Title Page

Global Warming: the impact on global coffee

"Many the wonders but nothing walks stranger than man.
The thing crosses the sea in the winter's storm,
Making his path through the roaring waves,
And she, the greatest of gods, the earth –
Ageless she is and unwearied – he wears her away
As the ploughs go up and down from year to year
And his mules turn up the soil.
Gay nations of birds he snares and leads,
Wild beast tribes and the salty brood of the sea
With the twisted mesh of his nets,
this clever man…"

Dr Peter S Baker
Global Director, Commodities
CABI Europe - UK
Silwood Park
Ascot
SL5 7TA
United Kingdom

Telephone: +44 (0) 1491 829175
Fax: +44 (0) 1491 829123
Email: p.baker@cabi.org

Dr Jeremy Haggar,
Coffee Theme Group Coordinator
(Associate Research Professor),
CATIE,
Apdo P-116,
Managua,
Nicaragua

Telephone: + (505) 2657268,
Fax: + (505) 2657114
Email: jhaggar@ibw.com.ni

1 Summary

An increasing weight of data, research papers and models all suggest that global warming is real. Most scientists now believe that the warming trend is largely irreversible; a 3^{o}C rise by the end of the century is no longer considered exaggerated.

It is clear that coffee regions will be increasingly affected, all becoming warmer, many also becoming either wetter or drier. We can also expect a greater frequency of extreme weather events.

Evidence from C America for example, suggests that this is already happening. Many famous C American coffees come from the seasonally dry Pacific facing mountain slopes and valleys. These include Antigua, Marcala, Segovias and Tarrazu amongst others. The majority of the top ten Nicaraguan Cup of Excellence coffees come from the Segovias region, an area with a long dry season of 5 to 6 months. Climate change predictions by the Ministry of National Resources and the Environment indicate that within this century rainfall will decline by an average of 30%, and temperatures rise by 1-2^{o}C. These changes would effectively eliminate coffee production in these regions. The prognosis for C America as a region is more extremes of rainfall that will cause both drought and flood. Coffee production in Nicaragua from the 2006-07 harvest is predicted to be half of 2005-06.

As with C America, so with other regions and whereas it is not possible to link any one extreme event to climate change, the weight of data, models and anecdotal evidence from farmers and other coffee professionals is all pointing to a realization that the climate is changing and that this will have negative effects.

Exactly how global warming will affect coffee production is still largely unquantified and it is urgent that work starts soon to use the increasingly sophisticated models now available to estimate global production well into the 21st century.

In this presentation we will review some of the current evidence and suggest that even if we can't quite believe it, we must rapidly start making plans and taking co-ordinated action now.

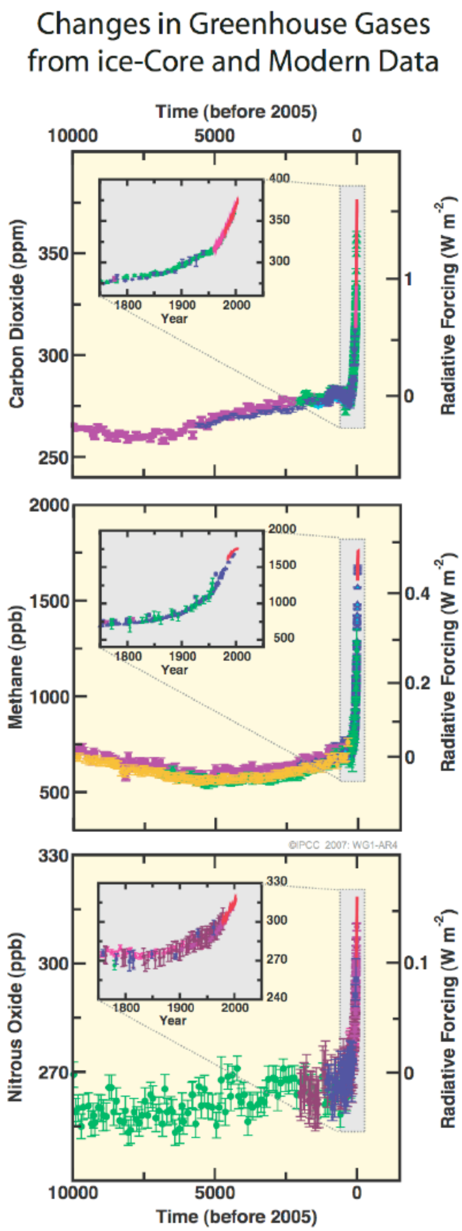
At a practical level we need to develop a range of activities to begin to help producers adapt to climate change and ensure the supply of good quality coffees, including:

- Detailed monitoring of changes in climate and production in coffee growing regions
- A more detailed mapping of likely climate change within each coffee region
- Zoning of areas according to level of change and vulnerability
- An estimation of the impact on quality and quantity of coffee production
- An evaluation of currently available adaptation techniques including field trials with a range of shade, irrigation, water conservation, erosion control etc. techniques
- Genetic improvement to identify more drought resistant quality coffee

2 Global warming now

a) The evidence
There is now no doubt that the world has been getting warmer over recent decades.

