Coffee & Climate: The Geometry of Change

A Rapid Field Diagnostic of Coffee Farmers' Production Challenges in the Trifinio region of Central America

Baker P.S.

For the Initiative for Coffee & Climate

www.coffeeandclimate.org

23rd – 29th September 2012

c/o E.D.E. Consulting (affiliate of Hanns R. Neumann Stiftung) • Am Sandtorpark 4 • Coffee Plaza • 20457 Hamburg • Germany

1. Mission purpose

The purpose of the visit to the Trifinio region, (Guatemala, Honduras and El Salvador), was to initiate studies for the development of adaptation tools for smallholder coffee farmers of this zone. A central principle of the Coffee & Climate Initiative is that adaptation tools must be appropriate to local environmental conditions and coherent with farmers' needs and capabilities. To this end, a programme of work has to be carried out to assess these factors and the visit was the first activity of this undertaking, using the methodology described below.

2. Background

Climate change is affecting Central America in quite extreme and unusual ways. Aguilar *et al.* (2005) confirm that the region has clearly warmed over the last few decades and extremes of temperature are increasing in frequency.

Although this region is under the influence of maritime air masses, the local and seasonal variations of precipitation are surprisingly high and some of this variability can be attributed to seasonal variations in the lower winds, associated to the dynamics of the Central American atmosphere and their interaction with the local topography.

Aguilar *et al.* (2005) state that trends show a larger increase in extremely high maximum temperatures than decrease in extremely cold maximum temperatures, which means that diurnal temperature ranges are increasing. Temperature indices show larger warming during the boreal summer and autumn (roughly the wet season), which reduces the seasonal contrast of the region. Additionally, Lennox (2012) provides compelling evidence of major increases in storm events over the past two decades (Fig. 1).

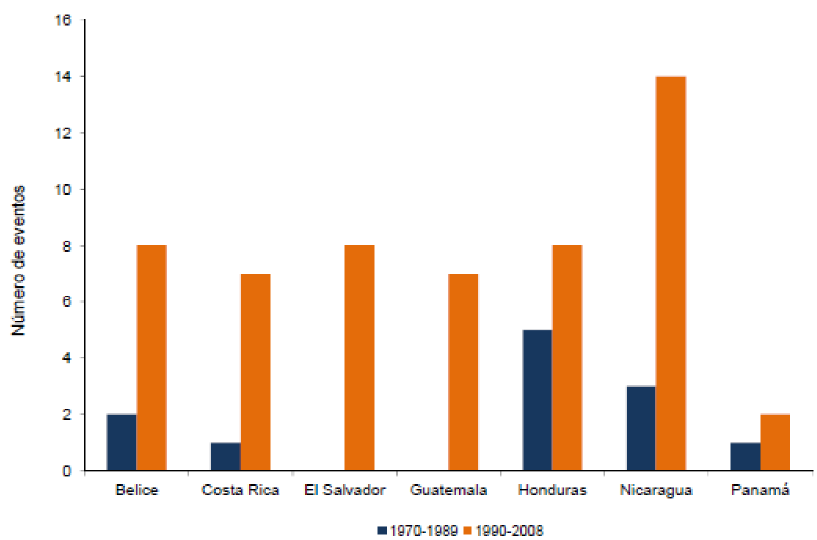

Figure 1. Number of Central American of hurricanes and tropical storms for the periods 1970-89 and 1990-2008 (from Lennox, 2012).

Climate projections for this region are also pessimistic, with an unusually high agreement between models that the area will get both warmer and drier over the next 20 to 50 years. The current trend for heavier and more frequent storms is also very likely to continue. Altogether this comprises a poor outlook for Arabica coffee farming, which thrives on moderate weather and a high probability that annual weather patterns will be similar. A detailed prognosis for coffee is lacking however and the lack of meteorological stations combined with the topographical complexity of the region means that uncertainty of outcomes is likely to remain high.

3. Methodology

The basic approach was a 'triangulation' method to evaluate different sources of information:

- local experts – especially extensionists with detailed experience of the local coffee zones
- farmers (including farm visits to inspect the state of growing coffee)
- available scientific knowledge

If data collected from all these sources has a large degree of overlap (i.e. agreement), then this gives confidence that our findings reflect current reality, based upon the best possible evidence available (Fig. 2). If the various sources conflict, then further investigations are necessary to discover the sources of any uncertainties.

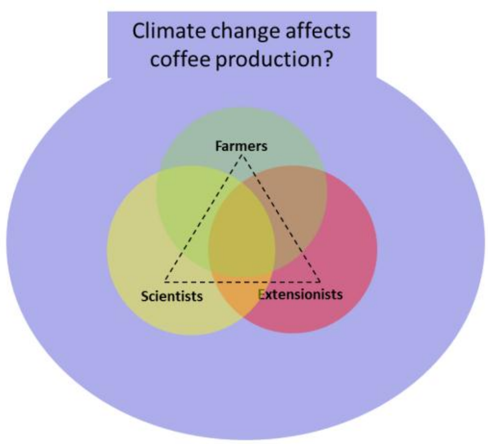

Figure 2. Triangulation: coherence of evidence from farmers, extensionists and scientists on the effects of climate is sought.

4. Findings

4.1 Expert opinion 1st meeting

Problem identification

A diagnostic meeting was held with eight technicians from PROTCAFES (Proyecto Trinacional Café Especial Sostenible) to discuss how climate change may be affecting coffee production.

The technicians were first asked whether they believed that climate change is already affecting coffee production; all eight agreed. They were then asked to rate, according to their experience, how severely a range of climate variables are affecting coffee production, both directly and/or indirectly (Fig. 3).

The extensionists graded responses 1 to 10 (low – high), though subsequently these responses were condensed to five categories, responding to very low, low, medium, high and very high impact.

For specific climatic events, they rated storms, irregular rain, high temperature range, drought, high temperatures and high winds as the most important. There was a wide range of opinion, but only one in eight responses graded any of the above at less than medium importance (Fig. 3, upper).

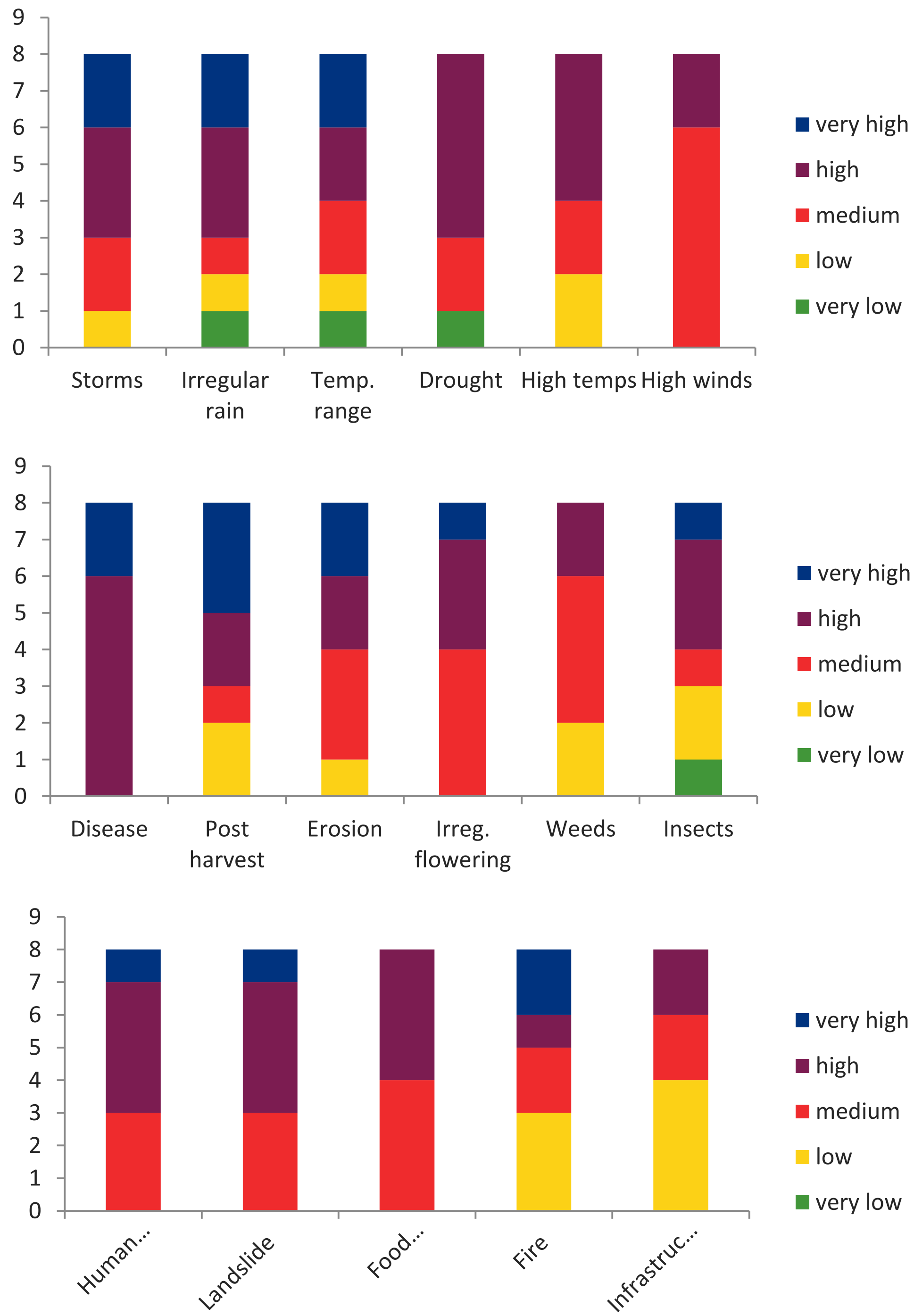

Figure 3. How extensionists rated the importance of climate related problems to current coffee growing in the Trifinio region. Upper: importance of specific climate variables; middle: effects on specific aspects of coffee growing; lower: broader effects. Factors are presented in approximate order of importance, decreasing from the left

For specific effects on coffee, disease registered the highest level of concern with all respondents rating it high or very high (Fig. 3, middle). For more general effects on coffee production, human health and landslides also featured as high risks (Fig. 3, lower). Overall, extensionists showed considerable concern about a wide range of factors, as evidence by the relative lack of low and very low scores (green and yellow in Fig. 3).

