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Climate change and coffee

Background

This document contains a report on the effects of climate change on producing countries to assist Members with preparations for the United Nations Framework Convention on Climate Change (UNFCCC) Conference to be held in Copenhagen from 7 to 18 December 2009.

The following Annexes are included in this document:

Annex I:	The impact of climate change on coffee: the views of stakeholders
Annex II:	Organizations providing funds for mitigation and adaptation to climate change
Annex III:	Ongoing research projects into the impact of climate change on agriculture
Annex IV:	References

Action

The Council is requested to note this document.

CLIMATE CHANGE AND COFFEE

Introduction – An overview of climate change and agriculture

More human beings derive their livelihood from agriculture than from any other economic activity; the majority are self-employed subsistence farmers living in the tropics. Despite growing urbanization, 75% of the world's poor live in rural areas, and agriculture remains the largest single contributor to their livelihoods. Agricultural development is therefore of vital importance to the alleviation of poverty in the developing world, both directly (by offering employment) and indirectly (by generating jobs away from the farm and pushing down food prices). Agriculture has received a great deal of attention from climate modellers because of its high dependence on the climate. Human dependence on agriculture, particularly in developing countries, also means that this activity has an important role in debates about adaptation to the impacts of climate change in developing countries.

Agriculture currently accounts for 24% of world output, employs 22% of world population and uses 40% of land area. Most studies of the impacts of climate change on agriculture indicate that there will be negative effects over the next century. Some estimate that 600 million additional people may be at risk of hunger if the global temperature increases by more than three degrees Celsius. But climate change is only one of a range of factors that may affect global food production in the future, so it is important to understand the scale of these impacts in relation to other changes, such as improvements in technology and farming systems.

Given the complex relationships between crops, atmospheric composition and temperature, combined with the complexities of world agricultural policies and trade, making predictions about the effects of climate change is necessarily a tentative process, the results of which should be treated with due caution.

1. Methodological approaches to climate change

This section provides a general overview of methodological approaches to climate change, including: measurement of the impact of climate change on agriculture; use of climate change scenarios; outputs; and other relevant aspects.

1.1 Measurement of the impact of climate change on agriculture

There are a number of tools used to understand potential effects of climate change on agriculture. These range from large-scale models representing the global climate, agriculture and food trade systems as they are now and extrapolated into the future, to small, farm-level or laboratory experiments used to study the responses of plant physiology to individual climatic drivers. The main methods currently in use are outlined below.

1.1.1 Global climate models

The most widely used approach is to use global climate change models, which make projections about future climates based on current understanding of the drivers of climate change and relate the outcomes of these models to potential impacts on crops. These models contain five main elements:

(a) Scenarios of future greenhouse gas emissions are developed based on sets of 'storyline' scenarios of possible future worlds. These define values for the main parameters affecting greenhouse gas emissions, including population growth, technology and economic activity (global GDP and regional variations in GDP). The most common scenarios in use in the literature are contained in the Special Report on Emissions Scenarios (SRES) developed by the Intergovernmental Panel on Climate Change (IPCC 2000).

(b) Scenarios of greenhouse gas concentrations in the atmosphere are then generated based on models of the processes that act to remove greenhouse gases from the atmosphere (e.g. uptake in the oceans and land, and chemical processes in the atmosphere).

(c) Scenarios of temperature changes are derived by feeding these modelled concentrations of greenhouse gases into general circulation models (GCMs) that model changes in temperature (known as radiative forcing) and the resulting changes in climate due to greenhouse gases.

(d) Impacts on agriculture are assessed by feeding these projections into crop response models, such as the 'Agro-ecological-zones' (AEZ) modelling framework (see, for example, Fischer 2002). These generally focus on the main cereal crops.

(e) Impacts on agricultural trade are investigated by linking these models with agricultural trade models such as the 'Basic Linked System' (BLS), developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute of Applied Systems Analysis (IIASA). The BLS is usually run using SRES scenarios 'with' and 'without' climate change factored in, in order to separate out the impacts of climate change variables from other influences.

1.1.2 Controlled field experiments

Controlled field experiments are another tool used to model the impacts of climate change on crops. Crops are grown in controlled environments where variables such as concentrations of different gases in the atmosphere, available water and temperature can be varied. These models are crucial to our understanding of how climate change affects specific crops and as inputs into large-scale climate models. Numerous uncertainties are involved when combining crop-scale experiments with large-scale global climate models, as outlined in the next section.

1.1.3 Integrated climate-crop models

Integrated climate-crop models are currently under development that attempt to address some of the problems outlined above. They focus on the fact that food crops are likely to respond to climate change in complex ways and to various extra-sectoral drivers, such as hydrological cycles. Examples include changes in land surface that may affect related parameters, such as water runoff, and feedbacks on climate change relating to changes in vegetation cover. There is also evidence that major changes in land use have had some effect on local climates, which are unaccounted for in most existing crop-climate models (Betts 2005).

1.1.4 Statistical analyses of past climates

Statistical analyses of the impacts of past climates on crop production can be used to estimate how crops may respond in the future and, to some extent, to test the accuracy of climate models by running them using measurable drivers from the past. However, there is no guarantee that relationships that have existed in the past will persist in future climates, so the application of such techniques is limited.

1.2 Climate change scenarios

Modelling studies of the impacts of climate change on agriculture are often based on a set of scenarios developed by the IPCC (2000). There are four scenario families defining four different storylines of different future worlds. These differ in terms of projections in population growth, world GDP changes, differences in per capita income between developed and developing countries and energy intensity of the economy (related to level of emissions).

Four qualitative storylines of future possible worlds (A1, A2, B1 and B2) define four equally valid scenario families. The storylines describe developments in many different social, economic, technological, environmental and policy dimensions.

The A1 storyline and scenario family are based on very fast economic growth, slow population growth, and the swift introduction of new and more efficient technologies. Major underlying themes include convergence among regions, capacity building and increased social and cultural interactions, with substantial declines in regional disparities in per capita income.

The A2 storyline and scenario family are based on a very heterogeneous pattern of development. The emphasis is on self-reliance and the preservation of local identities. Population growth is high, since fertility patterns change very slowly. Per capita economic growth and technological change are more fragmented and less rapid than in other storylines.

The B1 storyline and scenario family are based on a convergent world, characterized by with the same low population growth as in the A1 storyline, but with fast changes in economic structures toward a service and information economy, as well as the introduction of clean and resource-efficient technologies. Global solutions to economic, social, and environmental sustainability are emphasized, but without additional climate initiatives.

The B2 storyline and scenario family are based on a world that emphasizes local solutions to economic, social, and environmental sustainability. This world is characterized by moderate population growth, intermediate economic development, and less speedy and more heterogeneous technological change than in the B1 and A1 storylines.