The recent report by the Intergovernmental Panel on Climate Change (IPCC 2007; 33 drafting authors) confirms previous reports and leaves very little room for disbelief about the cause. Carbon dioxide concentrations in the atmosphere are higher than at any time in the last 600,000 years, and rates of accumulation are increasing. The same is true for methane, and nitrous oxide, which are also greenhouse gases; many scientists have now painstakingly pieced together an historical record of the change of concentration of these gases, going back at least 10,000 years. The results are clear and sobering (Fig. 1).



◄Figure 1. From the IPCC report 2007; concentrations of the major greenhouse gases over the last 10,000 years.

The increase in these gases comes mostly from human activity, especially the increased use of fossil fuels but also through changes in land use.

But the purpose of this presentation is not to look in any detail at the causes, but rather to concentrate on the effects.

Nor will this presentation deal with ways to reduce emissions (mitigation) – instead we will look at what might be done to adapt to the effects that global warming are causing and will inevitably continue to cause.

b) The effects
There are inescapable geophysical consequences of an increase in greenhouse gases:

i) The Earth (land & atmosphere) heats up as more of the sun's radiation is trapped in the atmosphere, due to the molecular properties of these greenhouse gases;
ii) As the temperature rises more water vapour is carried in the atmosphere.

This means that:
iii) The soil and air are becoming hotter, causing an increase in evaporation of water from soils and plants;
iv) Rainfall will sometimes be more intense because of the greater volume of water vapour contained in warmer air.

The changes in these two fundamental variables, temperature and water, will have profound effects on agriculture that we are only starting to study and understand.

A key difficulty is to know which regions will be most affected, how quickly temperatures will rise in each locality and to what extent patterns of rainfall will change as a result. But here we are getting increasingly convincing guidance from a very special group of scientists – the climate modellers.

The models they have produced – there are several – are evidence of a quiet revolution in science, the science of complexity. As Bradbury (1998) puts it:

> " …the science of complex systems threatens to remove our only remaining prop - our belief in our own intelligence - by showing that the real world is messy: its complexity irreducible …"

Our view of the future depends essentially on what they tell us. The calculations are so complex that they can only be carried out with massive computing power. Our belief in these models is increasing because a) there are several of them, produced independently by different groups; b) the models broadly agree; c) the sort of changes they have predicted over the last 15 or so years seem to be coming true. The work of these largely unsung teams represents a major advance in mankind's understanding of our environment.

c) The future revealed

In Fig. 2 below (IPPC, 2007) we can see projections of future changes in precipitation to the end of this century, based on a synthesis of several climate models. Two general things are clear – an increase in precipitation in a thin blue strand over the equator and a much broader brown band either side of the equator where precipitation will decline, by up to 20%.

