Methodology

Adaptation by agricultural communities to climate change through participatory & supply chain inclusive management

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Table of Contents

1. Introduction ........................................................................................................................................ 4
2. Vulnerability to Climate Change .................................................................................................... 5
3. Step 1: Estimating impacts using crop prediction models ............................................................. 7
   Current climate .................................................................................................................................. 7
   Future climate ................................................................................................................................... 7
   Global circulation models ............................................................................................................... 7
   Generation of future climate .......................................................................................................... 8
   Crop prediction .............................................................................................................................. 8
   Measure of confidence .................................................................................................................. 9
   Land Availability .......................................................................................................................... 9
4. Step 2: Elucidating the impacts on livelihoods ................................................................................ 9
   Livelihood indicators ................................................................................................................... 9
   Participatory workshops .............................................................................................................. 10
     Participatory Rural Appraisal ..................................................................................................... 10
     Workshop Equipment ............................................................................................................... 11
   In depth surveys .......................................................................................................................... 12
   Farm Level Vulnerability Analysis ............................................................................................... 13
   Construction of a Vulnerability Index ........................................................................................... 14
5. Step 3: Accounting for options of upstream supply chain actors ..................................................16
   Supply Chain Analysis and Supply Chain level Vulnerability Assessment .................................... 16
   Behavioral Assessment .............................................................................................................. 17
   Carbon footprints ....................................................................................................................... 17
6. Possible adaptation strategies ..........................................................................................................18
7. Step 4: Deriving a framework with response pathways .................................................................18
8. Summary and further outlook ........................................................................................................ 19
9. References .........................................................................................................................................19
Annex I Questionnaire Example: Jamaica .........................................................................................23
Table of Figures

Figure 1: IPCC Vulnerability approach ........................................................................................................6
Figure 2: Methodology ......................................................................................................................................6
Figure 3: Farmer leading discussion in focal workshop ..................................................................................11
Figure 4: Historic Calendar (Climatic and Social Phenomena) ....................................................................11
Figure 5: Matrix of Social Strata ..................................................................................................................11
Figure 6: Commercialization .........................................................................................................................11
Figure 7: Risk and Resilience Strategies .......................................................................................................12
Figure 8: Sustainable Livelihood Resources and Indicators .........................................................................12
Figure 9: Students doing interviews of farmers in Jamaica ............................................................................12
Figure 10: Follow up workshop to identify adaptation strategies in Bogota .................................................14
Figure 11: Vulnerability Index example: short story 1, female farmer in Sololá / Guatemala .......................15
Figure 12: Vulnerability Index example: short story 2, male farmer in Guasca / Colombia .........................15

Table of Tables

Table 1: Data on which WorldClim is based in the 3 case-study areas ............................................................... 7
1. Introduction

The aim of the project is to systematically address the challenge of climate change regarding farmers’ livelihoods and supply chains. The project recognizes that global climate change is no longer an academic theory but reality and especially concerning for some of the poorest rural communities. Therefore strategies need to be developed to mitigate negative impacts, address vulnerabilities and enable stakeholders to reap potential benefits by smart adaptation.

Following an initiative by Lash and Wellington (2007) to link climate change and profitability our approach is based on the argument that the ability to hedge against and manage climate risk in the supply chain as well as innovating around new technology and product opportunities is equally important for the food sector as its skills in mitigating regulatory costs, avoiding expensive litigation and other threats to corporate reputation. While firms increasingly appear to recognize the climate change challenge response pathways are not yet systematically developed.

Adaptation options have often been proposed to manage risks related to climate change in an ad hoc fashion (Smit and Skinner 2002). Most adaptation options are modifications to ongoing farm practices (Best Agricultural Practices –BPA) and public policy decision-making processes. More so, managers not only need options to respond to climate change in a systematic manner but to change their management, they need to be convinced that projected climate changes are real, and that they need to be confident that the projected changes will significantly impact on their enterprise (Howden et al. 2007). While ad hoc adaptations occur with partial success, what remains unclear and thereby prevents successful implementation elsewhere is the adaptation process itself. As climate change progresses with increasingly severe impacts a pro-active adaptation should be the objective of stakeholders. In contrast to ad hoc adaptation that takes place after climatic changes occurred, pro-active adaptation uses the available advanced knowledge about climate change to design smart investments. Food Supply Chains involve long term investments with a high climate dependency, representing a case that is identified by many authors as requiring immediate investigation with scientific methods in order to facilitate a pro-active planned adaptation process to climate change (Füssel 2007). This study intends to develop a methodology that enhances our understanding of vulnerabilities of supply chains from a bottom-up perspective to enable stakeholders to use the chain inherent capacity to adapt to progressive climate change.

On local spatial scales climate change impacts are often harder to predict than on global scales. This methodology report will describe the methodologies that were used throughout the research process to assess farmers’ vulnerability to climate change and develop supply chain and site-specific adaptation strategies and to develop a simple, useful and robust adaptation framework. The framework will facilitate a planned and purposeful adaptation process. This methodology report describes the process of identifying vulnerabilities of food supply chains, the development of adaptation options and their translation into concrete adaptation actions.
Specifically, we do this by analyzing and synthesizing three concrete examples, which are ongoing Oxfam GB supply chain projects:

**Case study 1.** Guatemala frozen vegetables value chain in the department of Sololá. This study was coordinated with SFL Climate Change assessment to enable to look broadly at both mitigation and adaptation aspects.

**Case study 2.** Bogotá metropolitan area small-scale farmers related food security. This study aims at highlighting the long-term CC impacts on the small-scale farmers that are currently sourcing the most relevant part of staple foods and vegetables to Bogotá.

**Case study 3.** Jamaica fresh vegetable market for the hotel industry. This study aims at analyzing the long term impact of CC on small-scale farmers in the island making a long term business case for the hotel industry and providing evidence to start policy discussion.

Our approach consists of four-steps that leverage the substantial collective knowledge of all actors in the investigated agricultural production and marketing systems to benefit from climate change opportunities.

1. Participatory analysis of the current and future biophysical suitability of crops under progressive climate change.
2. Analysis of the likely impacts of these changes on the livelihoods of local communities, and juxtapose these impacts with the adaptive capacity of communities.
3. Characterization of alternative options that upstream supply chain actors have at their disposal to balance the impacts of climate change on the selected business cases.
4. Derivation of a framework for collective, supply chain inclusive adaptation, including an action plan with concrete response pathways.