These four basic storylines are the basis for six scenario groups, A1F1 (fossil fuel intensive), A1B1 (balanced – i.e. not relying too much on any one source of energy), A1T (predominantly non-fossil fuel), A2, B1 and B2. In all, 40 different scenarios have been developed. Although all scenarios are equally valid and no probabilities of occurrence have been assigned, this study will focus on the four scenario groups that are most widely used, namely A1F1, A2, B1 and B2.

These scenarios form the primary drivers for emissions scenarios, which can be generated through modelling studies and used to make projections of temperature changes.

1.3 Model limitations and assumptions

There are currently significant uncertainties in our understanding of how climate change affects agriculture. Given the complexities of the systems involved, models have to simplify certain parameters, some of which may have large implications for the outcomes. In general, uncertainties become larger the further into the future projections are made.

1.3.1 Uncertainties in the drivers used for climate change and agriculture models

The inputs to models used for predicting the impacts of climate change on agriculture are themselves subject to large uncertainties and controversies. These include:

- uncertainties over future emissions;
- uncertainty over how the climate system will respond (e.g. temperature changes);
- difficulties in modelling natural variability and feedbacks due to a lack of understanding of complex relationships;
- disagreements in assumptions, including: criticism of the economic growth rates assumed in the SRES scenarios for being too high (Schiermier 2006); the SRES storylines not accounting for all possible future worlds (e.g. ‘disaster’ worlds) (Arnell et al. 2004); and population growth rates of the A2 scenario being too high compared to UN predictions (Fischer 2005); and
- crop yield change estimates (Parry 2004): uncertainties arise in using yield functions from field experiments in larger modelling studies; drought conditions are simulated in some models but not flooding; farm-level adaptation is often simulated based on current available technologies, but these may be very different in the future.

1.3.2 Assumptions in the socio-economic processes included in the models

- Human adaptation to climate change (enabling farmers to cope with changes) is considered in different ways and to different extents within different modelling studies. Some studies assume no adaptation, others assume autonomous adaptation (i.e. at the farm level) and others assume economy-wide adaptation (Stern 2006). Fischer (2002), for example, makes optimistic assumptions about adaptation, assuming “an advanced level of inputs and management for currently cultivated areas” (cited in Warren 2006). This results in production increases in some developing countries; and
- in food trade estimates, greater attention is dedicated to major cereal crops, despite likely shifts in the balance between arable and livestock lands, and sectors outside agriculture are very poorly modelled (Parry 2004).

1.3.3 Geographical scale issues

One of the biggest limitations of current modelling techniques is in bridging the scale gap between large-scale global climate models, which generally have a resolution of over 100km, and the small-scale of most farming systems, which are generally less than 10km.

Methods exist by which relevant outputs from large-scale models can be used as drivers for small-scale crop models, but these have been shown in some cases to give rise to systematic errors in estimated yields (Baron et al. 2005). Generating information about climate change that is useful for the purposes of adaptation at a field scale has therefore so far proven problematic.

1.3.4 Temporal scale issues

Most large-scale modelling studies have low temporal resolutions, meaning that sub-seasonal variations in weather and climate are not covered in detail. Prediction of precipitation and extreme events is particularly problematic (Parry 2004).

1.3.5 Regional biases

Current climate modelling studies have significant regional biases, due to a lack of information on model inputs such as precipitation patterns (both temporal and spatial) in developing countries. Modelling rainfall patterns is difficult in itself because of the small scales and short time frames involved, so this lack of data adds to the problem.

1.3.6 Crop responses to atmospheric composition

Significant uncertainties exist as to the influence of atmospheric CO_2 concentration on crops. This CO_2 ‘fertilisation’ effect occurs because of the dependence on CO_2 for plant growth. Increased atmospheric concentrations can stimulate photosynthesis and improve the efficiency of water use by plants. The extent to which this happens depends on the type of plant (different plants use different photosynthetic processes) and factors such as water availability, nutrient availability and pests and diseases (Stern 2006). Therefore, complex relationships exist between the atmospheric composition changes predicted by models and areas of increased water stress in particular (Slingo 2005). There are large differences in the projections of climate models, depending on whether they take CO_2 concentrations into account (Parry 2004). CO_2 concentration is known to have more of an effect on C3 crops (e.g. rice, wheat and soybean) than on C4 crops (e.g. maize, sugarcane and sorghum). In most modelling studies, CO_2 impacts are based on controlled field experiments that indicate that a 20% to 30% rise in yield is found to occur for moderate CO_2 increases. More recent evidence, however, indicates that the effect might be much less than originally estimated, resulting in an 8% to 15% increase for C3 plants and no significant change for C4 plants (Long et al. 2006, cited in Stern 2006).

It is also possible that some of these effects could be counteracted by other atmospheric gases such as levels of surface ozone, which could be important in countries such as China, where ozone concentrations are expected to rise. Crop interaction with atmospheric processes is generally not covered in large-scale modelling studies. For example, large changes in land use have been shown to have an influence over local climates, and crops themselves can have an impact on atmospheric composition (Erda et al. 2005).

1.3.7 Extreme events

Most large-scale climate studies model extreme events in terms of days per year that temperatures exceed a maximum threshold and the annual maximum one-day precipitation total (Slingo 2005). Their projections indicate that extreme events, such as floods and droughts, could increase in both severity and frequency as a result of climate change. There is, however, little information on factors such as the timing of drought periods in relation to crop life cycles and temporal clustering of intense weather systems. It follows that predicting the impacts of extreme events on crops through climate models is currently very difficult and poorly accounted for in most large-scale models.

1.4 Outputs

Combining the models and scenarios outlined above allows for projection of a number of different variables in relation to climate change over the next century. Most modelling studies focus on a set of different parameters relating to agricultural crops, because of their importance in the world economy and their sensitivity to climate change. In general, model outputs include projections of:

- changes in yields due to changes in seasonal climates;
- changes in production potential in relation to factors such as yields, available land suitable for agriculture and lengthened/shortened growing seasons;
- responses of crops to changes in atmospheric composition, such as concentrations of carbon dioxide;
- changes in prices resulting from climate change;
- changes in patterns of trade resulting from climate change;
- changes in the number of people at risk of hunger as a result of climate change, normally measured as the number of people whose incomes allow them to purchase cereals; and
- water runoff and related water stress, normally measured in terms of the number of litres of water available per person per year.

1.5 Other relevant aspects

There are many issues relating to the impacts of climate change on agriculture that are not covered in the scenarios outlined above, and the projections are hard to disaggregate in different scenarios. This section gives a brief overview of the potential impacts of climate change in other areas that have particular relevance to agriculture.