When asked to rate seriousness of named pests and diseases (Fig. 4), rust caused the most concern, followed by leaf spot (Ojo de Gallo, *Mycena citricolor*) and *Cercospora coffeicola*. Only coffee berry borer (CBB) featured as an insect of medium to high concern.

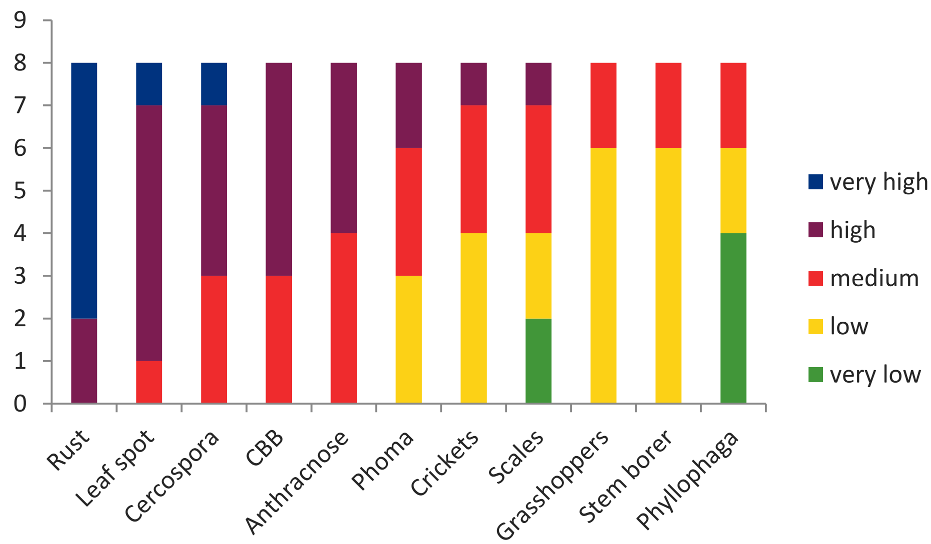

Figure 4. How extensionists rated the importance of pest and disease problems in the Trifinio region.

Extensionists were also asked about seriousness of non-coffee problems afflicting coffee farmers, including health, growing of other crops, basic infrastructure (roads) etc. Dengue, maize, beans, bronchitis and roads featured as the main concerns (Fig. 5).

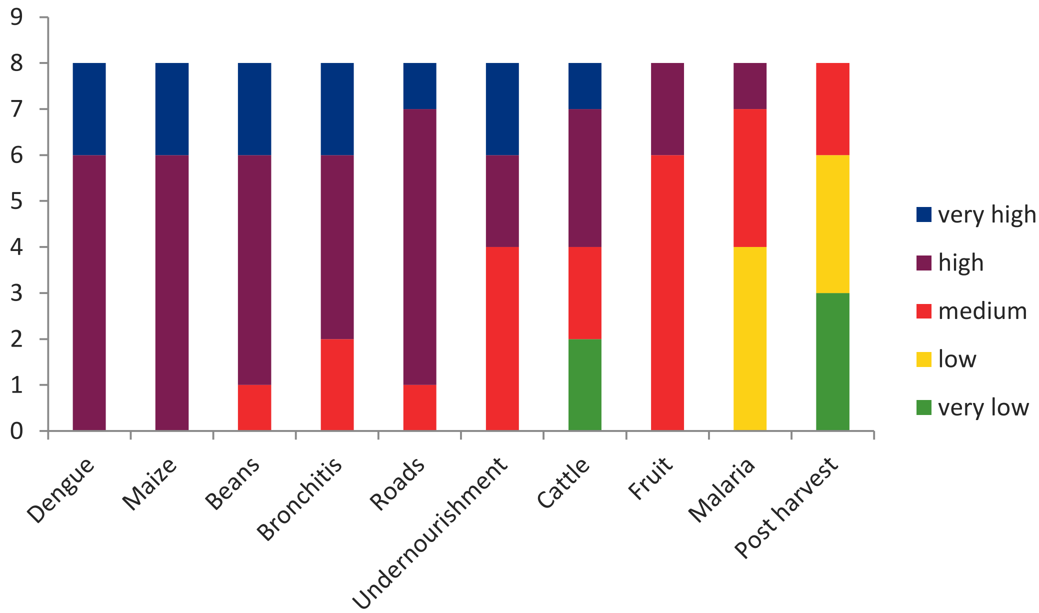

Figure 5. How extensionists rated the importance of other problems affecting Trifinio coffee farmers.

Identification of solutions

The extensionists were asked for their opinions on a range of possible solutions to the problems identified. As before they were asked to grade them from 1 to 10 in importance and these categories were later reduced to five categories. Results can be seen in Fig. 6, approximately graded in importance from left to right.

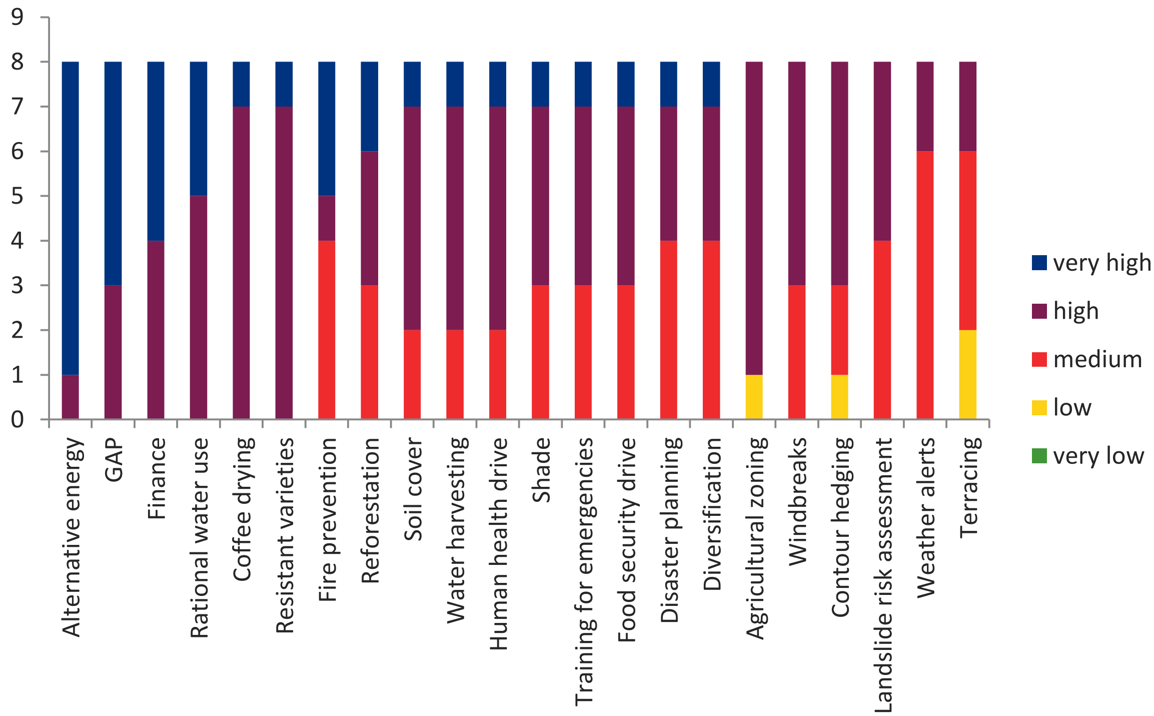

Figure 6. Extensionists' suggested solutions to farmers' problems in approximate order of importance, left to right. GAP = a good agricultural practice 'package' for farmers

The highest priority needs are tabulated below with brief comments (Table 1).

Solution (tool(s))	**Comment**
Alternative energy sources for houses	E.g. solar panels, improved stoves, efficient lighting
Good agricultural practice	A technology package to include soil analysis, correct fertilization and proactive preventative pest and disease interventions
Cheaper finance	Borrowing from 'coyotes' at exorbitant rates is still common
Better coffee drying	Adequate patios protected from unseasonal showers
Rational water use	Water on steep sloped farms is often scarce;
Improved coffee varieties	Especially newer catimors that have good cup profiles

Table 1. Principal tools for climate change adaptation suggested by extensionists.

4.2 Expert opinion 2nd meeting

After field visits, a second meeting with extensionists was convened to discuss solutions in more detail. This focused on the agreed urgent need to improve good agricultural practice especially in the light of the obvious effects of rust and anthracnose seen during farm visits.