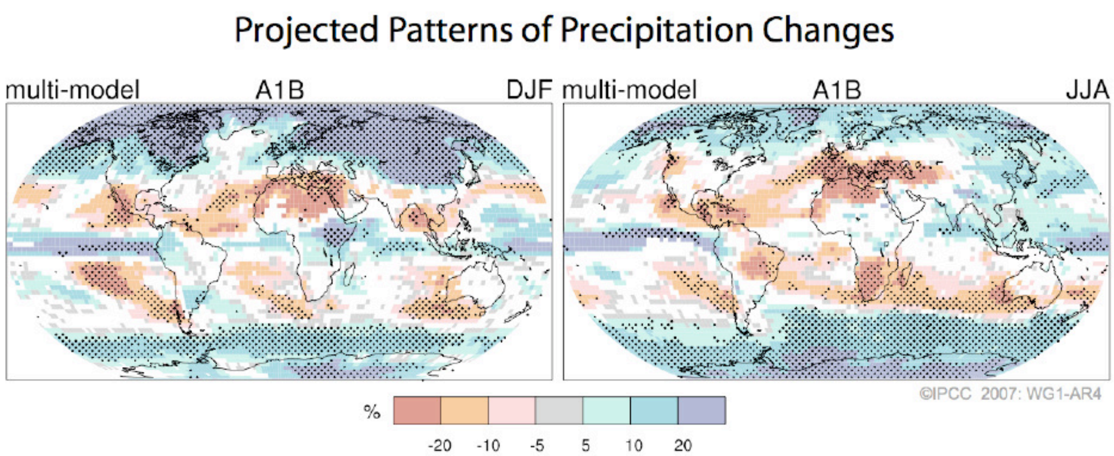


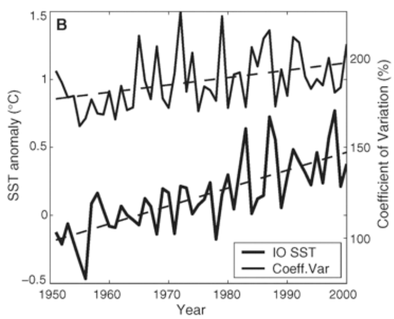
Figure 2. Changes in precipitation for period 2090–2099, relative to 1980–1999. Values are multi-model averages for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change (from IPCC 2007).

For some areas where coffee is grown, Mexico, Central America, the Caribbean and northern S America, these regions are all likely to become significantly drier, for both Dec to Feb and June to August periods modelled in Fig. 2.

On the other hand much of Colombia, Indonesia and Papua New Guinea are projected to get wetter for these periods. E. Africa will also become wetter, especially the December to February period, whilst both Brazil and Southern Africa may get substantially drier in the June - August period at least.

But how this translates into practical experience is less clear. For instance, a recent study by Goswami *et al.* (2005) found that there were significant increases in the frequency and the intensity of extreme monsoon rain events in central India over the past 50 years. Average rainfall did not change however, because there was a concomitant decline in moderate rainfall events. At the same time Webster *et al.* (2005) showed that the most noticeable trend in hurricanes and typhoons over the last 35 years has been a similar increase in intensity of these events – i.e. more force 4 and 5 events.

Hence simple averages are not enough to reveal the truth on the ground. The detail of the results are exactly what modelling predicts – greater variability, more heavy storms, even when overall rainfall does not change. This is bad for agriculture because heavy rainfall leads to greater erosion, landslides and so on.



◄ Figure 3. From Goswami *et al.* (2005): Indian monsoon variability has increased over the last 50 years (lower graph). Indian ocean surface sea temperatures have also risen during that time (upper graph). Similar occurrences are known also for hurricanes and typhoons.

d) How it will affect coffee production – the main issues

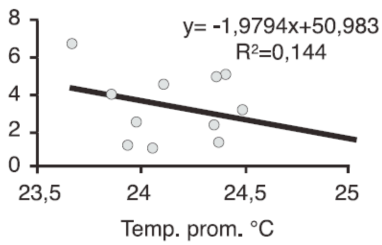
Here there is further uncertainty – just as we still do not know the details of how each region will change, neither are we sure how this will impact on coffee production. What follows are some concepts and a review of current evidence. It must be stressed that this is a preliminary view but one thing is certain however, there *will* be changes and they could be severe in some regions.

Quality: as temperatures rise, coffee will ripen more quickly, leading to a fall in quality. If temperatures rise by 3°C by the end of this century (no longer an extreme prognosis) this will mean that the lower limit for growing good quality Arabica will rise by roughly 150 ft (46m) per decade. Or 15 ft per year, or 1¼ft per month. Since coffee is a perennial that may be in the ground for 20+ years, decisions on planting or replanting should now take climate change into account. New areas currently too cold to grow coffee may become more favourable to the crop. This could be achieved by simply planting further up the mountainside, though in practice opportunities for this may be quite small, especially in countries that have limited high ground with the required suitable soils, infrastructure and absence of restrictions (e.g. national reserves, watershed protection schemes).

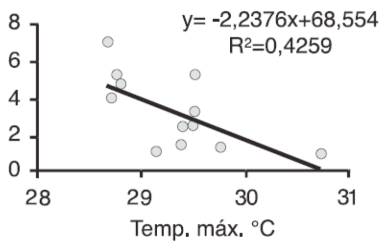
Those who police geographical indicators of origin, e.g. Antigua, Blue Mountain, will need to monitor quality at the lower extremes of the range to determine if quality continues to be acceptable there.

Quantity: as temperatures rise over the lower lying areas, coffee yields will be adversely affected. Fournier & di Stéfano (2004) have shown that yields on Finca San Luis (Ciudad Colón, Costa

Rica; 750 m above sea level) have been severely compromised by high average and high maximum temperatures (Fig. 3); thus it is inevitable that the lowest altitude coffee will tend to disappear.



