources. This trend is likely to worsen as claims on resources shift with e.g. the increased financial flows associated with mitigation instruments (CDM and emissions trading, Reduced Emissions from Deforestation and Degradation (REDD), biofuels and voluntary carbon schemes outside Kyoto's market mechanisms). An appropriate balance needs to be struck between governments' international mandates and the pro-poor dimensions of national policies (Slater, 2007)

As it is cited on (**Virola** *et al.*, 2008) and Based on the report of the Inter governmental Panel on Climate Change, climate change currently contributes to the global burden of disease and premature deaths. Projected trends in climate-change-related exposures of importance to human health will increase malnutrition and consequent disorders, including those relating to child growth and development (high confidence); increase the number of people suffering from death, disease and injury from heat waves, floods, storms, fires and droughts (high confidence); continue to change the range of some infectious disease vectors (high confidence); have mixed effects on malaria; in some places the geographical range will contract, elsewhere the geographical range will expand and the transmission season may be changed (very high confidence); increase the burden of diarrheal diseases (medium confidence); increase cardio-respiratory morbidity and mortality associated with ground-level ozone (high confidence); increase the number of people at risk of dengue (low confidence);

Climate change may slow rates of improvement in food security, although the projections are highly uncertain due to limitations in the number of crop and economic models available and simplification of the definition of food security to food availability. It is projected that in 2080 around 1300 million people (around 600 million could be at risk of hunger under the most extreme scenarios (Parry et al 2004), with the poorest countries worse affected. In these, a large portion of the population will continue to depend on agriculture and capacities to adapt to climate change (e.g. technologies, finances, investments, etc.), both at national and farm level are lowest. Within sub-Saharan Africa the negative impacts are likely to be strongest in north and south, possibly with some positive impacts in central African countries. General modelling studies on food security rarely consider how it could be disrupted by more extreme weather events. Under more moderate scenarios, climate change appears to have a negligible effect on the numbers of people at risk of hunger

Box 1. Climate change affects all four dimensions of food security

Food production and availability: Climate affects food production directly through changes in agro-ecological conditions and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural produce. Changes in land suitability, potential yields (e.g. CO2 fertilisation) and production of current cultivars are likely. Shifts in land suitability are likely to lead to increases in suitable cropland in higher latitudes and declines of potential cropland in lower latitudes.

Stability of food supplies: Weather conditions are expected to become more variable than at present, with increasing frequency and severity of extreme events. Greater fluctuation in crop yields and local food supplies can adversely affect the stability of food supplies and food security. Climatic fluctuations will be most pronounced in semi-arid and sub-humid regions and are likely to reduce crop yields and livestock numbers and productivity. As these areas are mostly in sub-Saharan Africa and South Asia, the poorest regions with the highest levels of chronic undernourishment will be exposed to the highest degree of instability.

Access to food: Access to food refers to the ability of individuals, communities and countries to purchase food in sufficient quantities and quality. Falling real prices for food and rising real incomes over the last 30 years have led to substantial improvements in access to food in many developing countries. Possible food price increases and declining rates of income growth resulting from climate change may reverse this trend.

Food utilization: Climate change may initiate a vicious circle where infectious diseases, including water-borne diseases, cause or compound hunger, which, in turn, makes the affected population more susceptible to those diseases. Results may include declines in labour productivity and an increase in poverty, morbidity and mortality.

Source: Schmidhuber and Tubiello (2007).

Agriculture and Climate Change Adaptation:

Adaptation to climate change is the adjustment of natural and human systems in response to expected or actual climatic factors in order to moderate the harm or benefit from change of its effects (IPCC, 2001). The concept includes changes in processes, practices and structures in ecological, economic and social systems (Wiegman, 2010). These broad definitions demonstrate that adaptation incorporates both Environmental and social-economic policy domains.

More specific delineations of adaptation and its dimensions remain to be formulated. Even in the UNFCCC, a commonly accepted definition of adaptation is not specified, nor have any of the recent submissions by Parties proposed one (Persson et al. 2009). Aside from their human and systems adjustment definition (as per above), the IPCC (2007) distinguishes between adaptive capacity and vulnerability. Adaptive capacity is defined as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages to take advantage of opportunities or cope with the consequences. Vulnerability implies the degree to which a system is susceptible to and unable to cope with adverse effects of climate change including climate variability and extremes.