Discussions focused on what should constitute a GAP package, the extent to which this should be modified according to altitude and the wide range of systemic fungicidal products mentioned.

GAP package

From discussions, a preliminary table was constructed (Table 2).

Timing	Action	Comments
After harvest	Soil and leaf analysis	Soil analysis is relatively affordable from local institutes; farmers should be encouraged to take advantage of this
Before flowering	Foliar application of micronutrients	According to soil/leaf analysis. If this has not been done then a routine application should be made.
Before flowering	Standard soil application of NPK fertilizer	Liming may also be necessary to raise pH, according to soil analysis
After flowering	Second foliar fertilizer application	Necessary?
June	Preventative application of copper oxychloride	
August	NPK application	
August	Preventative application of copper oxychloride	

Table 2. A preliminary outline of a GAP package, for further discussion.

Further comments and queries (by the consultant):

- Further consultation and discussion is needed to arrive at an agreed package .
- Standard recommendations from each country’s coffee institutes should be reviewed and compared; as much as is feasible, these should be followed unless good reasons for not doing so are apparent.
- The extent of foliar applications is questionable and the costs and benefits of this need to be assessed. It may be a good way to urgently redress serious imbalances, but may be an expensive routine measure, since it seems likely that two or more fungicide sprays will be recommended and there will be a limit to how many sprays farmers will be able to afford. Cenicafé (Colombia) have carried out extensive field experiments on foliar sprays and found they were never cost effective. However the drier conditions may mean that foliar applications are more effective in the case of Central America.
- The need for a third fungicide application: could this be on a needs basis, if farmers see sufficient signs of rust activity?

Systemic fungicides

During the field visits, a range of products were mentioned by extensionists, but which are the best ones to use and under what conditions? A preliminary list of these was made and extensionists were asked to show their preferences for one or two products (Table 3.)

Some points that need clarification:

- Under what circumstances should systemic applications be recommended?
- What are the costs and benefits of each?
- What is the minimum time required before harvest to ensure no tainting of the fungicide reaches the cup?
- Should the project have one/two firm product recommendation for each country?

Product	**Active ingredient(s)**	**Preference (votes)**
Alto 10	Cyproconazole	XXXXX
Opera	Pyraclostrobin + epoxiconazole	
Opus	Epoxiconazole	
Silvacur	Tebuconazole+triadimenole	XX
Funglak	Oxido de cobre + mancozeb	
Amistar Opti	Azoxistrobina+clorotalonilo	XXX
Propilak	Propiconazol	
Caporal	Triadimenol	X

Table 3. A preliminary list of systemic fungicides for applying to coffee, elicited from extensionists.

Major defoliation by coffee leaf rust, leading to die-back, which by harvest time may be severe. Bottom right: farmers' susceptible crop in the foreground is performing poorly compared with catimor variety in the background.

Zoning

It is clear that, for instance, coffee rust's effects at 1000 m above sea level are considerably more acute than at 1600 m. So to what extent should there different recommendations for different altitudes?

A brief discussion of this was held but no clearly agreed course of action emerged. Based on this meeting and field impressions, the consultant offers Table 4 as an initial point of discussion.

Altitude range	Shade level	Fungal control	Catimors	Comments
< 1000 m	>60%	At least three copper applications?	Not advised, should be trying other crops	Very marginal zone, farmers will have to diversify
1001-1200 m	60%	2 to 3 applications	Strongly advised	Marginal zone for coffee
1201-1400 m	40%	2 to 3 applications	Advised	
1401-1600 m	40%	2 applications	According to local conditions	SHB?
1600 m+	?	Spot applications only?	Not needed	Specialty zone

Table 4. A very preliminary attempt to zone coffee GAP recommendations.

Suggested next steps for development of a GAP package.
The discussions were useful to open up some of the difficulties in developing a sound GAP package. The complexity of the zone, with many microclimates and soil types, together with an increasingly extreme climate, make this a complex challenge. It will be difficult to arrive at a package that is comprehensive, affordable and adaptable to local conditions, especially by the time of the start of the next coffee season. Therefore a preliminary set of measures should be assembled and if, possible exposed to further comment before trials with farmers in 2013. Measures could include:

1. Review of field notebooks – especially for this year, what has worked under difficult conditions, which farmers escaped the worst damage from coffee rust, what did they do differently?

2. Consult standard recommendations from coffee institutes, how widely do they vary? Review evidence – are recommendations backed by good field data? How up-to-date are they? (They could be based on data from field conditions of 20 or more years ago and hence obsolete).

3. Expert workshop (extensionists, research scientists if available): once some data from above is available and graphed and tabulated, discuss with experts, to arrive at some agreement on a preliminary GAP package and how this needs to be modified according to different altitudes, slopes etc.

4. Farmer workshop: based on the above, discuss plans with farmer leaders, prospective participants of trials, on feasibility of proposed plans and make modifications where appropriate.

5. Review available spray machinery – pumps and nozzles are often inadequate for good coverage. Carry out some preliminary trials with water and fluorescent dye and paper strips to determine quality of coverage. This may need some specialist input.

From all this, arrive at an agreed preliminary best recommendation(s) for GAP for 2013 trials.

4.3 Meetings with other experts at the Trifinio technical centre
The presence of several project groups working at the Trifinio centre afforded an opportunity to get some other views on the effects of climate change in this region. People interviewed included Peter Wachowski and Balmore Ochoa of the Protección de Bosques y Cuencas project, Adriaan Vögel and William Ordoñez of the Programas Bosques y Agua project, Juan Carlos Montufar Celada, Director of the Trifinio technical centre and Danilo Padilla Coordinator of the environmental programme for the MAP project run by CATIE.

None of these people were directly working on climate change though all were familiar with the problems. They were specifically asked about availability of meteorological data for Trifinio, of direct interest to the present project. Responses varied from the view that such data existed and could be made available quite easily, to the opposite – that meteorological data was poor, with few years of low quality data that might be difficult to access. The general impression gained from comments on this subject is that the project cannot rely on this data to give much of a guide as to recent changes in the zone, nor areas that might be most exposed to aspects of climate change relevant to coffee growing.

Of most interest to the present project was the work of the Programas Bosques y Agua project, which is carrying out some quite detailed scientific work with indigenous groups of smallholder farmers that are growing coffee as one of their crops. They may well have some useful experiences and data, especially relating to control of erosion, water use etc. and if possible, the project should make a visit to their field sites.

The CATIE project has produced a useful guide to composting that should be reviewed to see if the techniques presented might be useful for coffee production.

Overall impression of the Trifinio centre: it is somewhat surprising that there seems to be no Trifinio project or official directly concerned with climate change.

4.4 Field visits – talking to farmers in El Salvador, Honduras and Guatemala

Some 15 farmers were visited in the three countries and questions put to them according to the form in Appendix 1. For the results presented below, these were added to a further 30 supplied by Pablo Ruiz based upon previous visits.

Main problems elicited from farmers
Answering the question 'what is your main problem in producing coffee?', answers were scored 3 for a first response, 2 for second and 1 for third. Results (Fig. 6) show a very high level of agreement on the main three problems: diseases, climate and finance.

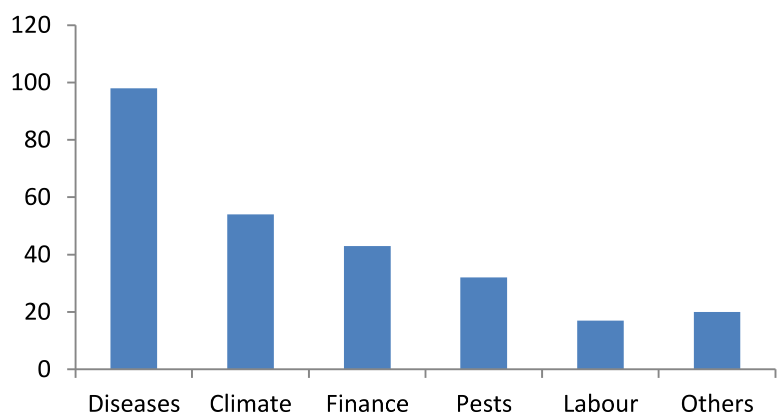

Figure 6. Farmers' three main production problems. First mentioned problem scored 3 points, second 2 points, third 1 point. 45 farmers interviewed.

The flare-up of coffee rust in recent weeks has almost certainly raised this issue to the top of the agenda. Since this is related to climate, then it is very clear that farmers are currently facing serious climate related challenges.

A range of other characteristics recorded during the farm visits are presented in Fig. 7.