◄**Figure 3 Yield (a relative 0 – 10 scale) declines with increased mean and especially maximum temperatures (from Fournier & di Stéfano, 2004).**



Migration: production could also move further north or south, though the patterns of predicted precipitation decline suggest that such opportunities might be rather few. E.g. W hemisphere production is unlikely to be able to migrate north through Mesoamerica, since this area is already dry, and is expected to get substantially drier. The effect of shorter and longer day length on flowering and tree growth would need further consideration and study as well.

An increase of production in S. Brazil, currently susceptible to frosts, is a possibility however since the likelihood of frosts in Brazil will decline, or even disappear, hence we may expect to see coffee in Brazil reverse its northerly migration of the last 20 years.

Pests and diseases: temperature increases will favour certain pests and diseases, e.g. the coffee berry borer, which currently has little impact over 1500 to 1600 m above sea level in many countries. Likewise coffee rust will increase its height range. Coffee Berry Disease however, which requires milder temperatures to flourish, may tend to decline in importance.

Some diseases and pests that are currently of little importance may achieve greater prominence, especially perhaps in countries that will become wetter – we already have seen for instance, a surge in American leaf spot (*Mycena citricolor*, 'ojo de gallo') in C America immediately following the major hurricanes of 2005. Human diseases such as leishmanaisis, malaria, dengue may become more prevalent in farm workers.

Soils: greater erosion is likely due to increased severity of rainstorms, whereas soils will dry out faster as temperatures rise.

Shade trees: shade trees may in many cases help to protect from increased temperatures, especially in droughts, though competition with coffee for available soil moisture will need careful study. However the shade trees themselves may become more stressed and may need to be replaced by more hardy species adapted to harsher conditions.

Irrigation: there will be greater interest in irrigation, but probable stricter controls on its use, as aquifers become overused or polluted. The combination of reduced rainfall but with interspersed heavy inundations together with high levels of fertilizer use will exacerbate the problem of nitrate pollution.

Genetic engineering: there will be increased interest in varieties that are more resistant to drought and since there is little genetic variation available within the Arabica genome and its close relatives, it will be tempting to look further afield. Brazilian scientists are already doing this.

Political: low lying areas in coffee countries that currently grow annual crops (e.g. maize, beans) may become unproductive and uneconomic for any conventional food crop, causing rising food prices, political unrest and increased pressure to grow more food crops on higher land where coffee currently grows. Governments of countries with fast-rising populations may feel tempted to enact draconian measures for strategic reasons, since global food availability may become more volatile.

Global output: all in all, there are likely to be fewer parts of the globe very suitable for growing coffee, especially quality coffee. This will lead to a concentration in production, something that has already been happening over the last 30 years[1]. Because of this likely concentration, global coffee output may become more volatile; if for instance, one or more major producer countries were to be affected by exceptionally adverse weather (e.g. an El Niño year) or some other crisis, it would tend to increase fluctuations in supply.

The take home message from this section – the future is going to be difficult, certainly hotter, and with more extremes of climate. This will be bad for many farmers and hence bad for the coffee industry as a whole. Now we will look in more detail at one region – arguably the region that will be most affected and one that is a principal source of coffees for many SCAA members.

[1] "The concentration of coffee production has increased (from 0.11 in 1970 to 0.14 in 2000), mainly reflecting the increased shares of Brazil and Vietnam. The concentration index, also known as the Herfindahl index, is defined as the squared sum of production shares of all countries. A value of unity indicates that a single country accounts for the entire production. Values close to zero indicate that a large number of countries have equal shares." (Baffes et al. 2005)..

3 Coffee in Central America

Many famous C American coffees come from the seasonally dry Pacific-facing mountain slopes and valleys. These include Guatemalan Antigua, Honduran Marcala, Nicaraguan Segovias and Costa Rican Tarrazu, amongst others. The majority of the top ten Nicaraguan Cup of Excellence coffees come from the Segovias region, an area with a long dry season of 5 to 6 months. According to predictions these are the areas most vulnerable to climate change.

Climate change predictions by the Ministry of National Resources and the Environment in Nicaragua indicate that within this century rainfall will decline by an average of 30%, and temperatures rise by 1-2°C. As a reference a one degree centigrade rise in temperature is considered roughly equivalent to 500 feet in altitude or the difference between a hard-bean and strictly hard-bean. So far, detailed predictions have only been made of the impacts on production and corn and beans, though the results are striking enough predicting a 40% reduction in production by 2020 for Pacific highland areas. If the predictions are correct, it looks likely that many of the coffee producing areas on the Pacific slope of Central America will go out of production.