### 2. Vulnerability to Climate Change

We base our research on the commonly used definition of vulnerability of the third assessment report (IPCC 2001) as outlined in the Working Group II report (McCarthy et al., 2001) in combination with the sustainable rural livelihood framework of Scoones (1998). Reviewing the state of the art of climate change vulnerability Hinkel (2011) finds that this approach is appropriate to identify vulnerable people, communities and regions when applied to narrowly defined local systems.

The third assessment report (TAR) of the IPCC defines **vulnerability** as “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.” In this definition exposure, sensitivity and adaptive capacity are defined as follows:

“**Exposure** is the character, magnitude and rate of climate change and variation”

“**Sensitivity** is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).”

“**Adaptive capacity** is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential
damages, to take advantage of opportunities, or to cope with the consequences.”

(Parry et al. 2007)

Figure 1: IPCC Vulnerability approach

However, this approach has been designed as top-down global circulation model (GCM) based. It has been useful in its narrow interpretation during the early years of climate change impact assessment (Hinkel 2011). With an increasing focus on vulnerability research that intends to support decision makers in adaptation policies, this approach has to be adjusted to these new needs. We therefore apply two distinct methodologies to assess vulnerability. On the one hand we indicate exposure and direct impact sensitivity by estimating the future suitability of key crops using crop prediction models. On the other hand we assess indirect sensitivity and adaptive capacity using the Sustainable Rural Livelihoods Framework by Scoones (1998) as modified by Farrington et al. (1999).

This way our vulnerability assessment is multi-dimensional: The GCM-based suitability predictions allow for spatial differentiation and projection of global climate change impacts over time. They therefore form the distinct climate change component that indicates the expected stress to the system that is analyzed.

The sustainable livelihood assessment yields a proxy that serves multiple purposes: It incorporates the fact that stress resilience is not merely a function of the resilience of the primary income source; it makes the current vulnerability spatially comparable; and directs attention to specific scarcities of the research regions. Thus, our approach allows us to pinpoint key weaknesses at the base of local supply chains.

Recent research argues that the classical IPCC definition of vulnerability catches only part of the picture. A critical role in adaptation and adaptive capacity plays the perception of hazard risk (e.g. Grothmann and Patt 2005). We thus included information about expected impact of climate change in part of our analysis to assess the motivation to adapt.

The steps involved in the assessment of the vulnerability and the subsequent development of alternative livelihood strategies are summarized in figure 2.
3. Step 1: Estimating impacts using crop prediction models

Current climate

As current climate (baseline) we used historical climate data from www.worldclim.org database (Hijmans et al. 2005). The WorldClim data are generated through interpolation of average monthly climate data from weather stations on a 30 arc-second resolution grid (often referred to as "1 km" resolution). Variables included are monthly total precipitation, and monthly mean, minimum and maximum temperature, and subsequently 19 bioclimatic variables (Hijmans et al. 2005) derived from the initial variables that are often used in crop niche modeling.

In the WorldClim database, climate layers were interpolated using:

- Major climate databases compiled by the Global Historical Climatology Network (GHCN), the FAO, the WMO, the International Center for Tropical Agriculture (CIAT), R-HYdronet, and a number of additional minor databases for Australia, New Zealand, the Nordic European Countries, Ecuador, Peru, Bolivia, amongst others.
- The SRTM elevation database (aggregated to 30 arc-seconds, "1 km")
- The ANUSPLIN software. ANUSPLIN is a program for interpolating noisy multivariate data using thin plate smoothing splines. We used latitude, longitude, and elevation as independent variables.

For stations for which there were records for multiple years, the averages were calculated for the 1960-90 period. Only records for which there were at least 10 years of data were used. In some cases the time period was extended to the 1950-2000 period to include records from areas for which there were few recent records available (e.g. DR Congo) or predominantly recent records (e.g. Amazonia).

After removing stations with errors, the database consisted globally of precipitation records from 47,554 locations, mean temperature from 24,542 locations, and minimum and maximum temperature for 14,835 locations.

Table 1: Data on which WorldClim is based in the 3 case-study areas.

<table>
<thead>
<tr>
<th>Study area</th>
<th>precipitation stations</th>
<th>mean temp. stations</th>
<th>min./max temp stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogota</td>
<td>370</td>
<td>124</td>
<td>76</td>
</tr>
<tr>
<td>Guatemala</td>
<td>61</td>
<td>59</td>
<td>18</td>
</tr>
<tr>
<td>Jamaica</td>
<td>51</td>
<td>38</td>
<td>7</td>
</tr>
</tbody>
</table>

Future climate

Global circulation models

A global circulation model (GCM) is a computer-based model that calculates and predicts how climate patterns will look like in the future. GCMs use equations of motion as a numerical weather prediction (NWP) model, with the purpose of numerically simulating changes in the climate as a result of slow changes in some boundary conditions (such as the solar constant) or physical parameters (such as the concentration of greenhouse gases). The model focuses on each grid cell and the transfer of energy between grid cells. Once the simulation is calculated a number of climate patterns can be determined; from ocean and wind currents to patterns in precipitation and rates of evaporation rates that affect, for example, lake-
levels and growth of agricultural plants. The GCMs are run in a number of specialized computer laboratories around the world. We used data in our analyses from these laboratories.

**Generation of future climate**

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report was based on the results of 21 global climate models (GCMs), data for which are available through an IPCC interface, or directly from the institutions that developed each individual model. The spatial resolution of the GCM results is inappropriate for analyzing the impacts on agriculture as in almost all cases the grid cells measure more than 100 km a side. This is especially a problem in heterogeneous landscapes such as those of the Andes, where, in some places, one cell can cover the entire width of the range.

Downscaling is therefore needed to provide higher-resolution surfaces of expected future climates if the likely impacts of climate change on agriculture are to be forecast.

We used a simple downscaling method (named delta method), based on the sum of interpolated anomalies to high resolution monthly climate surfaces from WorldClim (Hijmans et al. 2005). The method, basically, produces a smoothed (interpolated) surface of changes in climates (deltas or anomalies) and then applies this interpolated surface to the baseline climate (from WorldClim), taking into account the possible bias due to the difference in baselines. The method assumes that changes in climates are only relevant at coarse scales, and that relationships between variables are maintained towards the future (Jarvis and Ramirez 2010).

