Bridging the gap between climate science and development practice

FIC/IEH Methodology for analyzing climate change impacts on productive systems and value chains

Climate model simulations are essential elements of any adaptation strategy, as they make better planning possible through the anticipation of future impacts. However, efforts are currently scattered and not many institutions are systematically applying climate modelling to productive systems. The impact of increasing climate variability and more frequent extreme weather events on agriculture, livestock, fisheries, agribusiness and food value chains is unknown in most regions of the world, making the recommendation of viable, practical adaptation paths even harder.

The Climate Research Foundation (Fundación para la Investigación del Clima, FIC) and the Institute for Hunger Studies (Instituto de Estudios del Hambre, IEH) have been working since 2009 on the application of robust climate simulation to enhance food security in rural areas in Central American and Central Asian countries. They have developed an innovative methodology designed to analyze climate change impacts on productive systems in order to make recommendations for strengthening the resilience of vulnerable populations. This methodology is based on the adaptation and application of a robust downscaling tool, which has been shown to obtain excellent results in generating local climate change scenarios and analyzing their impact on productive systems.

This methodology has been already applied in development programmes funded by the European Commission, IFAD (International Fund for Agriculture Development) and bilateral donors. These programmes aimed at analysing the impact of climate change on sustainable livelihoods, agriculture productive systems and food value chains, and the conclusions and recommendations drawn through the use of this methodology have been highly regarded.

FIC – IEH Methodology

The methodology developed by FIC and IEH has very innovative aspects, such as the capacity for translating climate "scientific language" into the language used by experts and smallholder farmers/fisherfolk. On the one hand, it fulfils the necessary requirements for the robust generation of climate change scenarios using the most advanced climatic projections and downscaling methodologies. On the other hand, it uses a participatory approach, involving experts and smallholder farmers in the processes of defining the elements vulnerable to climate change and the formulation of indicators that will assess how climate change will influence a particular productive system or value chain.

The methodological process applied is based on three actions needed to address climate change adaptation:

1. Description of potential future climate conditions;
2. Evaluation of how this future climate will influence productive systems or value chains;
3. Recommendation of what to do to minimize the adverse impacts identified (and to take advantage of the positive ones), including effective measures of adaptation to the future climate.

These stages must be developed on a local scale because many of the adaptation interventions need to be defined at that level.

About FIC

The Climate Research Foundation (Fundación para la Investigación del Clima, FIC) is an independent non-profit organization founded in Spain in 1996. Its purpose is to improve adaptation to climate change through research and capacity building.

FIC's activities have been focused on future climate simulation; the assessment of future climate influence on several sectors (agriculture/ food security, biodiversity, hydrology ...) in collaboration with experts from each sector; the communication of research results; and capacity building. After almost 20 years of research, FIC developed one of the most powerful statistical downscaling tools for generating local climate scenarios: FICLIMA.

About IEH

The Institute for Hunger Studies (Instituto de Estudios del Hambre, IEH) is also a non-profit, independent organization. It was founded in Spain in 2001 and its purpose is to fight hunger and improve the food security and nutrition situation in developing countries.

IEH's main activities aim at providing support to governments, public and private institutions and civil society organizations through research, training and technical assistance in developing their hunger eradication policies and strategies.

IEH recognizes the negative impact of climate change on the food security situation of vulnerable populations. For this reason it has established a partnership with FIC for undertaking vulnerability studies aimed at generating climate scenarios, analyzing the effects of climate change and making recommendations on adaptation strategies.

Four key steps

The methodology applies the following steps:

1. **Generation of local future climate scenarios for the project area**
2. **Mapping the productive system or value chain and identifying the "critical elements" particularly vulnerable to climatic events**
3. **Analysis of the vulnerability of each of the critical elements identified and the effects of future climate on them**
4. **Making recommendations regarding each of the critical elements to minimize negative impacts and reinforce positive ones**