Analysis of the variations in temperature in coffee growing areas indicates that these changes are already happening. Research by Castellaños *et al.* (2003) for coffee growing sites in Mexico, Guatemala and Honduras using IPCC models indicated consistently higher temperatures between 1990 and 1995, compared to the previous 30 years (Fig. 4). As we now know, subsequently 1996-2005 have proven to have 9 of the 10 hottest years this century.

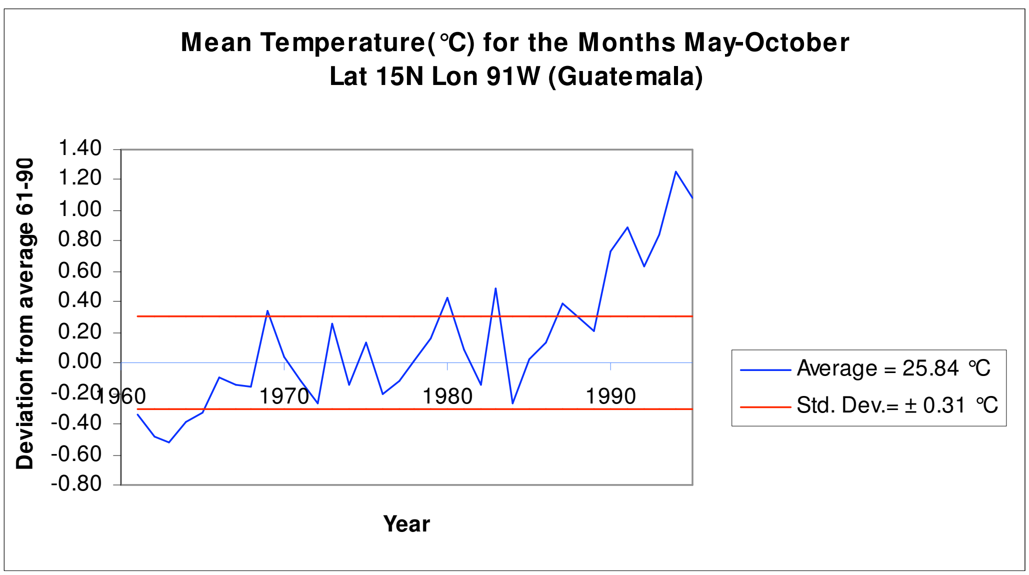


Figure 4. Variation in mean temperature for Antigua, Guatemala, as estimated from the IPCC data set (source Castellaños et al 2003).

a) How may climate change affect coffee production in Central America and Mexico?
Studies of the impact of climate change on coffee producing areas in Mexico by Gay *et al.* (2006) show that in Veracruz between 1969 and 1998 rainfall has decreased by 40mm per year and temperatures have increased by 0.02°C per year. Extrapolating these changes to 2020 they find that coffee production could decline by 34%, but most importantly this decline in production takes producers from making net profits of on average around US$200 per acre, to less than $20 per acre.

The impacts of climate change are not just seen in gradually increasing temperatures or decreasing rainfall, but in more frequent extreme climate events, especially driven by the El Niño – La Niña cycle. The past 6 years have shown extreme variation in rainfall and coffee yields in Nicaragua and other Central American countries. Although the fall in coffee prices had a substantial effect on coffee production during the early part of the decade, climate also seems to have contributed to highly fluctuating production over the last 3 years, when coffee prices have been relatively stable. In Nicaragua, for example, 2005 was one of the wettest years on record and coffee production also reached record levels (over 2 million 100lb sacks). This coincided with a La Niña event. However 2004 and 2006 were drier years, with coffee harvests considerably lower than in 2005. Although coffee is renowned for the biannual variations in production, these cycles are extreme.