CIAT downloaded the data from the Earth System Grid (ESG) data portal and applied the downscaling method on over 19 GCMs from the IPCC Fourth Assessment Report (Solomon et al. 2007) for the emission scenario SRES-A2 and for 2 different 30 year running mean periods (i.e. 2010-2039 [2020s], 2040-2069 [2050s]). Each dataset (SRES scenario – GCM – time slice) comprises 4 variables at a monthly time-step (mean, maximum, minimum temperature, and total precipitation), on a spatial resolution of 30 arc-seconds (Jarvis and Ramirez 2010)

**Crop prediction**

For most of the crops that are not staple or commodity crops there is a lack of detailed information. Hijmans et al. (2005) have developed a mechanistic model based on the Ecocrop database (FAO 2011) to spatially predict crop suitability without having prior knowledge or data available. The model essentially uses minimum, maximum, and mean monthly temperatures, and total monthly rainfall to determine a suitability index based on each parameter separately (i.e. temperature, rainfall), to finally determine an overall suitability rating (from 0 to 100) by multiplying both temperature and rainfall indices. Ecocrop does not require any coordinates or ground data and is therefore rather generic. To improve the results we use existing knowledge of geographic crop distribution such as the Spatial Production Allocation Model (SPAM), the Global biodiversity information facility (GBIF), CIAT own databases and expert knowledge gathered on the ground or through crowd sourcing tools. With a minimum of 60-100 geo-referenced sample sites gathered across the different sources we re-calculate the environmental factor ranges to calibrate the Ecocrop for the specific crops of the case studies.
Measure of confidence

Future crop suitability is predicted using each of the GCM models via Ecocrop algorithms described above. Two measurements of uncertainty are computed; one on the raw GCM data and one after having used the crop prediction model Ecocrop: (1) The coefficient of variation (CV) of precipitation and temperature, (2) the agreement among models (Ecocrop runs with different GCM’s) calculated as percentage of models predicting changes in the same direction as the average of all models at a given location and After initial runs, models that are significantly different from those of the other models according to (Tukey 1977) outlier test will be removed from further analysis.

Land Availability

An integral step in the modeling process is the determination of available land for crop production, as some areas may be inappropriate for a variety of reasons. Here, the following set of variables has been used to adequately derive the areas that are actually favourable: Land use, landscape protection and proximity to roads of access.

The information about current land use allows to determine areas that do not permit cultivation, e.g. due to water surfaces or surfaces closed by settlements. In the case of forest cover and protected areas the models allow to establish a certain degree of restriction for cultivars. This limitation is “softer” than in the aforementioned class, owing to the fact that it is not impossible to introduce cultivation in these areas; it is only not advisable to develop agricultural activities in these areas at present. Furthermore so called "open zones" are introduced. These represent buffer strips between ecologically important areas and the surrounding plots to protect sensitive natural environments. A similar restriction is overlaid for the areas where the soils are not fertile for the type of land cover that it has at this time. Both cases, the buffer zones as well as regions with marginal soil conditions require a careful management to achieve adequate use without failing to protect the environment. Another aspect that has been analyzed is the proximity to access roads, taking into account that at large distances between road and plot, the costs of transport of inputs and machinery needed for field work are higher, and thus, the harvested product.

Finally the area that is actually available to cultivation without any sort of restriction is delimited. These are areas in which presently cultivation of agricultural products is practiced or which are not subject to one of the restrictions above (Jarvis et al. 2010). To determine a complex set of variables to derive available land for specific crops will be part of a CIAT student thesis.

4. Step 2: Elucidating the impacts on livelihoods

Livelihood indicators

The UK Department for International Development (DFID) sustainable livelihood approach (Farrington et al. 1999) describes a framework for the analysis of livelihoods and poverty. It accounts for the notion that poverty cannot be simply described as a number that is below the poverty line. According to Scoones (1998) of interest to any livelihood analysis is the ability to successfully pursue livelihood...
strategies based on livelihood resources given a specific context.

Here, global climate change is the context and the stress to rural livelihoods that needs to be coped with. We assessed the resilience of the livelihoods by estimating its available resources in the form of capital stocks. In accordance with Farrington et al. (1999) we differentiate the capital forms physical, natural, human, social and financial capital. Based on expert knowledge, literature review and previous research experience for each capital form climate-related indicators and indicating variables where designed that could be measured on an ordinal scale. One set of variables addresses indirect sensitivity, another adaptive capacity. (Figure 8: Sustainable Livelihood Resources and Indicators).

Participatory workshops

Participatory workshops were held so that CIAT’s researchers could conduct an initial assessment of vulnerabilities. The aim of the workshops was to learn through discussions with farmers’ groups about their first hand experience with historical climate changes. Specifically the farmers’ perception of the impact of climate on natural and physical capital has been assessed in this manner.

Furthermore, these workshops were held with attention to gender roles, such that the results could also be used as outlined in the gender report:

**Gender Report.** The impact of climate change on men and women

**Participatory Rural Appraisal**

The workshops were conducted using a method called Participatory Rural Appraisal (PRA). This data collection technique utilizes facilitators to guide the discussion of a group of farmers to unearth the necessary information via a range of techniques (Bhandari 2003). For this particular project, the researchers made use of diagramming and visual sharing, where charts consisting of imagery were utilized to communicate ideas with the farmers (Chambers 1994). The entire discussions took place with the aid of charts and the farmers were asked to use beans and simple signs to indicate the magnitude, volume, frequency or intensity of specific variables. For example, to indicate the favorability of rainfall over a ten year period, farmers used 1 kidney bean to indicate rainfall of very low favorability, and 5 kidney beans to indicate highly favorable rainfall.

One of the advantages of this method is that it allows everyone present to not only hear what is happening, but to also “see” the discussion taking place (Chambers 1994). This is highly beneficial in rural communities as there is often a high level of illiteracy and diagramming and visual sharing allows the entire group to fully engage in the discussions (Chambers and Blackburn 1996). Thus, all the farmers present were able to crosscheck, correct each other discuss the information and come to consensus on the issues raised.

Another advantage of this system is that it is much less time consuming than questionnaires (Bhandari 2003; Chambers 1994). As recommended by Bhandari (2003) the large groups were split into 3-4 smaller groups to have preliminary discussion on different issues. The smaller groups were then reintegrated into one large group to discuss and verify the finding of the smaller groups and to reach a consensus. Additionally, this allowed the information that
is received to be openly verified by the participants.

The PRA also allowed the farmers to take charge of certain sections of the workshop. According to Chambers (1994) this allowed the farmers to become more relaxed when one of their own was moderating the session.