1.5.1 Relationships between climate change and soil degradation

Relationships between climate change and soil degradation are complex. According to IPCC (2001), land management practices will be the most influential factor on the organic matter content of the soil during the next few decades. However, semi-arid areas that already have poor soils are likely to feel the effects of climate change more severely, due to changes in vegetation cover, weather and climate patterns.

Climate change is likely to increase the frequency and distribution of stronger winds and increased rainfall, which are major determinants of erosion. The organic matter content and capacity to hold water of the soil is likely to decrease as a result. In semi-arid and arid areas, where nutrient content is already low and water stress already high, climate change could therefore act to decrease crop yields. This could exacerbate reductions in crop yield arising from temperature increases.

1.5.2 Water availability

In a warmer world, the hydrological cycle is likely to become more intense, and there some evidence already exists of more ‘very wet’ and ‘very dry’ areas compared to past measurements (IPCC 2007). Modelling changes in the hydrological cycle is challenging, particularly for events that happen on short temporal and spatial scales, such as thunderstorms and precipitation events, which can be very uncertain. While precipitation changes are hard to model, in areas of the world that are dependent on snow pack for water, warmer temperatures cause earlier thawing and less precipitation falls in the form of snow (Barnett 2005). This effect is the same even without changes in precipitation intensity (Barnett 2005). This implies more certainty in projections of water stress for areas where storage capacity is not sufficient than areas where water stress is related mainly to changes in precipitation.

In general, annual mean soil moisture is expected to decrease in semi-arid areas. The percentage changes of runoff in river basins is likely to increase in high latitudes and some of the wet tropics and decrease in mid latitudes and the dry tropics (IPCC 2007), although the extent and direction vary somewhat between models for given temperature changes. Climate change impacts on ground water are likely to vary significantly according to the location; shifts in recharge towards winter and lower summer recharge could occur in many aquifers, but recharge could increase in semi-arid and arid areas due to more frequent and heavier rainfall (IPCC 2007). However, globally the number of people experiencing extreme droughts at any one time could also increase by between 3 and 30% due to climate change for a 3^{o} to 4^{o} C warming (Stern 2006).

1.5.3 Extreme events

The effects of extreme climatic events on agriculture can be large, but these impacts are currently poorly modelled in climate-crop models, as highlighted in section 1.3.1. General understanding of the frequency and severity of extreme events is more advanced, with the likelihood of phenomena such as the warmer days and nights and more frequent hot days being 'virtually certain' (99% probability of occurring) in the 21st century.

A very important climatic event, with serious implications for agriculture is the El Niño Phenomenon. The term El Niño – Spanish for 'the Christ Child' – was originally used by fishermen to refer to the Pacific Ocean warm currents near the coasts of Peru and Ecuador that appeared periodically around Christmas time and lasted for a few months. Due to those currents, fish were much less abundant than usual. At the present time we use the same name for the large-scale warming of surface waters of the Pacific Ocean every 3-6 years, which usually lasts for 9-12 months, but may continue for up to 18 months, and dramatically affects the weather worldwide.

El Niño events happen irregularly. Their strength is estimated in surface atmospheric pressure anomalies and anomalies of land and sea surface temperatures.

The El Niño phenomenon dramatically affects the weather in many parts of the world. It is therefore important to predict its appearance. Various climate models, seasonal forecasting models, ocean-atmosphere coupled models, and statistical models attempt to predict El Niño as a part of interannual climate variability. Predicting El Niño has been possible only since the 1980s, when the power of computers became sufficient to cover very complicated large-scale ocean-atmosphere interactions.

The strongest El Niño events of the 20th century occurred in 1982/83 and in 1997/98. The effects of 1982/83 included significant storms throughout the southwest United States and one of Australia's worst droughts of the century. According to the World Meteorological Organization, the 1997/98 El Niño was a major factor in the record high temperatures observed in 1997. The estimated average surface temperature for land and sea worldwide was 0.4^{o} C higher than the 1961–1990 average of 16.5^{o} C. According to the National Oceanic and Atmospheric Administration (NOAA), 1998 has set all-time highs of global land and ocean surface temperatures, above record high levels in 1997. In 1998 the mean temperature was 0.7^{o} C above the long-term (since 1880) mean of 13.8^{o} C.

The impact of the 1997/98 El Niño was felt in many parts of the world: Droughts occurred in the Western Pacific Islands and Indonesia as well as in Mexico and Central America. In Indonesia drought caused uncontrollable forest fires and floods, while warm weather led to a bad fisheries season in Peru, and extreme rainfall and mud slides in southern California. Corals in the Pacific Ocean were bleached by warmer than average water, and shipping through the Panama Canal was restricted by below-average rainfall.

A very clear example of the consequences of the El Niño's effect on coffee production can be seen when studying its impact in Colombia**.** During its occurrence in the Andean region of Colombia, there is a decrease in the amount of rain and an increase in solar brilliance and temperature. The phenomenon in some regions causes decreased coffee production by lack of water on the ground, especially in those low-lying areas with less than 1,500 mm/year, precipitation levels low retention of moisture and crops' solar exposure. During El Niño episodes, there is a high risk of loss of coffee (occurrence of black beans, small beans and other defects) as the lack of water in the critical stage of development of the fruit affects bean quality. Also, increases have been recorded in coffee berry borer infestation levels that affect the quality of coffee.

2. The coffee sector and climate change

Climatic variability is the main factor responsible for the oscillations and frustrations of coffee yields in the world. Though adverse air temperatures, solar radiation and relative humidity influence many physiological processes of the coffee tree, those considered most important in defining potential yield are thermal and rainfall conditions.

Among almost 100 species of the *Coffea* genus, *Coffea arabica* L. (Arabica coffee) and *Coffea canephora* Pierre (Robusta coffee) economically dominate the world coffee trade, accounting for about 99% of world production.

Arabica coffee is native to the tropical forests of East Africa, at altitudes of 1,500 to 2,800 meters, between the latitudes of 4°N and 9°N. In this region, air temperature shows little seasonal fluctuation, with a mean annual air temperature between 18^o and 22^o C. Rainfall is well distributed, varying from 1,600 to more than 2,000 mm, with a dry season lasting three to four months coinciding with the coolest period. In this environment, Arabica coffee became established as an under-storey shrub.

Arabica coffee vegetates and fructifies very well in tropical highlands, such as the Southeast region of Brazil. It is usually affected in growth stages by environmental conditions, especially by photoperiodic variations and meteorological conditions, such as the distribution of rainfall and air temperature, which interfere in the crop phenology, and consequently in productivity and quality. For Arabica coffee, the optimum mean annual air temperature ranges from 18^o to 23^o C. Above 23^o C, the development and ripening of cherries are accelerated, often leading to loss of quality. Continuous exposure to daily temperatures as high as 30° C could result not only in reduced growth but also in abnormalities such as yellowing of leaves. A relatively high air temperature during blossoming, especially if associated with a prolonged dry season, may cause abortion of flowers. It should be noted, however, that selected cultivars under intensive management conditions have allowed Arabica coffee plantations to be spread to marginal regions with mean annual air temperatures as high as 24° to 25° C, with satisfactory yields, such as in the Northeast and North regions of Brazil. On the other hand, in regions with a mean annual air temperature below 18° C, growth is significantly hampered. Occurrence of frosts, even if sporadic, may strongly limit the economic viability of the crop.