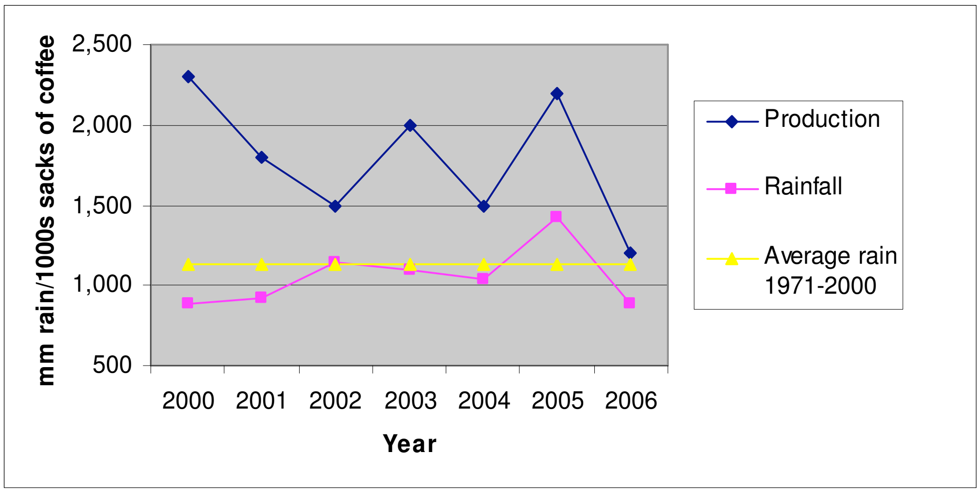


Figure 5. Variations in coffee production (thousands of 100lb sacks) and annual rainfall (averaged from 6 sites near to coffee growing regions) in Nicaragua. Data from National Territorial Institute, Nicaraguan Central Bank and Ministry of Agriculture. Production for 2006 is an estimate.

In surveys with farmers in northern Nicaragua and Eastern Honduras coffee production has varied from 540lbs to 930 lbs per acre green coffee over just the last three years and during which coffee prices have been relatively stable. Climate was the one of the three most important reason farmers gave for this variability (Table 1.).

Table 1. Farmer perceptions of the primary influences on yield variability in Nicaragua and Honduras.

	Lack of resources for management	Pests and Diseases	Climate extremes
% farmers who present this reason for variation in production	24-35%	0-43%	10-25%

As many in the southern USA know, high rainfall from La Niña-induced hurricanes is not necessarily good news either. Coffee production and the families of producers in the Pacific of Guatemala were seriously affected by the floods and destruction from Hurricane Stan which came just as the harvest was beginning at the start of October 2005. About 20% of the harvest was lost, and many coffee mills and access roads were damaged. The loss in coffee production from just the coffee cooperatives in Pacific Guatemala was estimated to run to US$4 million. An analysis of the data suggests that in 2005 C America was under the influence of a La Niña event that brought record high rainfall in 2005, but within 6 months it switched to El Niño with record low rainfall for 2006. Many attribute the crash in coffee production to these climate changes.

b) Impacts on recovering from the fall in coffee prices

With the moderate recovery in coffee prices since 2003, Central American coffee producers are attempting to re-establish their coffee plantations after their semi-abandonment between 2000 and 2003. For example, the major coffee cooperatives in Nicaragua (PRODECOOP, CECOCAFEN) and the Honduran Coffee Institute, amongst others, have initiated programs to plant millions of new coffee trees in 2006 and 2007. This is primarily to replenish old exhausted coffee plants, however the high variability in rainfall means this has become a risky investment. Unfortunately, after good rains in 2005 El Niño returned in mid-2006 and rainfall has been reduced; a long dry season is expected, which will probably lead to low survival of the new coffee plants.

During the previous El Niño cycle between 2000-2001 a group of farmers in Las Sabanas (a region that produced a top-ten Nicaraguan Cup of Excellence coffee in 2005) attempted to establish new coffee, but were only able to do so where evergreen shade trees were already established. Plantings of coffee with the temporary shade they normally employ, had very low survival, leaving only 25-35% alive after one year. Coffee planted under established tree shade had adequate survival of 56-96%. Additionally, a year later only the coffee with evergreen shade trees had grown well, while 60-80% of the plants under deciduous shade were considered in poor condition. In contrast, in the higher rainfall region of Matagalpa, all coffee plantings had over 80% survival and good growth irrespective of shade type. Permanent established shade conditions may prove essential to maintaining coffee production in these regions as they become hotter and drier.

The ECOM group in Nicaragua are so concerned by the effects of lack of rainfall that they have brought in drip-irrigation experts from India to help establish irrigation trials in the Segovias region. Obviously this represents a substantial investment, but also an added demand on declining water supplies. Other strategies include grafting Arabica buds onto more drought resistant Robusta rootstocks. Technical staff from PRODECOOP having been adapting shade management strategies to maintain higher levels of shade during the dry season, but then prune once the rains have started.

c) Impressions of local producers and exporters

The surprise in 2006 in Nicaragua has been that not only has coffee production been affected in the traditionally drier areas of Segovias, but also in the normally wetter areas of Jinotega and Matagalpa. The technical managers of PRODECOOP, and CECOCAFEN in Nicaragua have been stunned by a fall in coffee production of up to 50%. In one cooperative in San Juan de Rio Coco coffee production per farmer has declined by 27%. They definitively attribute this decline in production to climate change and are anxious to develop strategies to confront it. Their initiatives include identifying varieties more resilient to climate change, changing criteria for shade management, and trials with drip irrigation. At a national level the Ministry of Agriculture and National Coffee Commission estimate that the 2006-07 harvest will be half that of last year, representing a loss of income of US$100 million to the poorest country in Latin America.