The UNFCCC (2009) distinguishes between the categories of adaptation actions as actions that climate-proof socio-economic activities by integrating future climate risk; actions that expand the adaptive capacity of socio-economic activities to deal with future and not only current climate risks; And actions targeting activities adapting to climate change that would not otherwise be initiated under business-as-usual scenarios. According to FAO (2007), the international community acknowledges that adaptation to climate change is a pressing issue, especially for developing countries, and that more resources are needed to adequately reduce exposure to disturbed climate patterns. There is considerably less consensus on how the scale of adaptation that is needed can be achieved. These concerns are heightened because those most vulnerable to the effects of climate change, or the potential beneficiaries from adaptation, often lack the capacity and finance needed. Considerable efforts will be required to prepare developing countries in particular to deal with climate related impacts on agriculture

In its 2007 report, FAO distinguished between autonomous (micro - farm level) and planned (macro - policy level) adaptation. Examples of autonomous adaptation to climate change include changes in sowing dates, production of different crop varieties or species, changes in the use of irrigation and water supply, changes in the use of other inputs or in farm management (e.g. fertilizer, tillage methods, and grain drying). The range of adaptation strategies that autonomous actors have depends upon social, economic and political status (ISET, 2008). Vulnerable households may have to choose between an adaptation activity, such as constructing rain-harvesting or other irrigation methods in drought-prone areas, or paying for other important services like schooling or health care (Klein, 2002). Therefore the amount of autonomous adaptation desirable and feasible largely depends on the level of individual income and amount of available resources (Margulis et al., 2008).

Planned adaptations are sector-wide changes in processes or systems to build climate resilience or to encourage shifts in resources to a more efficient use under climate change effects (FAO, 2007). Examples of planned adaptations include addressing changes in food insecurity, identification of vulnerabilities, reassessment of agricultural research priorities, strengthening of agriculture extension and communication systems, adjustments in commodity and trade policy, and increased training and education. Planned adaptation policies take into account that, in addition to the important role of autonomous adaptation, there are limits to the capability of individuals to make long-term strategic adjustments in the absence of government policies that incentivize farmers and communities to adopt adaptation activities. Coordination of autonomous and planned adaptation activities is essential. In some cases, maladaptive adaptation has occurred because of a dis-harmony between planned and autonomous local-level actions. ISET (2008) cites the example of farming communities in India settling in flood plains which were designed to protect villages from adverse weather conditions. The result was repeated flooding of their fields, which caused more risks rather than reducing them. A further example is the improved use of chemical pesticides and herbicides to build crop resilience under increasingly difficult conditions.

There is also strong merit in incorporating autonomous adaptation processes to operate as a prime point of entry for policy development. ISET outlines the strategy of targeting autonomous adaptation as follows: At the micro level (individual, household), autonomous adaptation interventions cover the course of action individuals, households, communities and businesses take in response to the opportunities, constraints and risks they face within livelihood systems (ISET, 2008). By seeking to identify the factors that constrain actors in responding to risks and opportunities associated with natural hazards and changing climatic conditions, a variety of points of entry can be found where appropriately targeted support of other interventions can enhance existing or catalyse new adaptation responses. This approach is most effective when it can build on existing abilities of households, communities and businesses to adapt to climate variability and reduce their vulnerability to disaster risks.

Adaptation Costs: A challenge for developing countries in forming policy and implementing adaptation activities at whatever level is in setting aside adequate resources to facilitate adaptation and in developing a clear vision of how to use existing funding. Ascertaining the costs involved in adaptation has been hard to operationalize, and estimates have varied greatly for several reasons. First, estimating costs relies largely on climate projections, assessment of exposure, models of climate sensitivity and the forecasted potential impacts at a given level. Depending on which forecast is used, the potential impacts vary and therefore the corresponding adaptations vary as well. Furthermore there are different levels of adaptation - full adaptation may include all possible opportunities to mitigate risk/ benefit from climatic changes, whereas partial adaptation may focus on activities that avert the highest level or most probable risks (Margulis et al., 2008). Adaptation activities at the autonomous level are perhaps more widespread than planned adaptation measures, but their costs are harder to estimate because they are rolled out by private actors. There are also some grey areas as to what activities constitute adaptation measures, and there is a lack of a concise definition for adaptation (some are direct, others are more broad and cover both soft and hard activities). In addition, financial institutions do not agree on what is classified as adaptation finance, which makes it increasingly hard to find estimates on the current level of adaptation finance that is being leveraged in the private sector (Atteridge et al., 2009). Although there are obstacles to calculating the cost of adaptation given the uncertainty, this is not a valid justification for inaction and therefore should not hinder decision making regarding adaptation activities.

Under Article 3.3 of the UNFCCC, it is stated that "where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures." Persson et al. (2009) argue that this should hold as much for economics as for climate science and that the urgent and immediate adaptation needs of least developed countries must be strongly underlined.