Figure 3: Farmer leading discussion in focal workshop

As a result, they became more open in their discussions and began to raise issues that may have otherwise not been raised. This led to the sharing of information not only between the farmers and the researcher, but also among the farmers themselves. After quantify, ranking, evaluating and prioritizing the issues themselves, Chambers (1994) and Bhandari (2003) argued that the farmers will begin to better appreciate the outcome of the discussions and will be more likely to adopt principles that will lead to more sustainable livelihood practices.

PRA also supplement the other sources of data collection such as one on one interviews and secondary sources such as governmental reports (Chambers 1997). This process of triangulation involves the use different modes of data gathering technique to gather information on a particular variable or variables from different informants in different localities (Donnelly et al. 1997).

Workshop Equipment

The following figures demonstrate the visual tools that were used during the workshops.

Figure 4: Historic Calendar (Climatic and Social Phenomena)

Figure 5: Matrix of Social Strata

Figure 6: Commercialization
In depth surveys

In order to estimate level or availability of capital stocks, 19 indicators with 80 questions were conducted from smallholders through semi-structured interviews. We did 120 surveys in Guatemala, 122 in Bogotá and 130 in Jamaica. Please find the full questionnaires on the data collection disk or see the Jamaican example in Annex I. As outlined above DFID sustainable livelihood capital forms were decomposed into subcategories or indicators. For each of these indicators and its indicating variables questions were designed to obtain information about the level of resilience to climate change. Answers to these questions were rank able on an ordinal scale from low to high resilience.

Figure 8: Sustainable Livelihood Resources and Indicators

Two examples will clarify this procedure: To assess physical capital “roads of access” is an indicator. Its measurable variable is the quality of roads, the better the roads the higher the resilience. An example from the assessment of natural capital is the indicator water. Among other questions it was assessed by the duration of sufficient water availability per year.

Figure 9: Students doing interviews of farmers in Jamaica

Questionnaires had to be designed in a rather open manner to allow for regional differences. This resulted in a need to codify results after field work. The questionnaire yielded two kinds of results: open answers and pre coded answers on a 1 to 5 basis. The open answers either related to numerical values such as farm size in hectares or to categorical values such as activities performed by organizations. All answers both open and pre-coded were ranked according to their deductive ability to provide
resilience to climate change. In a consecutive step results were grouped, where possible, such that on a one (low resilience) to three (high resilience) ordinary scale most answers would fall into the intermediate category. Questions that only allowed for yes or no answers were handled such that the resilient category has been assigned a “3” and the sensitive category a “1”. This approach was meant to ensure that the final results reflect local differences in resilience of individual farmers, rather than regions. Some regions for example have access to quite advanced systems of waste management in which case farmers who recycle were believed to be more resilient than farmers who simply burn trash. However, in other regions virtually no one recycles, hypothetically due to a general lack of infrastructure and knowledge. Here, a household that disposes of trash in an environmentally sound way, such as “storage in a closed room” was assigned a high resilience value, despite the comparatively lower indication of capital.

This codification on ordinal scale has been the initial step in the subsequent analyses, namely the vulnerability analysis, a cluster analysis and the construction of a vulnerability index. These analyses served to identify and compare vulnerability at three different levels:

The farm level vulnerability analysis served to research supply chain level vulnerability. Cluster analysis allowed assigning unique characteristics to vulnerable and resilient households. The vulnerability index in turn yielded a proxy that helped to compare differences between the focus regions.

Questionnaires furthermore contained questions that were intended to yield information about the motivation to adapt. For each indicator farmers were supposed to estimate the impact of climate change on this indicator. The underlying assumption is that if a respondent expects a high impact the willingness to adapt is higher.

Another aspect that was part of the empirical data collection was gender. Some questions specifically addressed the gender situation in the focus regions. Information about gender specific workload, capital access and knowledge has been gathered.

Details on this may be found in the report:

**Gender Report.** The impact of climate change on men and women

**Farm Level Vulnerability Analysis**

The core purpose of the survey exercise was to identify key vulnerabilities of supply chains at the farm level, the potential point of attack of climate change risks. This formed the base for subsequent research to assess the adaptive capacity along the entire supply chain and eventually the development of the framework for adaptation.

Based on the codification outlined above the following analyses were conducted: Diagrams were prepared on the basis of the mode of each capital form to identify vulnerabilities. Despite the problem that the modal value masks information it was chosen to yield a clear indicator of the state of capital forms. Thus, for each supply chain, municipality, gender group and country the modal value analysis yielded a tool to analyze vulnerability.

Diagrams were used as a tool of analysis. This served to facilitate stakeholder workshops to identify adaptation strategies. For each capital form an in depth discussion of results ensured that no information was missed and noticeable
indicators identified. These results further backed the stakeholder workshops.

Furthermore a cluster analysis was conducted to identify principal clusters of individuals that have common characteristics and to identify principal classifiers. This method searches for common patterns within a data set and generates a statistic that shows the proximity of relationships between clouds of individuals based on the variation. Additionally it allows graphing variables that added most to the variation to between groups. That way variables may be filtered that are commonly found in all groups with equal probability and variables that determine group differences may be further analyzed. This method has been used in addition to the vulnerability analysis to describe vulnerable households in terms of characteristics.

**Construction of a Vulnerability Index**

The IPCC definition of vulnerability as a function of exposure, sensitivity and adaptive capacity suggests the construction of an index. While “vulnerability” is not directly measurable, indices have proven to be valuable in comparing vulnerable groups (Hinkel 2011). We therefore constructed such an index in order to compare regions and households.

Our index is a function of direct climate change impacts, indirect sensitivity, adaptive capacity and the expected impact. Thus we incorporate the biophysical impact data, the sustainable livelihood analysis data and socio-cognitive data. With this approach we attempt to catch the complex concept “vulnerability” in a comprehensive way. First, the construction of our indicator will be presented before some important limitations of this approach are briefly discussed.

The above cited IPCC definition of vulnerability has often been interpreted as a function:

\[
Vulnerability = Exposure + Sensitivity - Adaptive Capacity
\]

However, this approach has been criticized for giving equal weights to a directly measurable but relatively meaningless phenomenon like “temperature change” and a hardly measurable but meaningful concept like “adaptive capacity”. We hope to address this disparity by applying two changes. We translate the exposure into direct impacts (but keep calling it “exposure”). Furthermore we complement the original resource oriented definition by a proxy for awareness. This way our index consists of a biophysical, a socio-economic and a cognitive element. Thus,

\[
Vulnerability index = Exposure + Sensitivity + Adaptive Capacity + Expected Impact
\]

All parts of this index are given equal weights. This is achieved by rescaling all data on a 1 to 3 ordinal scale. The resulting index therefore ranges from 4 to 12, where 4 is high
vulnerability and 12 high resilience. The rescaling was conducted as follows.