Obviously these changes affect not just the technical managers, but the marketing managers, and on to the traders, roasters and consumers. If on-farm production is going to double or half from one year to the next, how can long-term commitments between producers and roasters be managed? You, as a roaster, just get to like a new coffee one year, and the next year you cannot find it, or if you can it's quality has changed! Nevertheless the cooperatives are doing their best to meet their commitments, for example PRODECOOP has managed to collect enough coffee to have just a 10% deficit on last year's harvest.

4 Coping with change

We hope that by now most readers of this paper will be convinced that coffee production is under threat from global warming. But there is little point in complaining about it, we need to quickly move on and try to see what we can do to help those likely to be affected.

There are a number of logical steps to take, including:

► Detailed monitoring of changes in climate and production in coffee growing regions
Much of the present information is based on a few isolated studies and models. In many coffee areas meteorological stations are in the towns in the valleys, not in the actual coffee growing areas. Also, reliable information on productivity in many countries is very scarce. Monitoring systems need to be developed for climate conditions in the coffee growing areas, and coffee productivity and quality in order to be able to quantify the impacts of climate change.

► A more detailed mapping of likely climate change within each coffee region
This has already begun, e.g. Delgado et al. (2004) where they modelled the effect on coffee growing in one state of Brazil. They found that an increase of 1°C and precipitation by 15% was enough to cause a major contraction in the current area of coffee. Such studies should be done for each country or region (ideally using several models) and in an organized way that leads to easy comprehension and comparability between regions.

► Zoning of areas according to level of change and vulnerability
Once maps with predicted changes are available, areas can be divided into zones, according to the likelihood and severity of changes. Mapping of areas most likely to be affected can be related also to assessments of vulnerability: e.g. increased rainfall related to susceptibility to erosion. Thus areas that may still be deemed climatically suitable for coffee into the future, would nevertheless need long term planning and investment to safeguard soils – e.g. by terracing, cover crops, shade tree selection and so on.

► An estimation of the impact on quality and quantity of coffee production
Once likely environmental changes are known for a region, this can be translated into the economic effects on the coffee industry. Enough is known about the factors affecting coffee production to make some estimates, but more work is required to develop a robust model from which to map areas of high, medium and low productivity.

► Genetic improvement to identify more drought resistant stocks
A coffee breeding program run by CATIE, CIRAD (French Agricultural Development Institute) and PROMECAFE (Coffee Institutes of Central America) has created hybrids between traditional coffee varieties and wild Ethiopian coffee plants. Several of these new materials are showing improved quality at lower altitudes (i.e. higher temperatures) and some appear to have greater adaptation to hotter drier climates. Results are preliminary, and investment is required to validate these initial results and apply them to the field.

► An evaluation of available adaptation techniques
At first simply a list of possibilities: E.g. for areas that are drying, the construction of water storage tanks such as those that can be seen in some fincas in El Salvador, to provide water for processing in the dry season. There exist a wide range of water saving measures that could be tried out and adapted to local needs and resources; this work could start soon.

Some level of adaptation to rising temperatures could be effected by increasing the level of shade. However if there is a concomitant reduction in rainfall, there could be problems of competition between shade trees and coffee for available moisture. And if rainfall increases, shade might make for unacceptably high humidities that would favour some diseases.

Trials therefore need to be carried out: trials of new coffee varieties, under new species of trees, either for shade or alternative income, that would be likely to thrive in the changing conditions. And experiments to look for interactions e.g. the relationship between shade levels, erosion, yield loss, disease incidence and so on.

► Consultation and planning
For an area where a significant decline in rainfall is predicted, at the earliest feasible opportunity there should follow consultation with farmers and other stakeholders in that region to share the information with them and then discuss possible adaptation measures. Furthermore, more effective monitoring of climate change and the impacts on production needs to be developed together with these stakeholders.

► A plan to develop adaptation trials across the region
An adaptive research plan to role out trials across a region. A coordinated, thorough and long term (multi-year) series of trials would yield invaluable data, both to guide policy and to refine models to best predict changes and likely adaptation strategies.

► A review of sustainable coffee schemes
Great strides in sustainable coffee have been made over recent years. But norms and indicators will need to change to take into account the new realities of climate change. Farmers will need a survival plan to convince us that their farms are truly sustainable and this may require a rethink about priorities.