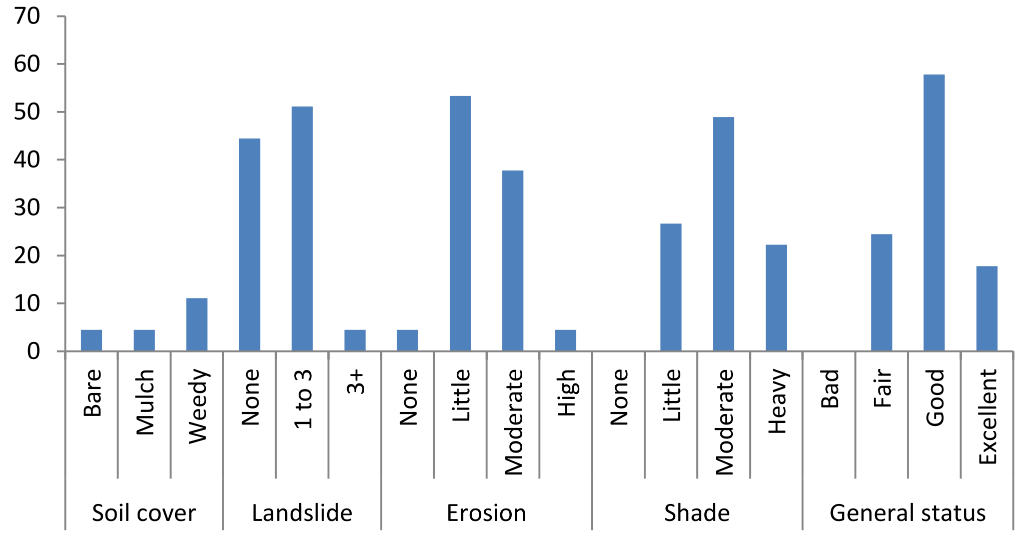

Figure 7. Characteristics of 45 farms visited; figures related to percentages found in each category.

Analysis of yield data supplied by farmers revealed a wide range of values that seems to be altitude dependent (Fig. 8). It is not known at this stage if this is typical of farms in the regions visited, this can be verified from field-book data.

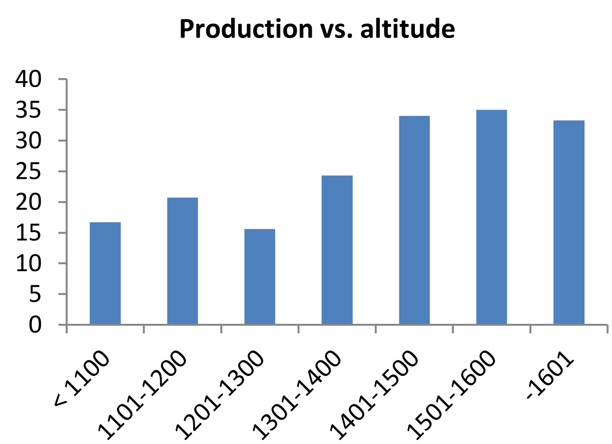

Figure 8. Coffee production of farms visited (46kg sacks of parchment per Manzana (0.7 ha).

General observations
Coffee: evidence of rust attack was widespread and was frequently accompanied by die-back (anthracnose). In many cases attacks were serious and it is evident that many farmers will suffer substantial yield reductions for the coming harvest. This seems especially unfortunate since most farms are otherwise in good condition with clear evidence that substantial investment has been made in renovation and fertilization that has resulted in heavy bearing. Since rust attacks may impact on next year's harvest as well, it is possible that many farmers will face major economic difficulties over the next two years. Much of the best-looking coffee turned out to be of catimor origin, include Lempira, IHCAFE 90 (including an improved cup-quality line) and Cuscatleco (Sarchimor), all of which proved to be virtually rust-free with little sign of die-back.

Shade: present in nearly all cases and was frequently more than 50%. Tree composition was quite varied and included pine in some cases, where mineral deficiencies were most common, caused almost certainly by acid soils. In the farms visited in the Esquipulas coffee zone, clear evidence remained of a severe hail and windstorm that had stripped leaves off coffee trees and felled a substantial number of shade trees.

Terrain: small landslides and erosion on uncovered soil slopes were not uncommon. A large landslide in the Esquipulas zone had caused abandonment of a village. Roads leading to the Honduran and Guatemalan farms were in very poor condition, some of the worst this writer has seen in Latin America. If this is representative of the area, and heavy rainfall continues, then transportation of the coffee harvest will be difficult and hence more costly. Degree of soil cover on coffee plots was very variable, with few well-covered, well controlled plots. Weedy plots however were uncommon, helped by the preponderance of shade.

Farmers: many were under 50, with some in their 20s or 30s. There were very few opportunities to glimpse families and hence gain any impression of overall wellbeing and living standard, except in Guatemala, where conditions looked quite primitive; women were working on milpa (maize) plots.

Overall: meetings with farmers and visual impressions both closely confirmed the opinions elicited from technicians in Section 4.1. It is evident therefore that climate-related events are having serious effects on production especially through the upsurge in rust which is related to unusual weather in the past few weeks especially, which has caught farmers by surprise. It would seem that farmers mostly apply fungicide in an *ad hoc* response to signs of rust rather than through a planned series of prophylactic applications.

A problem for this project therefore is to determine to what extent the causes of the upsurge are abnormal – possibly highly abnormal, and hence how likely they are to be repeated in coming years. If the likelihood of a repeat of such weather is at all high, this implies that a great deal of work needs to be undertaken with farmers to shift them from a 'just-in-time' to a 'just-in-case' approach to pest and disease management.

4.4 A brief review of scientific knowledge of climate change as it relates to coffee

Precipitation

Precipitation is a key variable of interest to coffee growing. CIAT (2012) provides a very pessimistic scenario for the Trifinio zone, with a projected catastrophic drop in precipitation of more than 20% for the Esquipulas area over the next eight years (Fig. 9) and a 50% fall by 2050.

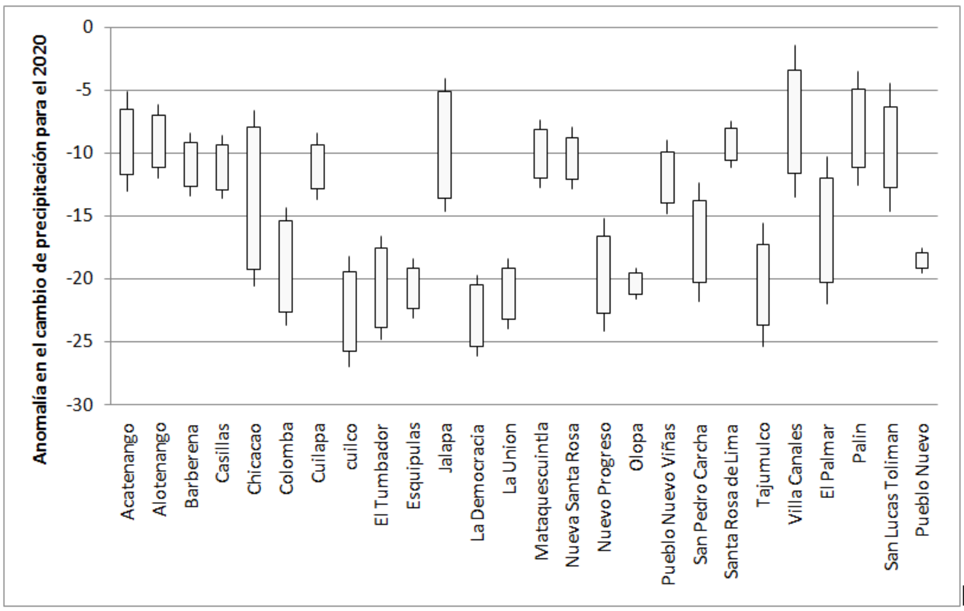

Figure 9. CIAT (2012) estimates of precipitation changes for Guatemala by 2020.

However, these estimates differ from other studies. Hence Hidalgo & Alfaro (2012) estimate an overall 4.9% reduction in precipitation for Guatemala by 2050, 2.3% for El Salvador and 2% for Honduras. They also show the wide range of variation between different simulations, with mean estimates of precipitation for 2020 virtually the same as today, as can be seen in Fig. 10 (temperature however seems very likely to rise, perhaps by an extra 0.25°C by 2020). On the face of it therefore, scenarios presented by CIAT (2012) seem unduly pessimistic.

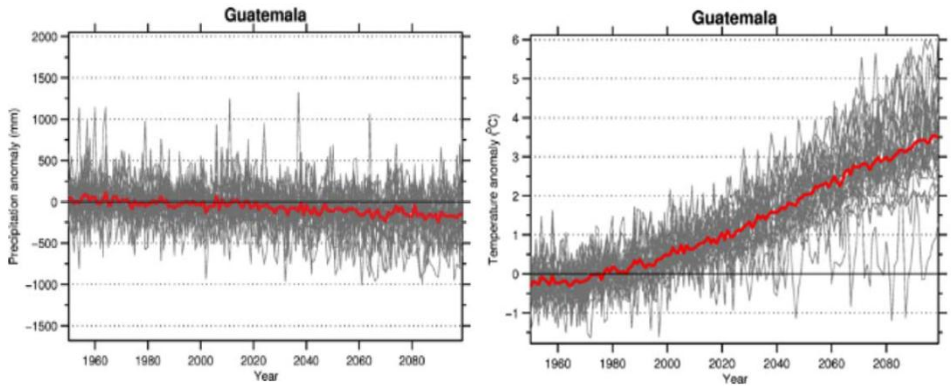

Figure 10. Spaghetti plot of the projections of annual precipitation (left) and temperature anomalies from 30 General Circulation Model runs. The anomalies were constructed with respect to the 1950-1999 period.