Exposure data for all three regions has been jointly analyzed and separated into three terciles of equal size. Unchanged suitability thus changed into a “2”, a negative change into “1” and positive changes where ranked as “3”.

The data from the sustainable livelihood assessment was treated as outlined above. However, in a subsequent step for each household a single indicator value for each sensitivity and adaptive capacity had to be derived. To do so, results of single questions were averaged over each indicator, i.e. if three questions related to water they were merged into a single indicator value “water”. All indicators were then averaged such that they constitute a value for each capital form. Last, the average over all capital forms constitutes the proxy for sensitivity and adaptive capacity of each household.

Data of expected impact was obtained as part of the household survey. The questions each related to the different indicators and capital forms. Respondents were asked whether they expect “no impact” to “strong impact” on a 0 to 5 scale. This data has been normalized such that the results reflect differences in individual perception and not differences between countries. Second, the data has been parted into terciles. I.e. if a respondent expects a small impact on average this was converted into a “1” and a household that expects a strong impact a “3”. The rationale is that a household that expects a strong impact is more willing to adapt.

See following two short stories as an example for our vulnerability index approach:

Figure 11: Vulnerability Index example: short story 1, female farmer in Sololá / Guatemala

Figure 12: Vulnerability Index example: short story 2, male farmer in Guasca / Colombia

The data has been subjected to analyses using the statistics software for social sciences SPSS V.17.0. In particular visual analyses, correlation analysis, multiple regression analysis, and t-Tests were conducted to identify relationships and differences between regions, households and capital forms.

From this analysis a couple of limitations to our index approach have to be derived. In particular two difficulties limited the applicability of the index results. One issue are the equal weights that we use to construct this index. This approach is chosen due to lack of alternative methods. The scientific literature mentions the possibility of assigning weights based on expert judgment, but such approaches have been
shown to be laborious and not necessarily successful. Sensitivity and Adaptive capacity are highly correlated most likely due to the assessment method. Thus, in our index the sustainable livelihood assessment implicitly has a higher weight as it is part of the index in its “indirect sensitivity” and “adaptive capacity” forms.

Another problem derives from the perception data. This data shows a high degree of variation and is not correlated with education, exposure or other possible variables. We therefore believe that a large share of respondents has not been able to give meaningful answers to our questions. Households largely lack knowledge about climate change and possible impacts. Thus, we limit our analysis to an overall average expected impact. We do not consider more detailed information, such as the expected impact on water resources. This way we can deduct the motivation of a household to adapt.

5. Step 3: Accounting for options of upstream supply chain actors

In order to analyze the option of upstream supply chain actors a process has been implemented that is based on three main steps: Value chain analysis, vulnerability assessment and evaluation of behavioral patterns. This process helps identify the characteristics of value chains which are affected by GCC impacts, their need to adapt to a new situation and important adaptive capacities to respond to the threat. To quantify possible options to mitigate future climate impact a life cycle based carbon footprint of a set of products has been conducted during the fieldwork and compared with general data from literature by Soil&More. Together with Cropster, a second external company, a internet based carbon footprint platform were developed.

Note: The methodologies described here either involved a complex Meta-Analysis of the data that was generated with the aforementioned methods, or have been done externally. Please refer to the accompanying reports for further descriptions of the methods applied and their approaches.

Adaptation Framework. Adaptation of Food Supply Chains to the Impacts of Progressively Changing Climate

Soil&More Methodology. Internet Based Carbon Footprint Calculation Methodology

Supply Chain Analysis and Supply Chain level Vulnerability Assessment

Food supply chains are complex constructs, difficult to address as a whole. A wide variety of people and entities coming from different social strata, intend to create value through a multitude of processes. These actors pursue individual objectives, face particular problems, and exploit diverse resources to finally satisfy customers’ needs. The interaction and interdependence of these elements determines to a significant degree the way the system responds to a common threat.

In order to gain insights in the characteristics and to assess chain-inclusive adaptive capacities of the supply chains that are the focus of this study, we conducted semi-structured interviews with experts of each supply system, respectively. A total of eleven open interviews with exporters, sourcing managers, representatives of NGOs and public institutions,
tradesmen, wholesalers and public relation officers were necessary to disclose required information. The interviews aimed at gaining insights in the structures and dynamics of the supply chains, power and relationships of stakeholders and resilience patterns along the system. Additionally, the information from the 24 participatory workshops (8 in each study site) with stakeholders and observations during fieldwork proved to be indispensable complements to these topics.

Adaptation Framework. Adaptation of Food Supply Chains to the Impacts of Progressively Changing Climate

Behavioral Assessment

The evaluation of behavioral patterns followed the same methodology as supply chain analysis. In semi-structured interviews, key stakeholders provided information about action cycles in value creation process, how supply chain actors relate to each other and revealed adaptive behaviors along the value chain. Fieldwork observations confirmed or undermined these insights.

Adaptation Framework. Adaptation of Food Supply Chains to the Impacts of Progressively Changing Climate

Carbon footprints

The IPCC classifies carbon footprint assessment methods according to their complexity. The methodology used here represents a Tier II approach. Tier II methods are process specific models based on empirical data. Tier I approaches are unspecific emission factor based calculations; Tier III approaches are highly complex process based simulation models. Thus, Tier II methods represent a feasible combination of complexity and data needs.

In a cooperation of Soil and More, Cropster and the Sustainable Food Laboratory the original Microsoft Excel based “Cool Farm Tool” (Hillier et al. 2011) has been adapted and implemented as an internet based carbon footprint platform. It is specially designed for farm based production and marketing systems.

The platform assesses the carbon footprint starting at the input use at farm level and ends with the transport to the point of sale. For all stages direct and indirect emissions are included in the analysis. At the farming stage emissions result from machinery fuel use, fertilizer use and transport to the next stage. Processing causes emissions mainly due to machinery use or indirect emissions from packaging material. Transport emissions to the point of sale are included based on statistics about means and distance of transport. The method has two major drawbacks. One stems from a lack of methodological knowledge concerning the assessment of Land Use Change emissions and the other from the need to develop a broadly applicable platform. Land Use Change contributes largely to GHG emissions in agriculture but currently no widely accepted assessment method exists. The latter means that certain processing cycles and specialized production processes may not be represented in all detail.