Robusta coffee is native to the lowland forests of the Congo River basin, extending up to Lake Victoria in Uganda. This species developed as a mid-storey tree in a dense, equatorial rainforest. In that region, the annual mean temperature ranges from 23° to 26° C, without large oscillations, with abundant rainfall superior to 2,000mm distributed over a 9 to 10 month period. High temperatures can be harmful, especially if the air is dry. Robusta is much less adaptable to lower temperatures than Arabica. Both leaves and fruits cannot withstand temperatures below 6° C or long periods at 15° C. As altitude is related to temperature, Robusta coffee can be grown between sea level and 800 meters, whereas Arabica coffee grows better at higher altitudes and is often grown in hilly areas, as in Colombia and Central America. Robusta coffee grows better in areas with annual mean temperature between 22° and 26° C, as in the Republic of Congo, Angola, Madagascar, Côte d'Ivoire, Vietnam, Indonesia and Uganda. In Brazil, the main areas that cultivate the Robusta are the lowland areas of the states of Espírito Santo (Southeast) and Rondônia (North).

The relationships between climatic parameters and the agricultural production are complex, because environmental factors affect the growth and the development of the plants in different ways during the phenological phases of the coffee crop. Agro-meteorological models related to growth, development and productivity can supply information for the monitoring of soil water and yield forecasts based on the air temperature and water stress derived by a soil water balance during different crop growth stages, quantifying the effect of the available soil water on the decrease in the final yield. The process of photosynthesis becomes limited when water stress occurs, due to closing of the stoma and reduction in other physiological activities of the plant.

Other climatic factors can reduce productivity, such as adverse air temperatures during different growth stages. A study was conducted aimed at the development of an agro-meteorological model (Camargo et al., 2006) that monitors and assesses the quantitative influence of climatic variables, such as air temperature and soil water balance on the coffee crop phenology and yield for different Brazilian regions. This kind of model could be an efficient tool to assess the environmental effects of new technologies and future climate change scenarios.

2.1 Possible effects of climate change on coffee production

A great degree of uncertainty still exists with regard to how individual producing regions will be affected, and how climate change will impact overall coffee production. However, experts expect some changes to occur, and these they could be significant in some regions. Among the most likely are:

2.1.1 Quality

As temperature rises, coffee ripens more quickly, leading to a fall in quality. According to Dr Peter Baker, from CABI, if temperatures rise by 3^{o} C by the end of this century (some experts believe an increase of up to 5^{o} C is possible), the lower altitude limit for growing good quality Arabica coffee will rise by roughly 150ft (46m) per decade. This is 15 feet per year, meaning that areas that are currently too cold for growing coffee could become suitable. However, land use at higher altitudes is restricted in many countries due to competition from other crops, inadequate soil, restrictions on cultivation, inappropriate rainfall patterns, lack of irrigation or simply an absence of infrastructure.

2.1.2 Yields

Temperature increases affect different aspects of the metabolism of coffee trees, such as flowering, photosynthesis, respiration and product composition, which in turn adversely affect coffee yields. In addition, many of the adaptation strategies discussed below also reduce yields.

2.1.3 Pests and diseases

Temperature increases will favour the proliferation of certain pests and diseases, as well as permitting their dispersion to regions where they were previously not present. In the case of the coffee berry borer (*Hypothenemus hampei*), which is considered to be the most damaging pest affecting coffee production, Jaramillo et al. (2009) predict a maximum intrinsic rate of population growth of 8.5% for every 1^{o} C increase. A study analysing the impact of climate change on coffee of nematodes (*Meloidoygne incognita*) and the leaf miner (*Leucoptera coffeella*) conducted in Brazil concluded that the infestation of coffee plantations by these pests under the future scenarios will increase when compared with the normal climatic conditions prevailing from 1961 to 1990. Similarly, a report from Colombia warns of the possible increased incidence of diseases, such as coffee rust (*Hemileia vastatrix*) and pink disease fungus (*Corticium salmonicolor*). As a result of the increased vulnerability of coffee plantations and the need to introduce more rigorous controls, production costs will tend to rise.

2.1.4 Irrigation

As aquifers become scarcer, there will be greater stress on their use, forcing stricter control measures. According to the IPCC Technical Paper Nr. VI: Climate change and water, “Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes (*very likely*) and parts of the tropics, and decreases in some subtropical and lower mid-latitude regions (*likely*)”. It concluded that many semi-arid areas, such as southern Africa and north-eastern Brazil, are likely to experience a decrease of water resources due to climate change. On the other hand, more intense precipitation and variability will very likely increase the risks of both flooding and drought in many areas. In areas that do not currently require irrigation, higher temperatures may result in increased evapotranspiration and reduced moisture content in the soil. Such areas may require the implantation of costly irrigation infrastructure. In addition, the useful life of coffee trees subject to hydric stress is likely to be shortened.

2.1.5 Global output

As a result of all the changes in the environment, there is a real possibility that fewer parts of the world will be suitable for growing quality coffee. If this were to happen, current trends in concentration of production could become even more pronounced. This in turn could make global production more prone to high fluctuations, as any severe disruption in output from one of the major producers would drastically curtail global output.

2.2 Possible impacts on coffee production and trade under different scenarios

This section analyses the different possible impacts on coffee of the four scenarios described in section 1.2. It should be noted that these are illustrative scenarios that only provide an outline framework for considering possible policy responses to climate change. No single modelling study includes all of the outputs listed and large variations exist in the assumptions made and the processes used. Nevertheless, the broad trends outlined are consistent with current research, but may deviate significantly from any specific study.

2.2.1 A1F1 scenario

In the A1F1 scenario, population growth increases towards nine billion by 2050 and then declines to around seven billion by 2100. Economic growth increases at about 3.5% per annum over this time with per capita income in developed countries reaching $76,000 and

$42,000 in developing countries. The average income ratio reduces to about 1.6, implying a more equitable world. It is questionable whether such high growth rates could be sustained in reality. Mortality and fertility rates decline over this period.