Precipitation intensity: Aguilar et al. (2005) show a clear trend to heavier rainfall events (Fig. 11). For Central America as a whole they describe it thus: *an intensified hydrological cycle with more rain coming from extreme events and more average rain per episode appears to characterize the region and does not appear to be linked to El Niño or dependant on the total amount of precipitation.*

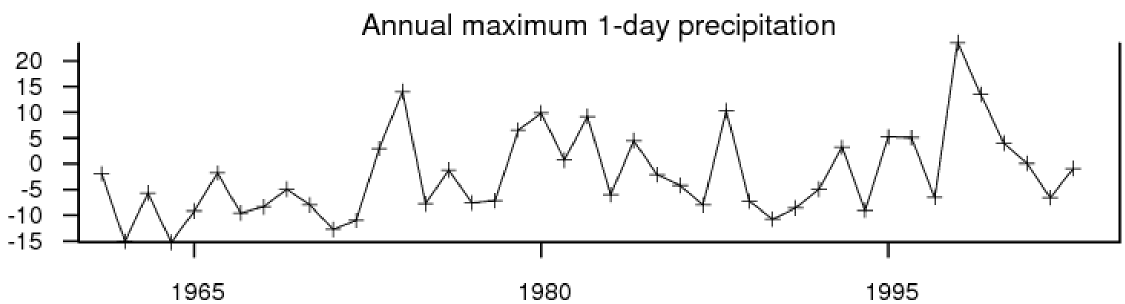

Figure 11. Regional annual anomalies (in mm) for to 1971-2000 for maximum one-day rainfall (RX1day) for 1961-2003 (Aguilar et al. 2005).

Timing of precipitation: the key event in the Trifinio zone for 2012 was the apparent disappearance of the usual ‘canicula’ or mid-summer drought (MSD) event, which is a familiar and regular Central American phenomenon that turns out to be centred more or less on the Trifinio zone (Fig. 12). This failure to appear may have played a key role in the recent rust upsurge, for it seems plausible that a dry spell might normally inhibit development of the rust epidemic to the extent that it could customarily be controlled by rather moderate, *ad hoc* measures as discussed above. Hence the recent and future changes in the MSD are of considerable potential interest to coffee growers.

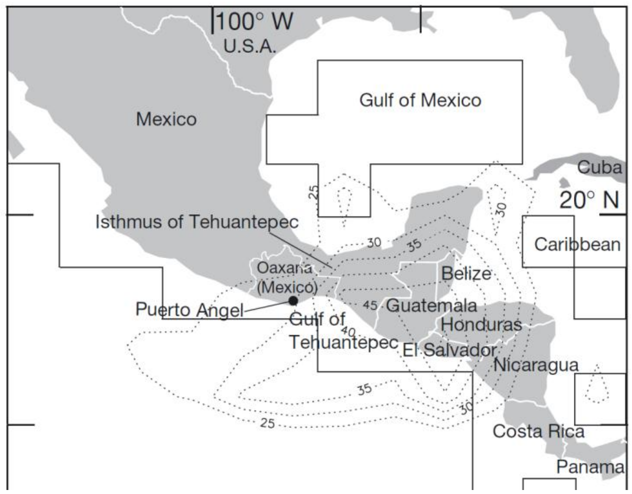

Figure 12. Mid-summer drought region. Dashed lines denote variance explained (%) by the second-order harmonic for climatological (1984 to 2000) May to October precipitation (Curtiss 2004).

Magaña et al. (1999) described a bimodal distribution of precipitation over southern Mexico and Central America during the summer months. They showed that the MSD is forced by the seasonal fluctuation of sea-surface temperature (SST) and it appears regardless of the phase of the El Niño/Southern Oscillation (ENSO) and that there was no concurrent relationship between the MSD and ENSO. Curtis (2004) however suggests that the strongest MSD, in terms of percentage decrease in mid-summer rainfall, occurs in El Niño as compared to neutral or La Niña years. 2012 is a neutral year, so it is perhaps not surprising that the MSD was weak this year but does not explain why it apparently did not show up at all.

Further speculation on this is beyond the scope of this report, especially since the extent to which it has disappeared in 2012 is currently not verifiable without access to meteorological records. If the MSD is related to SST however, then rapidly increasing temperatures in the region might well be expected to impact on this event and to some extent be predictable. The subject merits further investigation, possibly in the first instance by attempting to contact experts such as Curtiss at the Goddard Space Centre or others the National Oceanic and Atmospheric Administration (NOAA).

Occasional mention by farmers was also made of unseasonal rainfall, especially during the post-harvest period. Unfortunately we lack data to assess the extent of this problem and whether it is getting worse, but this undoubtedly a possibility that needs to be taken into account.

Overview of climate data

It can be stated with great confidence that:

- Temperatures, already significantly and noticeably higher than 20 or 30 years ago, will continue to rise and mostly likely accelerate;
- There will be increasing numbers of hot days and decreasing numbers of cold nights;
- Individual precipitation events will continue to increase in intensity;

It is also likely that coffee farming will be increasingly dominated by extreme weather events, ranging from duration of hours (severe storms with high winds and flooding), to weeks and months (prolonged rainfall, prolonged droughts). These will have impacts on both coffee and farmers' families and place them in increasing jeopardy. The increasing likelihood of these events may mean that insurance costs will be prohibitive. It may also mean that government, donor and NGO responses will be increasingly stretched to deal with the number and severity of events.

However, it is unlikely that it will be possible to predict which of the above events will become more probable – thus it is equally likely that, say, 2013 will be wet (high risk of rust) or dry (high risk of coffee berry borer), or even both in rapid succession.

Because of this fundamental uncertainty, together with the complex topography of the zone with multiple microclimates, accurate planning for specific climate events seems an unpromising strategy. Hence unlike project work in both Brazil (where tools tend to be oriented towards intense dry-season concerns) and Vietnam (where tools are oriented to water scarcity), in Central America it will be necessary to prepare for a wide range of eventualities to reflect the uncertainties and recent experience. This in turn will require a much broader and more comprehensive approach to managing risk, which for many farmers will effectively mean a major change in the way that they farm coffee. This approach will be summarised in the following section.

5. Managing risk

Risk = Hazard * Vulnerability

As frequencies and intensity of climatic hazards increase due to climate change, farmers' vulnerability must be reduced in order to maintain risk at constant levels.

Vulnerability = Sensitivity * Exposure – Adaptive Capacity

Vulnerability here can refer to the coffee/shade plots, as well as more broadly to farmers' livelihoods and infrastructure.

Sensitivity here means how any element of the system responds to climate – e.g. for rust the coffee plant is highly sensitive to increased humidity at key points in its cycle. Sensitivity could be reduced by planting a resistant catimor variety that is less sensitive to infection.

Exposure for example means the degree to which the coffee plant is exposed to high humidity. This is more difficult to control, but could be altered by reducing shade in some circumstances, though this would increase exposure to other weather variables.

Adaptive capacity means the resources and knowledge of farmers and support institutes to take the right action, e.g. apply prophylactic copper sprays in a timely and efficient manner.

Clearly then, to reduce vulnerability and therefore risk, sensitivity and exposure should be reduced and adaptive capacity of farmers increased. Table 5 resumes some of the risk factors and likely activities to reduce them.

Factor	**Sensitivity**	**Exposure**	**Adaptive Capacity**
Rust	Replant with catimor varieties	Copper based sprays	Field notebooks and participatory trials; cup testing. Develop business case for catimors.
	Preventative treatment with copper or systemics		Evaluate efficiency of available spray machinery. Train farmers on spraying.
Heavy rain, hail		Shade, windbreaks	Field case histories – would windbreaks work?
High temperatures		Shade	Farmer training in the various uses/abuses of shade.
Hurricanes		Shade; strengthening farmers' dwellings, etc.	Train farmers in emergency response procedures.
Landslides	Tree planting, hedging and ditching etc.		Risk assessment training for extensionists.
Soil erosion	Cover crops		Train farmers for cover crop use.
Drought	Gypsum soil treatment		Micro-trials to start with.
Roads	Resurfacing, regular ditch building and maintenance		Encourage farmers' groups and community action, municipal engagement
Post-harvest drying		Coverings against rain	Training
Subsistence crops	Soil erosion protection; resistant varieties		Training in efficient production, drip irrigation, composting, IPM etc
Human health		Vector control (dengue)	Awareness raising, training for extensionists and farmers
Early warnings	More timely applications for events triggered by ENSO		Extensionist and farmer training

Table 5. Classification of risk factors and a partial list of potential remedies (tools).

As can be seen from Table 5, the need for building capacity is great and this implies a major investment of time and funds on behalf of farmers and support institutes. It means that the farmer will have to take many more actions than previously and be prepared to outlay more funds in the hope of achieving a lower risk as s/he becomes more proactive and less reactive.

The question arises as to the farmer's willingness or ability to increase efforts to adapt, as well as our confidence in the efficacy of the measures recommended. Although there are always difficulties with recommendations, in a complex situation such as the present one, where uncertainties are high, it will be important to prioritise activities according to degree of confidence that they will work and farmers' abilities and willingness to implement.

Resilience

The main impression gained from the field visits is of farmers that have under-estimated risk in their attempts to extract maximum profit. In a situation where yearly risks are increasing and unquantifiable, a reactive 'wait until it gets bad' approach is no longer a rational approach. Farmers should be looking to increase resilience and reduce efforts to chase short-term profit as the graph below depicts (Fig. 13). In practice this will be difficult, but it should, in the opinion of this consultant, become an underlying principle of the project's activities. A primary purpose of the project should be to elucidate the minimum yield per hectare that is required for economic solvency and if this is achievable at all altitudes given proposed increases in production costs.