For further information on the methodology of carbon footprint assessments, please refer to the report as provided by Soil&More. See also the developed internet based carbon footprint platform of Cropster:

http://carbon.cropster.org/
Soil&More Methodology. Internet Based Carbon Footprint Calculation Methodology

6. Possible adaptation strategies

After analyzing collected data during the first field work phase we went back to the region and communities and presented preliminary results of vulnerability to farmers and supply-chain actors. We then asked them to think about what could be done and what adaptation and mitigation strategies they had in mind. We formed groups and separated farmers from supply-chain actors and instructed them to do a brainstorming and write down all the ideas that came to mind. In the second step, the possible adaptation and mitigation strategies were sorted and classified and the three most important ones were identified and selected by the groups. After presenting the three most important strategies of each group in the auditorium, the main ideas were discussed and a consensus reached among all the participants as to what were the three most important adaptation and mitigation strategies. The strategies that were deemed to be of the highest priority were selected as the three main strategies from each workshop.

7. Step 4: Deriving a framework with response pathways

The derivation of a framework with response pathways has been the integrating goal of this study. The framework is the result of all previous research steps and incorporates its findings and experiences. Its complete methodology is best described in the accompanying separate Framework Report.

In brief the approach is as follows: The overall supply chain level had to be examined, i.e. a characterization of GCC influence on the people and processes in food related value creation systems. In a first phase, however, the focus of our research was set on producers. Forming the base of the supply chain, regional and site-specific assessment of GCC impacts on rural livelihoods and small-holders already gives a helpful idea about further implications for the food chain which depends on the growers. This initial assessment has been conducted using the above outlined methodology for a detailed vulnerability analysis.

The producers’ vulnerability to climate change is a stress external to the downstream food supply chain. Using the above outlined qualitative methods, during the second phase it has been assessed how the chain would react under external pressure. It proved to be substantial to outline the nature of the organism supply chain. Overall and partial objectives of stakeholders, their setup and power dependencies, business focus, distribution of assets and availability of structures and many other indicators gave hints about the resilience of food supply chains under pressure of climate change impacts.

The approach to build upon the information from farm to overall value chain level using a range of quantitative and qualitative tools has emerged to be very effective in generating multi-faceted ideas to develop the concept for the supply chain adaptation framework.

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8. Summary and further outlook

To systematically address the challenge of climate change regarding farmers’ livelihoods and supply chains we analyzed three concrete examples of Oxfam ongoing projects in Guatemala, Colombia and Jamaica.

The overarching goal of the study has been to develop a framework that allows practitioners to robustly assess vulnerabilities to food supply chains in order to design effective adaptation measures.

We postulated that climate change risks attack at the bottom of the supply chain, the producers. Therefore we started off with a careful assessment of climate related stresses and risks to crop production. State-of-the-art ecological niche modeling was applied to project key changes to production conditions. Additionally the indirect sensitivity as well as the adaptive capacity of producers has been assessed using a sustainable livelihood approach. Based on expert knowledge and research experience a questionnaire has been designed and used to identify key weaknesses of the actors that are most exposed to climate change: smallholder farmers.

In our methodology we used the commonly IPCC definition of vulnerability and applied two changes to open out a biophysical, a socio-economic and a cognitive element to derive a so called Vulnerability Index.

For each region initial results, analyzed after conducted baseline data throughout workshops and surveys in the region, served as a base for discussions at stakeholder and farmer workshops in the second phase of our field work. This way feasible adaptation strategies could be derived in a participatory manner. In parallel, qualitative methods were used to analyze the structure and dynamics of local supply chains.

Throughout all steps experience and feedback have been used to develop and adjust the framework for supply chain inclusive adaptation. The framework incorporates methodologies and analyses from the fields of business, climatology, geography and sociology. Independently from scale, crop and site outlined chain-inclusive adaptation framework facilitates both to respond effectively to GCC and help locate and patch resilience gaps throughout the system.

Doubtless, for the next step to implement adaptation framework on a local level and to convince policy makers for effective decisions, further actions are needed. We propose to apply adaptation strategies first on a small scale by starting with pilot areas and get political attention by ongoing campaigns. This small pilot best adaptation practice cases feed the continuing research process on developing adaptation strategies for progressive climate change and serve to share monitored implementation and knowledge for sites with similar vulnerability index.

9. References


I. GENERAL FAMILY INFORMATION

Name of homeowner ______________________________________________

Civil status Married In a relationship Single (a) Other _______________

Number of children men ______ women________ age ________________

Possession of household assets

Size of farm(Ha)_________Own (%)______Renting(%)_____Other(%)_______________

Location of the farm municipality _____________________Community ______________

II. INDICATORS OF SENSITIVITY AND CAPACITY OF ADAPTATION TO PHYSICAL CAPITAL

Indicator 1: Routes of Access (Quality and distance)

1. Does climate change affect your routes of access? (with regard to all family members)

   0 Not at all   1 Little   2 more or less   3 yes   4 Quite alot   5 Very much so

2. How many hours does it take you to get from your farm to the collection centre?

   0. Does not apply
   1. More than 6 hours
   2. 4 to 6 hours
   3. 2-4 hours
   4. 1-2 hours
   5. Less than one hour

3. What are the roads like from your farm to the collection centre?

   0. Does not apply
   1. Sidewalks, mainly used by horse
   2. Gauge
   3. Fair
   5. Well paved

Indicator 2: Transport of products and other (type and availability)

4. Does climate change affect the transportation of your products? (with regard to all family members)

   0 Not at all   1 Little   2 more or less   3 yes   4 Quite alot   5 Very much so

5. How do you transport your products to the collection centre?

   0. Doesn’t apply
   1. By Man/ use of animals
   2. Road
   3. Truck (owned)
   4. Truck (rented)

Indicator 3: Quality of accommodation

6. Does climate change affect the structure of your accommodation? (with regard to all family members)

   0 Not at all   1 Little   2 more or less   3 yes   4 Quite alot   5 Very much so

7. What material is your home built up?

   1. Does not apply
   2. Wood and Straw and/or Adobe and Straw
   3. Wood and tile

8. Do you have water, electricity and sewerage?
   0. Does not apply
   1. None
   2. Only water
   3. We have water and latrines
   4. We have water, electricity and latrines
   5. We have water, electricity, sanitation and sewage

III. INDICATORS OF SENSITIVITY TO NATURAL CAPITAL

Indicator 4: Access and availability of water

9. Has climate change affected your Access to or the availability of water? (with regard to all family members)
   0. Not at all
   1. Little
   2. More or less
   3. Yes
   4. Quite a lot
   5. Very much so