In this scenario, it is likely that crop yields will decrease, although this change may be small at a global average, especially until 2050, depending on the effects of CO_2 'fertilization'. Yields would decrease especially in Africa, possibly by as much as 20%, according to some estimates. The beneficial effects of CO_2 in most areas of the continent may be less pronounced because of large and damaging increases in temperature. Coffee production is also likely to decrease globally, and particularly in Africa. Coffee prices vary inversely with production changes and this scenario generates the largest price increases out of all of the scenarios described here. Measures of the additional number of people at risk of hunger indicate that climate change has less impact than might be expected because of low population growth and high rates of economic growth in all areas when beneficial CO_2 effects are included. Without these effects, the number increases substantially towards the end of the century. The number of people suffering from water stress also shows little increase because of low population growth.

2.2.2 A2 scenario

The A2 scenario is characterized by very high population growth, rising from around eight billion in 2020 to around 15 billion in 2100. Economic growth increases at around 2% per annum, a much lower rate than A1F1. Average per capita income in developed countries reaches around $37,000, compared to $7,300 in developing countries. Income differences between developed and developing countries decrease, but large differences remain. In this scenario, global yields are likely to decrease towards 2050 as they do in A1F1 but decreases are less pronounced towards the 2080s.

Coffee production decreases by up to 10% compared to the reference case without climate change. Coffee price increases are likely to be high. High population growth, a greater concentration of people living in the developing world, greater economic disparities and greater regional differences in climate increase the number of people at risk of hunger dramatically since there are no positive CO_2 effects.

2.2.3 B1 scenario

In the B1 scenario, population growth follows a similar pattern to A1F1, but economic growth increases at a lower rate (around 2.75% per annum). Average per capita income increases to $55,000 in developed countries and $29,000 in developing countries, implying lower growth rates of around 10% for developed countries and 20% for developing countries in comparison with the A1F1 scenario. Income ratios between developed and developing countries are much lower than those existing today, implying a more equitable world.

In this scenario, global coffee production is expected to decrease but much less markedly than in the A scenarios, mainly due to less extreme changes in temperature. As with other scenarios, the results depend heavily on the effects of CO_2 on crop yield. Coffee prices increase gradually, but remain low. This scenario results in the least dependence of developing countries on agricultural imports (about 170 million tonnes by 2080). The number of people at risk of hunger is much lower than in the A scenarios because of reduced inequality, lower population and higher rates of growth. The number of people suffering water stress varies in the same way as the A1F1 scenario.

2.2.4 B2 Scenario

Population growth in the B2 world increases gradually towards ten billion by the end of the century. The rate of economic growth is similar to the A2 scenario but differences between developed and developing countries are less (although still greater than A1F1 and B1). Technological change is less rapid and more diverse than the B1 and A1 storylines. Efforts to improve environmental protection and social equity focus on local and regional levels.

In this scenario, global decreases in yield are expected, although this again depends on the CO_2 effect. The highest yield decreases are expected in Africa and South America, although these are not as pronounced as in the A2 scenario. If beneficial CO_2 effects are assumed, then yield increases might be expected, especially in high latitudes and Asia and reductions in yield will be much less severe in Africa compared with no CO_2 effects. Global production is likely to decrease although much less than in the A scenarios, resulting in less extreme increases in prices. The number of people at risk of hunger is predicted to be low, mainly due to increased income in developing countries.

2.3 Strategies for mitigation and adaptation

2.3.1 Mitigation

Mitigation of global warming involves taking actions to reduce greenhouse gas emissions and to enhance sinks aimed at reducing the extent of global warming. This is in distinction to adaptation to global warming which involves taking action to minimize the effects of global warming. Mitigation is effective at avoiding warming, but not at rapidly reversing it. Scientific consensus on global warming, together with the precautionary principle and the fear of abrupt climate change is leading to increased effort to develop new technologies and sciences and carefully manage others in an attempt to mitigate global warming. The Stern

Review identifies several ways of mitigating climate change. These include reducing demand for emissions-intensive goods and services, increasing efficiency gains, increasing use and development of low-carbon technologies, and reducing non-fossil fuel emissions.

2.3.2 Adaptation

Because of the current and projected climate disruption caused by high levels of greenhouse gas emissions by the industrialized nations, adaptation is a necessary strategy at all scales to complement climate change mitigation efforts because no certainty exists that all climate change can be mitigated. Indeed the odds are quite high that in the long run more warming is inevitable, given the geologic evidence of the most similar glacial / interglacial cycle that happened about 400,000 years ago. This similarity is determined by the shape of the Earth's orbit and how close the Sun is when the most land, that is the northern hemisphere, is being warmed by it.

Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damage. Extremes, variability, and rates of change are all key features in addressing vulnerability and adaptation to climate change, not simply changes in average climate conditions.

Human and natural systems will to some degree adapt autonomously to climate change. Planned adaptation can supplement autonomous adaptation, though there are more options and greater possibility for offering incentives in the case of adaptation of human systems than in the case of adaptation to protect natural systems.

2.3.3 Disadvantaged nations

The ability of human systems to adapt to and cope with climate change generally depends on such factors as wealth, technology, education, information, skills, infrastructure, access to resources, management capabilities, and socio-political will. There is potential for more advantaged and less advantaged countries to enhance and/or acquire adaptive capabilities. Populations and communities are highly variable in their endowments with these attributes, and disadvantaged countries are weakest in this regard. As a result, they have lesser capacity to adapt and are more vulnerable to climate change damages, just as they are more vulnerable to other stresses. This condition is most extreme among the most disadvantaged people.

2.3.4 Mutual reinforcement

Many communities and regions that are vulnerable to climate change are also under pressure from forces such as population growth, resource depletion, and poverty. Policies that lessen pressures on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, enhance adaptive capacity, and reduce vulnerability to climate and other stresses. Inclusion of climatic risks in the design and implementation of national and international development initiatives such as polar cities can promote equity and development that is more sustainable and that reduces vulnerability to climate change.

A study by the American National Centre for Policy Analysis (2009) argues that adaptation is more cost-effective than mitigation. Their report makes the following observations:

1. By 2085, the contribution of (unmitigated) warming to the above listed problems is generally smaller than other factors unrelated to climate change.
2. More important, these risks would be lowered much more effectively and economically by reducing current and future vulnerability to climate change rather than through its mitigation.
3. Finally, adaptation would help developing countries cope with major problems now, and through 2085 and beyond, whereas generations would pass before anything less than draconian mitigation would have a discernible effect.

2.4 Adaptation for the coffee industry

Adaptation to climate change must occur through the prevention and removal of maladaptive practises. Maladaptation refers to adaptation measures that do not succeed in reducing vulnerability but increase it instead. Examples of measures that prevent or avoid maladaptation include better management of irrigation systems and better building regulations on coasts and in floodplains.