Adaptation Financing: Opportunities and Obstacles: Developing countries face significant challenges in marshalling the resources necessary to fund their adaptation activities. Multilateral negotiations on adaptation funds have stagnated given the difficulties in ascertaining the exact costs of adaptation and an ongoing lack of political commitment to adequately address financing needs for activities in developing countries. At present USD 244 million has been distributed for adaptation activities, with the regional breakdown shown in Table 2. Although most estimates vary, the indication is that billions of dollars annually are required (Müller, 2008). The Intergovernmental Panel on Climate Change (IPCC) concluded that the costs of stabilizing greenhouse gas concentrations will rise gradually as mitigation efforts move atmospheric concentrations of carbon dioxide (CO_2) from 650 ppm to 550 ppm and will rise more sharply as concentrations decrease further, from 550 ppm to 450 ppm (Metz et al., 2001). According to (UNFCCC, 2007) The human and financial costs to countries of coping with extreme weather events, crop failures and other emergencies related to climate are growing and will continue to grow higher. Developing countries, especially Least Developed Countries (LDCs) and Small Island Developing States (SIDS), who are already facing difficulties in alleviating poverty as a result of their economic situation, are particularly vulnerable to the adverse effects of climate change because they have fewer resources to adapt: socially, technologically and financially.

Table 2: Amounts disbursed for adaptation activities by region

Region	Amount dispersed (USD millions)
Africa	118.6
Asia	50.3
Europe	1.1
Middle East	16.0
Oceania	20.2
North America	8.2
Central America	7.6
	244.0

Source: www.climatefundsupdate.org

Conclusion: The greatest threats and effects of climate change are on food security and the impact on agriculture. Ensuring food security at the national level is therefore high priority. The issue is especially important because it provides the link between production and availability on the one hand and potential use on the other. Agriculture accounts for about 13–15 per cent of global GHG emissions .These GHG emissions are predicted to rise by 35–60 per cent by 2030 in response to population growth and changing diets in developing countries, in particular towards greater consumption of ruminant meats and dairy products, as well as the further spread of industrial and factory farming in developed and developing countries. Emissions from agriculture come from four principal subsectors: agricultural soils, livestock and manure management, rice cultivation, and the burning of agricultural residues and savanna for land clearing. Climate change can influence agricultural production through rise in temperature, precipitation, Changes in atmospheric CO2 and Sea level rise. Generally, climate change tends to affect asset, human health, biodiversity, food security and agriculture.

A way forward

- To make agriculture GHG efficient and climate-resilient, landscape and farming systems need to be changed in order to actively absorb and store carbon in soils and vegetation; reduce emissions of methane from rice production, livestock and burning; and decrease nitrous oxide emissions from inorganic fertilizers, on the one hand, and enhance the resilience of production systems and ecosystem services to climate change, on the other hand.
- ***Switching Planting Date:*** Perhaps the simplest farmer adaptations have to do with changes in on-farm management, which include decisions about what crops to grow and when and how to grow them. One of the more straightforward of these possible adaptations is the option to shift when in the year crops are planted. Current decisions about when to plant are made based on a number of factors, including available soil moisture, the expected timing of temperature extremes, and the demands of multi-cropped systems. Year-to-year shifts in planting dates are already a demonstrated farmer adaptation in the face of climate variability, particularly for farmers in rainfed environments who often must wait for the onset of the rainy season in order to plant.
- ***Switching varieties or crop:*** A second possible farmer adaptation to climate change is to switch varieties or crops to something better suited to the new climates they face. Farmer currently growing maize might switch to a faster-maturing maize variety if drought becomes more common, or might choose to grow a potentially more drought-tolerant crop like sorghum. In other way Growing crops well adapted to local conditions with disease and pest resistance as well as drought tolerance
- ***Diversify income:*** on-farm adaptations are not the only possibility for bolstering food security in the face of a changing climate. Many rural poor lean heavily on agricultural activities for income generation, off-farm income can also play an important role in economic livelihoods. To the extent that

non-agricultural income sources are less climate-sensitive than farm activities, further diversification of incomes out of agriculture might seem a promising adaptation strategy in the face of a changing climate.

- Enhancing water availability through better use of groundwater storage, enhancing groundwater recharge where feasible, and increasing surface water storage. Given the current economic situation of many water-stressed countries, however, managing demand is equally important: reducing water consumption and improving water use efficiency;
- Increasing awareness on climate change and food security policy agendas
- Development agencies should Make all their programs more responsive to climate change impacts
- Enhancing Social Protection Schemes
- Strengthening Resilient Community-based Development

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