10. Where does the water come from for your consumption and/or agriculture
    Top ___ Middle ___ lower ___ from the basin
    Well ____ Filtration ____ River ____ Ravine ____ Other ____

11. How far do you have to travel to obtain water?
    0. Does not apply
    1. More than 100m but less than 500m
    2. More than 50m but less than 100m
    3. None

12. Do you have water all year round? Yes__ No__
    1. Almost never we have sufficient water
    2. We have sufficient water 3 months in the year
    3. We have sufficient water 6 months in the year
    4. We have sufficient water all year round
    5. We have plenty of water all year round

13. Who is responsible for getting the water
    Husband_____ Wife _____ Son_____ daughter_____ Sons_____ Daughters ______Todos_____

14. The water for your consumption is drinkable? Yes__ No__
    0. No
    1. Very bad quality
    2. Bad quality
    3. Normal quality
    4. Good quality
    5. Very good quality

15. Who is responsible for the regulation of water in your community and the opening of new networks of water?

Indicator 5: Contamination

16. To what extent does climate change contaminate your environment? (With regard to all family members)
    0. Not at all
    1. Little
    2. More or less
    3. Yes
    4. Quite a lot
    5. Very much so

17. What do you do with the house waste?
    0. Does not apply
    1. I don’t know of any waste management, I dispose of it in the streams or open fields
2. I know of waste management, I only collect and bury it
3. I know of waste management, separate plastics, glass, metals, other
4. I know of waste management, separating, recycling and compost
5. I do all of the previous and also prepare farm manure

18. What do you do with the stubble of the crops?
   0. Does not apply
   1. Dispose of them
   2. Leave them to decompose in the ground?
   3. Prepare manure for the farm.
   4. Others (specify)

19. What do you do with containers of chemicals, fertilizers, bags and others, after use?

20. What do you do with the left over chemicals after application?

21. How many crops are burned each year, in order to sow crops? Area strings?

**Indicator 6: Conservation**

22. Does climate change affect the conservation of your natural resources? *(With regard to all family members)*
   
   0 Not at all    1 little    2 more or less    3 yes    4 Quite alot    5 Very much so

23. What area of forest is preserved on your farm? Area_________ Mz

24. Does climate change adversely affect natural resources? Yes_______ No_______

25. What type of practices are there in order to protect implements? Hedgerows_____ Wind break curtains_____ Ditches_______ Others_____

**Indicator 7: Soil conditions and fertility**

26. Do the affects of climate change affect the fertility of soil in your farm? *(With regard to all family members)*
   
   0 Not at all    1 little    2 more or less    3 yes    4 Quite alot    5 Very much so

27. Do you consider the soils on your farm to be fertile? Yes_______ No_______ One Part_____

28. Are there areas of soil in your farm that erode or wash away in winter? Yes_______ No_____

29. Information about the soil and its fertility

<table>
<thead>
<tr>
<th>Area (Mz)</th>
<th>Type of soil</th>
<th>Topography of ground</th>
<th>Crop residue cover (litter, ...)</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

**Topography: flat, inclined, leaning semi**

30. Do you implement crop rotation? Yes/No

31. How often do you do it and how much time does it take (Annually frequency, months)

**IV Adaptive capacity indicators for human capital**
Indicator 8. Access to formal and informal education

32. Does climate change affect the education of your family? (With regard to all family members)
0 Not at all  1 Little  2 more or less  3 yes  4 Quite alot  5 Very much so

33. You have Access to the education? yes_____ No_____

34. Levels of education (for age): a) ____________ b) ____________
c) ____________ d) ____________ e) ____________ f) ____________
g) ____________ h) ____________ i) ____________ j) ____________

35. Have you received technical assistance? Yes___ No_____
   Why? ____________________________________________________________

36. How did you find the technical assistance?
   0. Does not apply
   1. Poor
   2. Average
   3. Good
   4. Very Good
   5. Excellent
   Why? ____________________________________________________________

37. For what product cultivation do you receive technical assistance?
   ________________________________________________________________

38. What have you learnt through technical assistance?
   ________________________________________________________________

39. Have you applied what you have learned? Yes_____ No_____ As applied?
   ________________________________________________________________

40. Have you received capacity assistance in farming systems? Yes (How many days in the year)_____ No_____

41. Have you received capacitation assistance in marketing? Yes (How many days in the year) No_____

42. Do you have the help of family assistance workers? Yes (How many) ______ NO____

Indicator 9. Level of knowledge of farming systems management

43. Climate change effects the management of his production systems? (With regard to all family members)
   0 Not at all  1 Little  2 more or less  3 yes  4 Quite alot  5 Very much so

44. Are you developing plans of sowing? Yes_____ No_____  

45. Do you keep records of the farm? Yes_____ No_____ What have you recorded?
   0 Nothing
   1 Only labor
   2 Labor and inputs
   3 Labor, inputs and services

47. Who is responsible for keeping records?
   Husband___ Wife___ Son___ Daughter___ Other___

48. How do you respond with your crops when there are pests and diseases as a result of climate change?
Why ________________________________________________________________

49. What practices/approaches do you adopt to control the outbreaks and plagues amongst crops?

   __________________________________________________________________________

Indicator 10. Health and feeding

50. Does climate change affect the feeding of your family? (With regard to the whole family)
   0 Not at all  1 little  2 more or less  3 yes  4 Quite alot  5 Very much so

51. How do these climate changes affect the feeding of you and your family?
   __________________________________________________________________________
   __________________________________________________________________________

52. Is the production of your farm enough to cover the food needs of you and your family? _____
   Comment _________________________________________________________________

53. From what your family consumes, how much produce is bought and how much produce is produced on the farm?
   0 Not applied
   1 Everything bought
   2 80% bought and 20% produced
   3 Half bought and half produced
   4 20% bought and 80% produced
   5 We buy almost nothing

V Indicators for adaptive capacity for social capital

Indicator 11. Organization

54. Does climate change affect organisations in which you participate? (V. f.)
   0 Not at all  1 Little  2 more or less  3 yes  4 Quite alot  5 Very much so

55. What organisations work in your community, what activities do they do? How long have they worked in the area? Do you feel their work has produced results?

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of organización</th>
<th>Activities that have been performed</th>
<th>Time (Year)</th>
<th>Achievements</th>
</tr>
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</table>
56. In what organisations do you and your family participate?