Planning for climate change must involve consideration of climate related risks including those which have slow onset, such as changes in temperature and precipitation leading to agricultural losses and drought and biodiversity losses, and those which happen more suddenly such as tropical storms and floods. Past and present experiences in dealing with climate variability and extreme events provide valuable information for reducing vulnerability and enhancing resilience to future climate-related adverse impacts.

For all regions there is a need to enhance technical capacity to assess, plan and integrate adaptation needs into sectoral development plans. Also necessary is to support integration of adaptation into sectoral policy, particularly in areas of water, agriculture, coastal zones and managing natural ecosystems. Needs-based regional technological transfer is an important area in United Nations efforts helping countries to adapt. This technical transfer can include ‘hard’ forms of technology, such as new irrigation systems or drought-resistant seeds, or ‘soft’ technologies, such as insurance schemes or crop rotation patterns; or can they can of course involve a combination of hard and soft.

Another important adaptation strategy is economic diversification within sectors to reduce dependence on climate-sensitive resources, particularly for countries that rely on narrow ranges of climate-sensitive economic activities, such as the export of climate-sensitive crops.

2.4.1 Adaptation strategies

There are several actions that could make coffee producers better prepared for facing the potential consequences of climate change in their areas. Among some of the most important are:

- detailed monitoring of changes in climate and production: so far, only Brazil has began to elaborate maps classifying those areas more prone to the spread of specific pests according to the likely impact of climate change. Market mechanisms such as providing financial support to growers only if they choose recommended crops are being used already, providing the kind of governmental guidance needed to assure the long-term viability of the coffee industry;
- detailed mapping of likely climate change within each coffee region: The United Nations Framework Convention on Climate Change (UNFCCC) is enabling least developed countries to identify their immediate priorities for adaptation options via the National Adaptation Programmes of Action (NAPAs) which identify their urgent and most immediate needs, that is, those for which further delay could increase vulnerability or lead to increased costs in the future. Over 40 least developed countries have received funding under the Convention to prepare their NAPAs, drawing on existing information and community-level input to prioritize adaptation plans. As a result, many countries have already submitted their NAPAs to the UNFCCC secretariat;
- migration: Production could move northwards or southwards (latitudinal expansion) in search of more appropriate climate conditions. One likely scenario would be a southward shift in Brazilian production, to areas where the likelihood of frosts is in the decline or might even disappear altogether. However, widespread latitudinal changes will be difficult due to the susceptibility of both Arabica and Robusta coffee to changes in photoperiod, with effects ranging from a noticeable decrease of the growth phase to an inhibition of flower development. In addition, it should be noted that coffee is currently grown in areas of Nepal and China (Yunnan province) that lie outside the ‘normal’ tropical distribution range of coffee cultivation. As temperature increases, production may also move to areas of higher altitude (altitudinal expansion) whose climate will become more suitable for coffee plantation. However, both movements in geographical location and in altitude may be restricted by the factors mentioned in item 2.1.1 above;

- estimation of the impact on quality of coffee production: As temperatures go up, coffee will ripen more quickly, leading to a fall in quality. This means that areas currently favourable to the cultivation of coffee will no longer be so in 20 years, and others currently too cold may become suitable. This dislocation of existing areas towards new ones is highly problematic, given the increasingly high competition for fertile land across all regions;
- a strategy to facilitate diversification out of coffee when necessary: Diversification has been on the agenda for many years now, but has proven particularly challenging, mainly because of lack of adequate substitutes. It is expected however that with increasing pressure on food crops, more land that is currently used for coffee production might find itself subject to competition from profitable crops;
- evaluation of available adaptation techniques, such as shade management systems: Although originally a shade tree, current coffee plantations can prosper without shade in zones with adequate climate and soils. However, when production has been taken to areas with less than desirable conditions, or that will be affected by climate change, the use of shading management is highly advisable, the main effects being the decrease in air temperature fluctuations by as much as 3^{o} – 4^{o} C, decrease in wind speeds and increase in air humidity. Generally speaking, shading has been adopted to avoid large reductions in night temperatures at high elevations, or in high latitudes such as Paraná State in Brazil;
- planting at high densities, vegetated soil and irrigation: With all these the main aim is to maintain and/or increase organic matter and soil water retention capacity, thereby enhancing the viability cultivation under adverse climatic conditions; and
- genetic breeding: The main objectives when it comes to genetic manipulation are those of developing higher yields, increased quality and strength, and longevity. Brazil and Colombia have been at the forefront of research in this domain, especially when it came to producing plants resistant to coffee leaf rust. It is thus essential that genetic improvement based on selective breeding of Arabica and Robusta species contributes to the long-term sustainability of coffee cultivation in potentially affected lands. In some cases, research has focused on developing varieties that could cope well with higher temperatures and remain highly productive at the same time. A good example is the programme for genetic improvement conducted by the *Instituto Agronomico de Campinas* (IAC) that is currently working on the possibility of transferring the characteristics of Robusta to Arabica coffee, such as resistance to pests, vigour, and above all, higher resistance to higher temperatures. Equally important is research on varieties that are less water demanding.

ANNEX I

THE IMPACT OF CLIMATE CHANGE ON COFFEE: THE VIEWS OF STAKEHOLDERS

This annex aims at allowing the stakeholders in the coffee sector, especially growers, to present their views on climate change. The material below is a collection of statements by non-governmental organizations (NGOs), producer associations, certification schemes and other leaders in the sector that are witnessing first-hand the consequences of climate change.

Brazil

During recent decades, Brazilian coffee production has shifted northwards, away from areas prone to frosts and in search of more benign climates. However, as a result of temperature increases and a reduction in frosts, coffee planting in the southern parts of the country is once again becoming desirable. As a matter of fact, temperatures consistently above the historical average have been registered by the country's meteorological agencies since the 1990s. Overall, scientists agree that, given the rise in temperatures, coffee planting will become increasingly viable in the southern states such as Paraná, Santa Catarina and Rio Grande do Sul, formerly considered too prone to the risk of frosts. During the 1990s, researchers from that region began to notice how overall agricultural productivity began to fell. High temperatures in October during successive years, when blossoming takes place, provoked the early loss of flowers, preventing the formation of the cherry in some cases.

According to the Brazilian Agricultural Research Agency EMBRAPA, a one degree increase in temperature could reduce by 200,000 square kilometres the current areas with climatic potential for coffee plantation. A three degree increase would remove a further 320,000 square kilometres, while a catastrophic increase of 5.8 degrees would wipe out another 310,000.