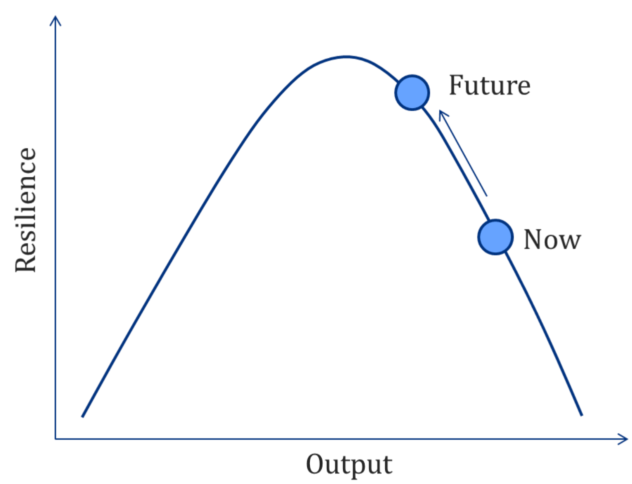

Figure 13. The trade-off between output and resilience (after Goerner et al. 2009).

Essentially, the job of extensionists becomes one of exploring the 'sweet-spot' on the above curve, which will be an optimal trade-off between farmers ambitions of a bumper harvest and the extensionist's fears of catastrophic losses.

In the following section a wide range of measures will be briefly covered, that should to be considered by the local team.

6. Suggested actions

From the previous sections, we see many climate threats to farms and farmers, with little certainty of which ones will be the next priority. Hence currently rust is the main preoccupation, but if a strong El Niño arrives next year, priorities will quickly change. However because rust is the current worry and because of the principle of 'never let a crisis go to waste', initial activities need to concentrate on treating and preventing rust and learning lessons.

To a greater or lesser extent therefore, the following list will have to be modified by local staff to achieve sufficient successes to warrant project expansion. Hence the following list of actions – in roughly descending order of priority, is approximate only.

Action	Priority	Activities	Comments
Analyse field notebooks	High	Discover how well catimors have performed during the present and past seasons. Yields and costs vs. altitudes	Yield and quality information & attack by Ojo de Gallo. Estimate overall costs vs. conventional vars. for a range of altitudes and shade intensities. Are there clear height differences? How much coffee does a farmer need to produce to achieve a reasonable profit?
Further farm fact-finding	High	Sample farms leading up to 2012 harvest. Look for farms in the same area (where possible) that are clear 'winners' and 'losers' Measure unusual events	What correlates with success? Are there certain combinations of height, shade, slope orientation, variety that have done well/badly under this years' conditions? E.g. the Esquipulas windstorm impact – number of trees felled; area of impact; erosion events – where did they happen; was there cover; which tree spp. resisted best?
Cup-testing of catimors	High	Blind cupping of catimors from this years' harvest for a range of altitudes.	How good are the newest 'improved' varieties? Compare with non-catimors from neighbouring plots if possible
Develop GAP package	High	Agree on a limited number of key actions	See section 4.2 above for discussion of this
Review farmers' spray machinery	High	Nozzles are a priority; test for efficiency of coverage	Spray machinery is often poor and can seriously compromise the efficiency of applied products
Cover crops	High	Collect promising species and trial in a range of	Cover crops need to be improved, or at least trialled more intensively

coffee & climate
enabling effective response

		microclimates	
Develop extensionists' field-notebook	High	Include some simple tables to fill out in order to better capture local experiences	E.g. record new weather events, landslips etc. Record innovations (e.g. unusual, effective soil cover plants, water storage)
Develop extensionists' toolkit	High	Camera and GPS Tape measure Tow-rope & saw pH soil kit	Encourage liberal use of camera to record new events. Train and encourage extensionists to formally collect important data
Develop farmers' emergency response protocol	High	Seek assistance from govt./NGO relief agencies on best coping strategies for extreme events	Construct 'dos & don'ts' list; output could be a brief list to stick into the back of the farmer's field notebook.
Landslide risk assessment	High	Seek guidance from a relevant authority on how to make a basic evaluation of risk of major (life-threatening) avalanches.	Ideally, extensionists should have the capability to quickly assess work areas for potentially catastrophic collapse and know whom to contact when in doubt.
Subsistence crops	High	Initial diagnostic of how many farmers produce their own food, amount of time they spend on it, and principal problems.	Farmers may become increasingly dependent on subsistence food crops if coffee suffers severe effects of extreme weather patterns. Since food prices may well continue to rise, buying in food will be less affordable.
Alternative energy	High	Collect information about regional initiatives, expertise etc. By end of project, carry out a diagnostic with farmers on energy needs and problems. Organize training for at least one extensionist if locally available.	Extensionists felt this was very important. However this will be a long-term problem and is beyond the immediate scope of the current project.
Develop farmers' emergency kit	Moderate	A basic toolkit to survive an extreme event.	e.g. torch, batteries, water-proof material (infants), matches etc., as advised by disaster professionals.
Farmer & worker health	Moderate	During visits, note general health of farmer, enquire about family, workers; record accounts of ill-health, e.g. dengue, malaria, bronchitis.	As temperatures rise and prolonged high humid events take place, there will be more insect vectored disease outbreaks.
Early warning	Moderate	Contact experts on storm and ENSO events, websites, for relevant information.	Trial limited messaging service to selected farmers to gauge utility of warning messaging.
Road infrastructure	Moderate	Encourage community and	Roads are deteriorating and in some

		municipal activities to jointly improve infrastructure	cases inadequate for current needs
Zoning	Moderate	Develop the concept of different altitude zones for coffee, where recommendations would differ. By the end of the project, some agreement about the concept of zoning with approximate altitude ranges and number of categories should be established.	E.g. top altitude coffee could be more orientated to maximise production, whereas lowest would be oriented towards increasing resilience and diversification. It will be important in the future that extensionists are always aware which zone they are working in and the implications this has for recommendations.
Drying	Moderate	Observe problems during the coming harvest season. Improve options for drying, including covers, tests for resting coffee.	Untimely rainfall may be an increasing problem for coffee drying.
Water harvesting	Moderate	Observe and document examples of water harvesting and water-sparing technology, however simple. Look for regional expertise and documentation of this.	Droughts are likely to become more common; farmers will need to store more water.
Nursery techniques	Moderate	Experiments to improve root development prior to planting out. Make use of the mycorrhizal production facility at Zamorano by mounting simple tests with additives to bags. Large bag sizes, deeper sleeves etc. could be tried.	Increased planting rates of resistant coffee will be needed in the future which will have to survive during unexpected severe weather events.
Collect available meteorological data	Medium - Low	All available meteorological data from the Trifinio zone should be collected and graphed to look for trends in increasingly extreme weather.	This is categorized as medium-low because of the possible unreliability of the data and its dubious utility.
Preliminary gypsum evaluation	Medium-Low	Micro scale trials on a range of soil types to establish primary effect on root depth	One or very few trees per treatment only. Liaise with HRNS Brazil for detail.
Improve weather data	Low	Set up on-finca weather stations according to available funds.	Some larger farmers especially may be keen on data and measurement. If these farmers can be found, their activities should be encouraged.

Diversification	High	Extensionists should collect data from any low-altitude coffee farmers abandoning coffee.	There will be an inevitable loss of farmers at lowest altitudes. Much can be learned about their experiences and decision-making criteria.
	Low	The experiences of coffee farmers outside the zone (e.g. Pacific slope farmers in Guatemala/El Salvador) should be collected where feasible.	Especially any reports (e.g. by Anacafé etc.) may give useful guidance as to performance of diversification crops.
Arabica to Robusta	Low	Some Robusta is being grown commercially near Esquipulas, attempts to visit should be made. Look and ask for information about Robusta growing in C. America.	Some Robusta is/was grown in Chiapas by large fincas, below Arabica altitudes. In India this is quite common, even mixed Arabica & Robusta on the same plantation.

Table 6. Synopsis of actions that could be taken or initiated during present and future projects related to climate change.

A low-growing cover plant from El Salvador

Tactical overview

The above tabulated list is a counsel of perfection that cannot be completed within the present project – local management will have to determine priorities according to resources available. However, most of the suggestions should be seriously considered and some, which at this stage require little more than information collecting and/or training, might be accomplished with relatively little effort.

The above can be boiled down to some key concepts:

Rust control strategy

I.e. short term – spray;
medium to long – replace with catimors;
long term – diversify at lowest altitudes.
This disease will not go away and even if next years' conditions are not conducive, it will return. Smallholder farmers simply cannot afford continual assaults from this disease.

The main challenge is to weigh the increased costs of protective sprays and/or replacement with catimors against the expected yields, prices and price differentials for coffees from a range of altitudes. This is a multi-dimensional problem that has no easy answer, especially under widely varying year-on-year conditions. Full exploration of this situation could take years of effort.

This is where the field notebooks could be of great benefit. An early analysis of results to date followed by an expert panel assembled to review it could help to produce a first approximation for planning next year's activities. As soon as available, yield data from the coming (2012-13) harvest should be analysed to help understand the full impact of this year's rust epidemic.

By the end of the current project a preliminary strategy should be available regarding the need for a major strategy on replanting with catimors.

Specialty vs. commercial

Related to the rust problem, it is clear that some farmers regard themselves as specialty producers so they will be averse to changing to catimors. Those at lower altitudes may well find diminishing returns on the extra expenses involved with susceptible varieties. If these farmers are a large sub-group, then a separate strategy may be needed to deal with their needs and possible misconceptions.