► A plan to help diversify some regions out of coffee
A long term plan of education, trials, market chain development to help farmers adapt to new realities – this especially in low lying areas in countries that will become drier where farmers will need help to diversify (partially or wholly).

► A plan to finance research, training, awareness etc.
The above points will require an overarching plan, with fund raising, team building and strategic planning. This will most likely form part of a country's strategic agriculture plan, that will attempt to protect rural livelihoods, water resources and biodiversity as well.

► Above all, education where electronic media will be prominent
What we need are 'thought tools' – we have seen the power of climate models and their visual projections to guide and even change the direction of our thoughts. In the future simulations will become more common, as will expert systems, decision tools, and the like, all backed by tremendous computing power at very low prices.

Such tools could show the 'best guess' effects of climate change on coffee growing for a given zone, e.g. an interactive computer model where a farmer, extensionist, researcher, decision maker, is asked to input details of a farm (height, location, soil, etc.). Upon supplying this information the program would give a read out of likely yield loss, and ways to reduce it. At the same time the computer program, or rather an integrated series of modules, would be able to suggest alternatives to coffee – e.g. new trees species to plant, new crops, as well as the likely cost of the changes.

5 Conclusions

We argue that:

- The changes that climate change will wreak on coffee may have seemed to be in the distant future, but we can now see that this is a misconception – changes are already under way and their consequences must start to be tackled now and in a concerted fashion;
- Although individuals may feel powerless, there are some simple actions to take and adaptation techniques to try at the farm level;
- Although the future is uncertain, much of the coffee lands of the world must continue to remain productive even if this means diversifying out of coffee – either partially, to spread risk, or completely because the crop is no longer profitable;
- The actions that we take now and in the next few years will determine how much of these lands can remain productive and sustainable for following generations;
- The role of the coffee lands in the future of the many countries where it is grown will become more important rather than less so – especially the upland areas because rain will continue to fall there and they will have to be farmed, possibly for primary food crops.
- In the name of sustainability, it is our duty to hand our lands and our industry down to the next generation in the best condition that we are able.

Coffee is a sort of lead indicator for commodity crops; it often sets the pace that others then follow; hence there is a responsibility and leadership role for those that want to take it up.

A final caveat: what we have presented here in this paper is only an approximation of what will occur; things will happen that we have not considered.

"…Language, and thought like the wind
And the feelings that make the town
He has taught himself, and shelter against the cold,
Refuge from rain. He can always help himself.
He faces no future helpless."

Sophocles (BC 441)

6 References

Baffes J, Lewin B, Varangis P, (2005). Coffee: market setting and policies. In: Global Agricultural Trade and Developing Countries. World Bank, Washington DC. Chapter 16 297-309.

Bradbury RH, (1998). Sustainable development as a subversive issue. *Nature & Resources* October 1998 UNESCO.

Castellaños E, Conde C, Eakin H, Tucker C, (2003). Adapting to market shocks and climate variability in Mesoamerica: The coffee crisis in Mexico, Guatemala and Honduras. Final Report to Interamerican Institute – Global Change Research. Pp20.

Delgado Assad E, Silveira PintoH, Zullo Junior J, Helminsk Ávila AM, (2004). Impacto das mudanças climáticas no zoneamento agroclimático do café no Brasil. Pesq. Agropec. Bras. Brasília, 39: 1057-1064.

Fournier LA, Di Stéfano JF, (2004). Variaciones climáticas entre 1988 y 2001, y sus posibles efectos sobre la fenologa de varias especies leñosas y el manejo de un cafetal con sombra en ciudad Colón de Mora, Costa Rica. Agronomía Costarricense 28(1): 101-120.

Gay C, Estrada F, Conde C, Eakin H, Villers L, (2006). Potential impacts of climate change on agriculture: a case study of coffee production in Veracruz, Mexico. Climate Change 79 259-288.

Goswami BN, Venugopal V, Sengupta D, Madhusoodanan MS, Xavier Prince K, (2005). Increasing Trend of Extreme Rain Events Over India in a Warming Environment. Science 309, 1088

IPCC (Intergovernmental Panel on Climate Change) (2007). Climate Change; The Physical Science Basis. Summary for Policymakers Contribution of Working Group I to the Fourth Assessment Report, 21 pp.

Sophocles, (BC 441). Antigone, l.332-367. Trans. Elizabeth Wyckoff; Chicago University Press 1954.

Webster PJ, Holland GJ, Curry JA, Chang HR, (2005). Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment. Science 309, 1844 -1846.