Colombia

Production costs are likely to increase due to new climatic conditions favouring the proliferation of insects, plagues and pathogens. Thus, although many pests are naturally limited by their present predators, an unstable climate can alter this assessment and foster conditions favourable to the proliferation of pathogens and insects, which will serve as inoculum for epidemics and epizootics populations. For example, in the case of the coffee berry borer, drier environments may affect the presence of the fungus *Beauveria bassiana*, reducing its effectiveness in inhibiting natural or artificial infections and promoting an increase of the populations of this pest. Similarly, an increase of rainfall during the year can counteract the restrictive effect of dry periods on the proliferation of pathogens, thus enabling the continuity of a life-cycle that otherwise would be interrupted. The same effect can occur as a result of higher temperatures. Continuous life cycles in organisms with high reproduction capacity may result in a rate of exponential growth of their populations and permanent damage to plantations. Finally, the increase in temperature in altitude and latitude in mountain regions will allow the spread of diseases to regions where it was not present earlier. Likewise, production can be affected adversely due to the incidence of diseases such as the coffee leaf rust, the pink disease (*Corticium salmonicolor*) and radical ulcers (*Rosellinia*) among others, whose proliferation is facilitated by the persistence of rain and the occurrence of a high relative humidity in the environment. Water deficiency is not common in most coffee areas of Colombia and thus irrigation is not needed. However, increases in average temperature cause high evaporation, soil water losses and higher rates of perspiration, thus increasing water requirements. If this were the case, many farmers would have to introduce some sort of infrastructure for irrigation, inevitable increasing their production costs.

There is no doubt that in the likelihood of significant global warming, chances are that in some regions coffee plantations would have to be transferred to higher altitudes, seeking more suitable environmental conditions for production. There is great interest in acquiring as much knowledge on the methodologies and use of impact scenarios to allow the assessment of the implications of climate change on the growth and development of the coffee sector.

Costa Rica

Costa Rican coffee farmers are facing threats from climate change but the rising temperatures are also expanding high-altitude regions where the country's most prized beans are grown. In Costa Rica, the temperature increases may help transform mountainous land that was once too chilly for delicate coffee trees into prime coffee-planting territory.

The strictly hard-bean Arabica coffee sought by specialty roasters is only found at high altitudes, so the shift could mean more opportunities for a country already known for its quality coffee. According to an agronomist of the Coopedota coffee cooperative, coffee can now be grown at 2,000 meters, whereas before plants have not survived above 1,800 meters.

India

Arabica farms in India are already experiencing the negative effects of global warming. In the Coorg region, some areas have seen rainfall drop by one-third, from 106 inches per year to 70 inches, dramatically changing the ecosystem and growing conditions. With higher temperatures, too, infestation of Arabica plants by the white stem borer has destroyed up to 35% of the crop, and Robusta plants, immune to that pest, have been hit instead by the coffee berry borer. Growers who had never given a thought to irrigation in such a wet climate have had to dig deep, high-volume wells, lowering the water table in the region. The Indian government has paid farmers to monitor the life cycle of the borers so that a means to fighting them effectively can be designed.

Kenya

In Kenya, the total area for coffee and tea cultivation is expected to remain unchanged but to migrate upwards. The land now used around Mount Kenya for tea production would all become useless for tea, and production would have to move up the mountain. That area is now forested, and the forests would likely be cut down, accelerating local and global warming. In growing areas already well suited to coffee and tea cultivation, the effects of global warming are many. The soil tends to dry more quickly, leading to cracking that can impact the smaller roots and soil organisms that support the health of the coffee tree. Coffee evolved under the canopy of larger trees, and so, in Arabica, the outer layer of the leaf cannot tolerate heat stress and it may wilt. Both of these effects make the plant more vulnerable to pathogens, especially exotic pathogens that may move into the area as it heats up. In terms of quality, higher temperatures may cause the flowering period to expand, stretching out the fruiting period, with a resulting decrease in quality.

Mexico

According to the President of the National Union of Coffee Producers, Eleuterio González Martínez, coffee production in the country is in risk by climatic change and the advance of pests. In an interview the coffee leader asserted that “with climatic change there is no longer a clear divide as to what culture is in a greater degree of risk”. Mr Gonzalez explained that previously optimal areas for the coffee production were between 600 and 1,200 meters of altitude above sea level, but now that border no longer exists. Latest reports have shown that coffees trees as high as 1,200 meters are being affected by the coffee berry borer pest. That is to say, where before it was considered free from risk, “with climate change, all altitudes are at risk in coffee production". He also emphasized that there is no programme of insuring small producers, although all of them are threatened by climate change.

Peru

Rising temperatures and erratic weather patterns are changing historic trends in coffee growing areas, a region closely tied to the impact of climate change because of its rapidly melting tropical glaciers. Farmers have reported that warmer temperatures are responsible for their early start this year – about a month earlier than last. They are also reporting high-altitude plants are maturing at times more typical of their low-land counterparts.

Traditionally, Peruvian coffee growers start picking their crop in April, some six months before the global Arabica harvest. Its different growing season has given Peru, the world's sixth largest exporter of coffee, a unique comparative advantage. If the season continues to move earlier, farmers worry they could lose their privileged position. Peruvian growers have said the scarcity of rains this year in some coffee-producing areas is the result of rising global temperatures.

There is already an in-depth study being carried out by the German Agency for Technical Cooperation (GTZ) and Cafédirect aimed at making adaptation to climate change available to small producers. Research is taking place in four major coffee growing areas, with extensive interviews to coffee growers as well as local agronomists. On the whole, the main changes reported so far are:

Temperature: increases in temperature matched by sudden cold fronts provoking frost and hail.

Rainfall: reduction in rainfall levels, prolonged droughts and reduced availability of water. In some areas total levels have not affected, but its distribution has, with torrential rains causing floods and land movements.