There should therefore be a clear delineation in regard to those farmers who consider themselves specialty producers, and those who are producing more standard grades. Only a quite detailed study could show the costs and benefits for farmers at different altitudes adopting one system or the other.

Costs and benefits
Increased understanding of costs and benefits of coffee growing at different altitudes is absolutely essential to guide choices and avoid maladaptation – the field notebooks will be a key tool.

Emergency avoidance and response strategy
What should all stakeholders do in an emergency? Clear and robust plans should be in place for trained participants, so that when something happens, or is about to happen, everyone knows what to do. There needs to be a clear policy of the extent to which the project can divide itself between purely climate impacts on coffee growing and impacts on livelihoods.

Building farm resilience
In the case of the Brazil and Vietnam projects, it seems legitimate to generally encourage very high production levels because of the currently low downside risks of climate change. In the case of Trifinio however a different and complex strategy is needed. There is a strong case to be made that farmers should be encouraged to strive less for high yields in order to build resilience and spread risks to the likely frequent shocks caused by climate fluctuations, both wet and dry. This will involve diversification in lower marginal zones.

Building resilience of infrastructure – roads, drying facilities
General infrastructure looks inadequate for a modern coffee industry. There will be increasing assaults on it due to extreme climate events, but it is doubtful if public funding will increase proportionally. Hence a collective, community strategy to proactively take control is required. This however will be time-consuming to foster.

Climate change in action – experience and innovation
The Trifinio region's coffee is a laboratory of experiences to learn from. How do farmers and their fincas cope with and adapt to extreme climate? The team has a great opportunity to build a unique library of practical experiences from which to develop relevant and cost-effective adaptation tools.

For this reason, the work of the extensionists, both through the development of field data by way of the field notebooks, as well as their wide experience of the region will have to be heavily relied upon.

For this reason also, regular short training and knowledge workshops should be considered as a way to upgrade and fully avail of their skills. They should be provided with a kit of tools to help them record as much information as possible, as well as training on things of interest to record and feed back to project managers as well as a broad range of practical advice to dispense to farmers.

Knowledge and data
The scarcity of meteorological data, added to the evident complexity of the zone (altitude, topography, soils) and probable increasingly varying weather patterns, together suggest that it will be difficult to use and rely upon meteorological data to indicate areas most exposed to current and future risks, let alone to show how climate has changed over recent years.

On the other hand, the existence of a very wide range of other projects and organisations active in the field, suggest that there is a great wealth of expertise to tap into. However, finding the most appropriate people and relevant reports etc. will take time and will have to be a fairly minor component of present project activities. Priorities include:

- Determining the extent to which any diversification options might be relevant and cost-effective for the most marginal coffee farmers

- Determining correct procedures to carry out for risk assessments of farms, above all in respect to potential landslides of plots and surrounding roads.

- Determining correct emergency procedures for farmers to adopt in the face of heavy storms or hurricanes.

The final result of the activities will be the development of a range of tools that are outlined in Appendix 2.

7. Hypotheses and principles
It is useful to develop some basic hypotheses about how climate is and will affect coffee in the Trifinio zone, in order to orientate future work and project development. The following are some initial suggestions. These should be examined from time to time to see whether events and new knowledge are congruent with these hypotheses and whether specific activities are testing them. The list is preliminary and incomplete, new ones can be added as the team become more familiar with the topic.

H1 Temperatures are rising with more hot days which will lead to increasing incidence of some pests and diseases, especially at lower altitudes.
Farmers will be increasingly caught out by unexpected combinations of hot and or wet weather that can provoke aggressive pest and disease outbreaks at altitudes previously only lightly affected.

H2 Rainfall patterns are more unpredictable and/or intermittent than formerly. A specific is the less reliable mid-summer drought (MSD).
A test for utility of meteorological data may be to see if local records show 2012 to be particularly unusual.

H3 Severe storms, prolonged dry and wet spells are all increasingly likely in the future.

Hence coffee farmers will have to be prepared for all eventualities, there is no single type of climate event that merits a special focus to the total detriment of others. This means too that it is unlikely that a comprehensive analysis of available meteorological data from the Trifinio zone would be much of a guide to future events.

H4 Early warning advisories from national and international meteorological institutes are sufficiently useful to be the basis of warnings and updates to farmers.
Information about approaching storms, hurricanes and ENSO events can be useful to farmers, but how this can be turned into simple and opportune messages may largely be a question of trial and error initially.

H5 Shade is an important tool to combat various aspects of climate extremes.
The current rust outbreak seems worse in less shaded areas, though this needs verification. It is likely that increasing shade would reduce bearing and hence stress on the plant during rust attack. Less stressed trees would succumb less to anthracnose die-back. Shade will also protect against severe rain, hail etc. and extreme maximum temperatures. Getting the shade level right for each altitude and slope orientation will be difficult.

H6 Catimors are an important tool to protect against rust attacks and are the most cost-effective solution at altitudes less than ~1500m.
The truth of this assertion needs to be tested, especially in regard to cup quality and hence farm-gate price. Doubts about susceptibility to Ojo de Gallo also need to be investigated.

H7 Existing ground-cover species are good controllers of soil erosion.
General ground cover is poor – this in part is due to shade which limits the need for it, but there are species that thrive in shady conditions. These need to be collected and tested.

H8 There is a minimum profitable altitude for growing coffee, which is approximately 1000 m.
This figure is a pure guess – current data from field notebooks can help to test this hypothesis.

H9 Farmers in the Trifinio zone are poorly buffered against climate change. They will have increasing difficulties in the future.
Coffee farmers in Trifinio and Central America face severe climate-related challenges, possibly the most varied of any coffee farmers in the world. Attention should be paid to general livelihood conditions of farmers, e.g. safety preparedness for major events like hurricanes. Attention should also be paid to food security and availability of energy sources. All this falls under the heading of 'building adaptive capacity for increased resilience'.

Guiding principles (a partial, provisional list)
The following is an additional list of concepts that need to be considered by the team.

Risk assessment: accurate estimation of risks and recent tendencies is difficult due to the complex topography and lack of local data. To a great extent, reliance will have to be put in the collective wisdom of experts and farmers. A great deal of the project is therefore about collecting and analysing information to test ideas and hypotheses such as those listed above.

Data: utility of data collection can be maximised by improving extensionists' abilities and facilities to record events, outcomes and innovations related to climate change.

Priorities: initial activities should concentrate on matters of most immediate concern to farmers – in this case coffee rust, how to treat it and prevent it.

Livelihoods: farmers and their families are as much at risk as the coffee itself. Attention should be paid to enhancing their capabilities to respond to emergencies.

Maladaptation: there will be an accumulating risk of encouraging farmers to spend increasing funds and time on prevention and resilience-building activities for increasingly risky rewards.
Again, the field notebooks are a primary tool to guide farmers. Some uncomfortable decisions may have to be made with some farmers about their long-term future in coffee growing.

Final words
For the first time in this Coffee and Climate project, we see the full panoply of climatic events as significant risk factors happening in real time. The activities of the project in this region are therefore particularly important because it represents a laboratory of experiences upon which to develop and sharpen the adaptation tools. Additionally there is a large range of expertise and practical knowledge to potentially draw upon in the immediate zone and the wider region, which is currently fragmented and unaligned for coffee farming needs. If adequately sourced therefore, there is a major opportunity of gaining a wide range of vital experience on how to adapt to an equally wide range of climatic events and thereby take a leadership role in this field.

Many thanks especially to Pablo Ruiz and all HRNS staff for such an interesting and well-organized visit.

8. References

Aguilar E, et al. (2005). Changes in precipitation and temperature extremes in Central America and northern South America, 1961–2003. J.Geophys. Res. 110: D23107, doi:10.1029/2005JD006119.

CIAT (2012). Escenarios del Impacto del Clima Futuro en Áreas de Cultivo de Café en Guatemala, Informe Final. http://dapa.ciat.cgiar.org/wp-content/uploads/2012/03/Informe-Guatemala-Fine.pdf

Curtiss S (2004). Diurnal cycle of rainfall and surface winds and the mid-summer drought of Mexico/Central America. Clim Res 27: 1–8.

Goerner SJ, Lietaer B, Ulanowicz RE, (2009). Quantifying economic sustainability: Implications for free-enterprise theory, policy and practice. Ecological Economics 69: 76–81.

Hidalgo HG, Alfaro EJ, (2012). Some physical and socio-economic aspects of climate change in Central America. Progress in Physical Geography, DOI: 10.1177/0309133312438906.

Lennox J, (2012). La Economía del cambio climático en Centroamérica. Reunión del UNFCCC Ciudad de México, 22 de julio 2012.

Magaña V, Amador JA, Medina S (1999). The midsummer drought over Mexico and Central America. J Clim 12: 1577–1588.

Tyres used for erosion control in El Salvador

Appendix 1. Example of farm questionnaire.

Below is an example of the diagnostic form used during field-trips. This should be modified and improved according to experience.