57. What have the organisations received?
   - Technical assistance
   - Credit
   - Capacitation
   - Information
   - Others

58. Since when have they participated in the organisation? Time in years

59. What members of your family have participated in the organisation?
   - Husband
   - Wife
   - Son
   - Daughter
   - All

Indicator 12: General (Take decisions, Work distribution)

60. How much free time do you and your family have? Men (time in hours)
    Women (time in hours)

61. How do you distribute the work between men and women?
   1. 
   2. 
   3. 

VI Indicators or sensibility and adaptive capacity to factors of financial capital

Indicator 13: Credit Access

62. Have much have climate changes affected your access to credit? (with regard to the whole family)
   0  Not at all  1 Little  2 more or less  3 yes  4 Quite alot  5 Very much so

63. Do you have credit access? Yes  No  Body

64. Which of these is the type of credit you receive? In kind  effective  other

65. Time to repay credit? 3 Months  6 Months  1 Year  1-3 days

66. What is the interest rate?
   - Más de 40%
   - 40-20%
   - 20-18%
   - 15-10%
   - Less than 10%

67. What do they request as a form of guarantee?
   - Mortgages
   - Agrarian Pledge
   - Production

Indicator 14. Variability of annual production

68. Do climate changes affect the annual production of your cultivations? (with regard to the whole family)
   0  Not at all  1 Little  2 more or less  3 yes  4 Quite alot  5 Very much so

69. What yield did you have for your crop production between the years 2006-2010, what were there sales prices?

<table>
<thead>
<tr>
<th>Cultivos</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>R qq/He</th>
<th>P/V</th>
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</table>

Indicator 15. Price Variability, Includes indicator 18 and national statistics

70. How often (years) is there a fall in the production rate?

71. Do weather changes affect the sales prices of your crops? (with regard to the whole family)
Indicator 16 y 17. Variability in annual revenue and income diversification

72. Does climate change affect your annual earnings? (with regard to the whole family)

0 Not at all 1 Little 2 more or less 3 yes 4 Quite alot 5 Very much so

73. What is your income? (en quetzales)

<table>
<thead>
<tr>
<th>Ingresos</th>
<th>Años</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2007</td>
</tr>
<tr>
<td></td>
<td>2008</td>
</tr>
<tr>
<td></td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>2010</td>
</tr>
</tbody>
</table>

74. Does climate change affect your income diversification? (with regard to the whole family)

0 Not at all 1 Little 2 more or less 3 yes 4 Quite alot 5 Very much so

Indicator 18. Access to market niches

75. Does climate change affect your access to market niches? (with regard to the whole family)

0 Not at all 1 Little 2 more or less 3 yes 4 Quite alot 5 Very much so

76. Who do you sell your products to? _________________________

77. Do you sell your products with any certification? ________________________________

78. Does climate change cause variation in the quality of your products? Yes ___ No ___

Comment________________________________________________________________________

Indicator 19. Access to alternative technology

79. Does climate change affect your access to alternative technology? (with regard to the whole family)

0 Not at all 1 Little 2 more or less 3 yes 4 Quite alot 5 Very much so

80. ¿Do you have Access to information on other crops, according to the weather conditions in your region? Yes ___ No ___

VII PRODUCTION COSTS FOR THE CULTIVATION OF:

<table>
<thead>
<tr>
<th>Cuadro 01. . Production costs for 1 mz of anual cultivation in quezales</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>Unit</td>
</tr>
<tr>
<td>Preparation of terrain</td>
<td>Wage</td>
</tr>
<tr>
<td>Sowing</td>
<td>Wage</td>
</tr>
<tr>
<td>Weeding</td>
<td>Wage</td>
</tr>
<tr>
<td>Fertilisation</td>
<td>Wage</td>
</tr>
<tr>
<td>Harvest</td>
<td>Wage</td>
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</table>
### Various Wage

<table>
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<tr>
<th>Sub Total</th>
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<tbody>
<tr>
<td>Input/Crop established</td>
</tr>
<tr>
<td>Seed Lbs</td>
</tr>
<tr>
<td>Fertilisers Lbs</td>
</tr>
<tr>
<td>Foliar Litros</td>
</tr>
<tr>
<td>Insecticides Litros</td>
</tr>
<tr>
<td>Fungicides Various</td>
</tr>
<tr>
<td>Materials y tools Various</td>
</tr>
</tbody>
</table>

| Service/crop established |
| Value of land use Mz |
| Transport market Qq |
| Contingencies Quezales |

| Total direct costs |

**Elaboration of objectives:**

*What are the major objectives you wish to accomplish as a small holder farmer?* *(Preguntar con respecto a los indicadores, respuesta abierta)*

**Comment:**

**Elaboration of risks:**

*What are the major risks you possibly will be facing in the future? Please, select the 5 major risks according to their priority referring to the urgency to solve the problem (1 =highest; 5 =lowest).*

- [ ] Routes of Access (Quality and distance)
- [ ] Transport of products and other (type and availability)
- [ ] Quality of accommodation
- [ ] Access and availability of water
- [ ] Contamination
- [ ] Conservation
- [ ] Soil conditions and fertility
- [ ] Access to formal and informal education
- [ ] Level of knowledge of farming systems management
- [ ] Health and feeding
Organisation

Gender (Take decisions, Work distribution)

Credit Access

Variability of annual production

Price Variability, Includes indicator “niche markets” and national statistics)

Variability in annual revenue and income diversification

Access to market niches

Access to alternative technology

Production costs of goods

Please, indicate the probability (subjective) for the above mentioned risks/problems to become reality:

Risk/priority no.:
1) O very improbable O improbable O possible O probable O very probable
2) O very improbable O improbable O possible O probable O very probable
3) O very improbable O improbable O possible O probable O very probable
4) O very improbable O improbable O possible O probable O very probable
5) O very improbable O improbable O possible O probable O very probable

Please, indicate the weightiness of the consequences imposed by above mentioned risks:

Risk/priority no.:
1) O very low O low O moderate O high O very high
2) O very low O low O moderate O high O very high
3) O very low O low O moderate O high O very high
4) O very low O low O moderate O high O very high
5) O very low O low O moderate O high O very high

Please, indicate possible solutions/alternatives for the above mentioned risks:

1)__________________________________________________________
2)__________________________________________________________
3)__________________________________________________________
4)__________________________________________________________
5)__________________________________________________________

Could you imagine that collaboration/cooperation with other participants of the supply chain could mitigate these risks?

YES_______ NO______

In which way/why not?

____________________________________________________________________________________

____________________________________________________________________________________