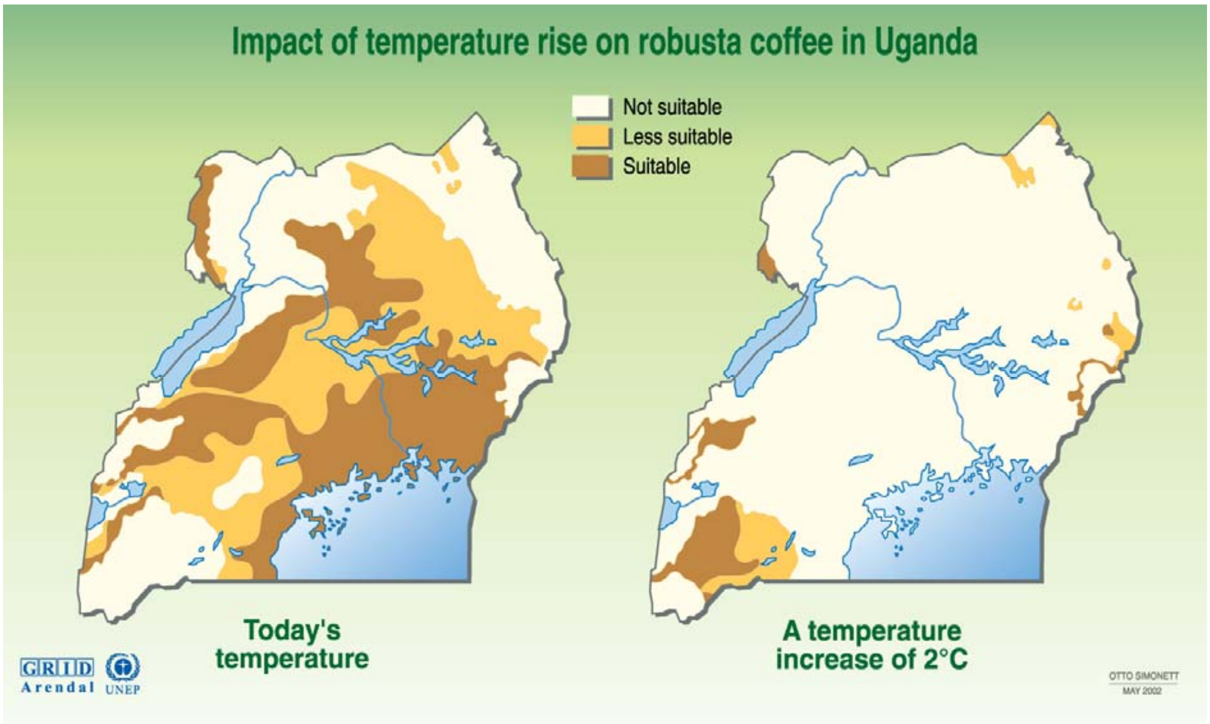
Winds: stronger winds have been responsible for the destruction of trees, roads and general infrastructure, as well as causing serious damage to coffee plantations.

Tanzania

An opposite example of the migration of prime coffee-growing areas is illustrated by Tanzania. There, where coffee contributes significantly to the GNP, the Organization for Economic Co-Operation and Development has collected scientific models of the changes that would occur when the current warming trend continues through the next few decades. Here, though, increased temperatures are expected to increase coffee yields by nearly 20 percent. This is very good news, not only for coffee growers but for the nation's GNP, so Tanzania has a complex strategy for reacting to global warming, taking advantage of the benefits to exports while adapting to forecast losses in local staple crops such as corn.

Uganda

Perhaps in no country can the potential negative consequences of global warming be felt more than Uganda. A report published by Oxfam warns of the threat of a drastic reduction in the country's land suitable for coffee cultivation. The report, called "Turning up the heat, Climate Change and Poverty in Uganda" states that "if average global temperatures rise by two degrees or more, then most of Uganda is likely to cease to be suitable for coffee. This may happen in 40 years or perhaps as little as 30." It also makes clear that there are signs already of erratic rainfall patterns in the country. According to Oxfam, the devastation caused by the floods and landslides is already a cause for concern, especially when scientific experts warn that the current change in climatic conditions is just the beginning of these sorts of natural disasters.



Source: Otto Simonett, Potential impacts of global warming, GRID-Geneva, case studies on climatic change. Geneva, 1989.

The increase in erratic rainfall in the March to July rainy season has brought droughts and reductions in crop yields and plant varieties. But the rainfall towards the end of the year is more intense and destructive, Oxfam said, bringing floods, landslides and soil erosion. As such, Uganda's "coffee crop is in danger of extinction if temperatures rise too far".

On the positive side, however, some farmers have apparently begun to implement mitigation strategies such as growing more trees to create a cool shade for coffee, mulching or covering soil with grass to retain irrigation water, and digging long terraces in the ground to capture rainwater. How effective these measures will prove remains to be seen.

ANNEX II

ORGANIZATIONS PROVIDING FUNDS FOR MITIGATION AND ADAPTATION TO CLIMATE CHANGE

The following is a table with a comprehensive list of those organizations providing funds for mitigation and adaptation to climate change, including any amounts disbursed up to date on such programmes.

Name and link	**Type**	**Administered by**	**Areas of focus**	**Number of projects**	**Total funds disbursed to date (US$ millions)**
Adaptation Fund	Multilateral	Adaptation Fund Board	Adaptation	0	0.0
Clean Technology Fund	Multilateral	The World Bank	Mitigation – general	0	0.0
Cool Earth Partnership	Bilateral	Government of Japan	Adaptation, Mitigation - general	0	.0
Environmental Transformation Fund – International Window	Bilateral	Government of the United Kingdom	Adaptation, Mitigation - general	0	0.0
Forest Carbon Partnership Facility	Multilateral	The World Bank	Mitigation – REDD	0	0.0
Forest Investment Program	Multilateral	The World bank	Mitigation – REDD	0	0.0
GEF Trust Fund - Climate Change focal area	Multilateral	The Global Environment Facility (GEF)	Adaptation, Mitigation - general	591	2,388.7
Global Climate Change Alliance	Bilateral	The European Commission	Adaptation, Mitigation - general, Mitigation – REDD	0	0.0
International Climate Initiative	Bilateral	Government of Germany	Adaptation, Mitigation - general	128	347.2
International Forest Carbon Initiative	Bilateral	Government of Australia	Mitigation – REDD	0	0.0
Least Developed Countries Fund	Multilateral	The Global Environment Facility (GEF)	Adaptation	62	47.5
MDG Achievement Fund – Environment and Climate Change thematic window	Multilateral	UNDP	Adaptation, Mitigation - general	16	85.5
Pilot Program for Climate Resilience	Multilateral	The World Bank	Adaptation	0	0.0
Scaling-Up Renewable Energy Program for Low Income Countries	Multilateral	The World Bank	Mitigation – general	0	0.0
Special Climate Change Fund	Multilateral	The Global Environment Facility (GEF)	Adaptation	14	59.8
Strategic Climate Fund	Multilateral	The World Bank	Adaptation, Mitigation - general, Mitigation – REDD	0	0.0
Strategic Priority on Adaptation	Multilateral	The Global Environment Facility (GEF)	Adaptation	22	50.0
UN-REDD Programme	Multilateral	UNDP	Mitigation – REDD	0	0.0

ANNEX III

ONGOIN RESEARCH PROJECTS INTO THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE

Projects currently under implementation to research the implications of climate change on agriculture include:

- Energy Conservation in Small Sector Tea Processing Units in South India, funded by the Global Environment Facility (GEF) Trust Fund – Climate Change focal area (mitigation efforts), US$1.0 million;
- Obtaining Biofuels and Non-wood Cellulose Fiber from Agricultural Residues/Waste in Peru, GEF Trust Fund – Climate Change focal area (GEF), US$1.0 million; and
- Adaptation to the effects of drought and climate change in Agro-ecological Zone 1 and 2 in Zambia, Least Developed Countries Fund (LDCF), US$3.5 million.

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