DIAGNÓSTICO DE PRODUCTOR

Fecha	

Ubicación			
Depto.		Nombre de finca	
Municipio		GPS	
Tipo suelo		Altura (ASNM)	

Productor		
	Nombre	
	Edad	

Finca		
	Tamaño (ha.)	
	Variedad principal (ca	
	Densidad	
	Producción última	

Marcar la casilla

Problemas	Clima	Plagas	Enfermedades	Financiero	Mano de obra	Otro
Principal						
Secundario						
Terciario						

5 palabras claves del productor				

Diagnóstico visual

Marcar la casilla

Cobertura de suelo	Descubier	Con Cultiv	Mulch	Maleza
Deslizamientos	Ninguno	1 a 2	3+	
Erosión	Ninguna	Poco	Regular	Alta
Salud del cafetal	Mala	Regular	Buena	Excelente
Sombra	Ninguna	Poca	Regular	Alta

5 palabras claves del entrevistador

Calificación general de la finca [1 = muy mal a 10 = muy bien]

Innovación relevante:

Otros comentarios:

Appendix 2 Specific Tools

Outlined below are a range of possible tools to be developed and tested by local staff. They are invited to take these as starting points and develop them accordingly. Ideally certain tools could be championed by nominated individuals who are made responsible for collecting further information and planning activities; effectively they would be invited to take ownership for one or more tools. Tools are a principal output of the project and hence each one should be turned into a dossier of information with clear accounts of activities to test them in the field.

Tool: Good Agricultural Practice

Type: no/low-regrets
Feasibility: high
Applicability: to be carried out in all areas
Effectiveness: high

Concept: farmer to adopt a rigorous series of measures to cope with increased stresses caused by more extreme weather.

Activity: a series of measures starting with soil (and leaf if affordable) analysis to determine nutrient requirements for the following season.

Based on this, a planned series of shade regulation, applications of applications of fertilizers and fungicides in the form of a protocol.

Details of the protocol to be tested in 2013 will be determined by an expert panel.

Drawbacks: requires a change in mind-set of some farmers, away from a needs-based 'just-in-time' approach to a proactive interventionist strategy.

Many farmers may need extra financing to carry this out?

May take time to show that benefits outweigh costs – in some years, some interventions may retrospectively be viewed as unnecessary because of rapidly changing climatic conditions.

Protocols will be different according to altitude, it will take time to optimize these.

Tool: Adoption of catimors

Type: resilience, no/low-regrets
Feasibility: high
Applicability: to be carried out in all zones below (1500 m?) and with all farmers not intent upon specialty premiums
Effectiveness: high

Concept: catimors are resistant to coffee leaf rust and hence no costly fungicidal sprays are required.

Activity: a phased replacement of susceptible varieties, to be most rigorously pursued at lowest altitudes.

Drawbacks: some reports of increased susceptibility to leaf spot fungus (Ojo de Gallo)

Renowned for poor cup quality, therefore farm-gate price will often be lower than for susceptible varieties.

Tool: Accurate shade measurement

Type: assessment tool
Feasibility: high
Applicability: universal
Effectiveness: high

Concept: shade is a vital component of the Central American coffee system – too little shade exposes coffee to high sun temperatures, causes excessive flowering and exposure to wind, hail etc. Too much on the other hand, leads to poor yields and in some cases higher disease incidences. The ideal shade level also varies according to altitude, slope orientation and time of year.

Until there is a reliable model available, shade levels need to be set entirely according to experience; some/many farmers have achieved ideal levels of shade through a process of trial and error.

A major strategy of the present project is to learn directly from successes and failures from project farmers. In the case of shade therefore, it is important to be able to accurately quantify shade levels.

Activity: for all project field plots, as well as other plots with particularly good or bad-looking coffee production, measure shade within plots three to four times per year using a camera.

Procedure: set camera to widest angle, hold vertically overhead within the plot and take photo. Repeat about 10 to 12 times over the complete plot.

Analysis: there is a computer programme to analyse percentage shade, but for initial quick results, visual inspection of images by a 3 or 4 member panel, viewing images through a grid of small squares, can arrive at a reasonable estimate.

Drawbacks: none foreseen

Tool: Ground-cover for erosion protection

Type: resilience
Feasibility: high
Applicability: to be carried out in all zones – but especially steep slopes and soils that seem most prone to erosion
Effectiveness: high

Concept: low growing non-aggressive plants form a complete cover of soil and reduce soil erosion, because roots of the cover crop anchor the soil, improve soil structure and slowing action on running water. A good cover will also reduce the need for weed control activities.

Activity: assay locally procured varieties under a range of conditions and evaluate speed of growth, ability to compete against other weeds and farmer satisfaction.

Drawbacks: some cover plants may hide fallen berries and therefore harbour coffee berry borer; during dry years this could be a problem.

Tool: Farmer's emergency response protocol and kit

Type: resilience
Feasibility: high
Applicability: everywhere
Effectiveness: not known

Concept: some/many farmers will face increasing emergencies caused by extreme weather. A simple list of dos and don'ts plus a basic survival kit may help them during a crisis.

Activity: from expert advice (including lessons learned from previous events) develop a simple list of the most important actions and activities before, during and after an event (this will principally be severe storms).

Assemble a simple kit consisting of (say): torch, batteries, water bottle(s), matches, battery charger for mobile, emergency numbers, rain-proof material for children – for location in farmers' houses.

Drawbacks: none foreseen

Tool: Landslide risk assessment

Type: resilience
Feasibility: ?
Applicability: Steep areas
Effectiveness: not known

Concept: landslips will become more common, it is not impossible to imagine that farmers or even project staff could be victims.

Activity: from expert advice (hopefully from lessons learned from previous events) and training, develop a simple risk assessment exercise to carryout for all steeply sloped areas on farms where the project is active.

Drawbacks: none foreseen

Tool: Early warning service

Type: risk avoidance
Feasibility: ?
Applicability: everywhere
Effectiveness: not known

Concept: farmers can benefit from early warning of approaching storms, or slower events such as onset of an El Niño event.

Activity: from expert advice, regularly access information services (e.g. NOAA, WMO, national and regional meteorological services), select information that is relevant to farmers and distil into text messages or tweets.

Drawbacks: none foreseen

Tool: Infrastructure repair

Type: community-based adaptation (resilience)
Feasibility: ?
Applicability: everywhere
Effectiveness: not known

Concept: farmers should be helped to rebuild and improve infrastructure, especially roads/tracks leading to individual farms and villages.

Activity by extensionists: foster/encourage community meetings to discuss infrastructure problems, rate concern about this and elicit response ideas. Approach municipalities/other sources for financial assistance – e.g. to provide raw materials such as stones, cement, bricks for farmers themselves to effect repairs.

Drawbacks: time-consuming to set up

Tool: Patio drying – use of parabolicas

Type: no/low-regrets
Feasibility: ?
Applicability: everywhere
Effectiveness: useful under some conditions

Concept: open-sun patio drying is increasingly risky in areas where out-of-season rainfall is a threat. Use of polythene covered solar driers can assist speedy drying of small amounts of coffee.

Activity: set up trials with farmers/co-ops who have been especially affected by drying problems.

Drawbacks: costs may be high per unit area; temperatures can rise too high inside; turning the coffee can be more laborious.

Tool: Patio drying – resting during drying

Type: resilience, no/low-regrets
Feasibility: ?
Applicability: everywhere
Effectiveness: not known

Concept: coffee drying space can be very limited during peak harvest. A recent paper (Izquierdo et al 2011) suggests that both washed and natural coffees can be rested for up to 30 days in wooden crates without affecting cup quality and that this process actually speeds up total drying time.

Activity: set up small-scale trials (a few kg only) with farmer/co-op to test the validity of these claims. Subject the final product to blind cup-tests.

Drawbacks: none foreseen

Tool: improving growth of coffee seedlings in nurseries - mycorrhizae

Type: resilience, no/low-regrets
Feasibility: ?
Applicability: everywhere
Effectiveness: not known

Concept: replanting coffee will become increasingly important if farmers are to keep up with latest advances and as well maintain plots at peak performance. At the same time, planting out may become more problematic if this coincides with extreme weather events. Good root structure gives the coffee seedling the best chance of quick and strong growth. Mycorrhizae can help the seedling assimilate soil nutrients more easily and hence grow more vigorously

Activity: set up small-scale trials with coffee seedlings with and without the recommended dose of mycorrhizae. Evaluate growth performance compared with control plants and at intervals by destructive sampling to view root growth.
Drawbacks: none foreseen

Tool: diversification – Arabica to Robusta

Type: resilience
Feasibility: ?
Applicability: altitudes below 1000 m
Effectiveness: not known

Concept: it will be increasingly inevitable that some farmers who are already in marginal zones will have to abandon coffee.

Activity: visit areas where Robusta is being grown to learn from experiences. Calculate costs and benefits. If initial impressions prove favourable, start small trials with farmers who show an interest.

Drawbacks: none foreseen

Tool: gypsum micro-trial

Type: resilience
Feasibility: ?
Applicability: potentially universal
Effectiveness: potentially high on the right soil

Concept: in Brazil gypsum has been shown to cause deeper root growth by opening soil structure and pushing nutrients to deeper layers in the soil. Roots grow down to follow the nutrients. Deeper roots provide resilience to drought.

Activity: small-scale tests to evaluate whether the technique to improve root depth works with Trifinio soils and hence improve resilience to drought**.** Carry out very small trials (e.g. one to three trees per treatment), in diverse locations – e.g. on farms on any unused scrap of land, with young recently planted out coffee trees. Carry out soil test first, then apply gypsum (one or more doses) take occasional measurements of tree health and growth to compare with controls. Examine root structure through excavation after 9 to 12 months.

This experiment can be done on other tree types as well – it could feasibly be a technique to help anchor shade trees on erosion-prone soils.

Drawbacks: few if done at very small scale. Unlikely to work on sandy, open-structure soils.