STEP 1: Generating local future scenarios for the project area

Many "adaptation projects" define adaptation recommendations without addressing "what climate we need to adapt to", i.e., without properly defining the future climate. The FIC/IEH methodology puts a lot of emphasis on the production and use of technically robust and reliable future climate simulations. However, before producing those simulations, we need to pay attention to the technical requirements they need to fulfil for adaptation purposes:

a) Use of the most recent Climate Models

Climate Models are renewed and improved continuously, and a new version usually appears every 4 to 6 years and is used for the corresponding IPCC-AR (Intergovernmental Panel on Climate Change Assessment Report). It is very important to use the most recent CMs to ensure the most robust future climate simulations possible.

b) Need of future projections on a daily scale

Daily series are needed to explain many essential climate features. For example, the precipitation and temperature distribution within a month (number of consecutive days without precipitation, maximum accumulated precipitation over five days, maximum precipitation in 24 hours... or the effect of several consecutive days of extreme temperatures on health or agriculture, for example.) These factors affect specific characteristics of the productive systems. Daily series are also necessary for running many impact assessment models: hydrology, agriculture and food security, phyto-climatology, etc.

c) Need of future projections with local resolution

The causes of climate change are global (greenhouse gas emissions all over the planet), but the consequences will be local: the future climate will bring changes with regard to the present climate that will be very different for locations very close to one another, depending on topographical influences. Also, local information about future climate is required for many adaptation activities; for example, to determine the variety of coffee to be planted in a particular place.

Despite being the most powerful tools available today for the simulation of future climate, Climate Models (CM) are not able to represent local climate details. To solve this problem, "downscaling" techniques have been developed. These techniques obtain the local-scale surface effects (precipitation, temperature) required for impact assessment and the adaptation of the valuable information provided by the CMs (low-resolution atmospheric configurations).

FIC-IEH methodology uses the latest Climate Models

The most recent CMs available are those of CMIP5 (Coupled Model Intercomparison Project Phase 5), and their results are used for IPCC AR5. One of the main new features introduced by CMIP5 has to do with the CMs: most of them are Earth System Models (ESM), a new generation of CMs. Another important new feature is the way future radiative forcing (which depends on society's evolution) is taken into consideration: the traditionally-used GHG emission scenarios (A2, B1, A1B...) have been replaced by so-called Representative Concentration Pathways (RCPs), which introduce relevant differences.

Studies using scenarios obtained with previous models will be probably considered obsolete in the near future. For all these reasons, CMIP5 CMs are used in FIC-IEH methodology.

Some downscaling tools provide information with local detail, but it is often a simple interpolation or redistribution of the data provided by the CMs. The use of more sophisticated downscaling methods is required to ensure reliable local simulations that take topographical influences into account.

d) Handling of uncertainties

The quantification of the uncertainties inherent in any climatic simulation is one of the areas upon which the scientific community is focusing significant efforts. To assess these uncertainties, CMs and RCPs should be used as much as possible to obtain future projections.

Uncertainty quantification also has to be done on a local scale: future climate simulations of different locations can have different uncertainties, due to topographical influences. The more similar the projections obtained from different CMs and RCPs are for a particular location, the fewer climate simulation uncertainties there are for that location.

The FICLIMA downscaling technique

Statistical downscaling techniques consist of establishing relationships between large-scale atmospheric fields (predictors) and high-resolution surface variables such as temperature and precipitation (predictands). The scenarios are built applying those relationships to the outputs (simulations of the predictors for the future) provided by CMs.

FIC-IEH methodology uses the 'FICLIMA' downscaling technique, developed by FIC, which has been successfully verified in several national and international projects. FICLIMA has been used to produce official local scenarios for the Spanish National Programme on Adaptation to Climate Change, and has been adapted and applied in other regions of the world.

The FICLIMA technique and its application to climate change impact studies comply with the previously explained requirements: FICLIMA uses the newest Climate Models from CMIP5; it works on a daily scale and uses daily series of maximum and minimum temperatures, precipitation and other variables for each CM/RCP projection; it uses local information from observatories and/or available grid points; uncertainties are considered and quantified by means of downscaling as many projections as possible (several CMs with several RCPs each); and detailed verification and validation processes are undertaken for each variable, observatory or grid point and CM (see Figures 1 and 2).

After the verification and validation procedures, local future climate scenarios are produced by applying the downscaling technique to each of the projections available (one projection for each CM under each RCP). Figure 3 shows the temperature and precipitation changes obtained in a particular study, as an average of different stations, for several CMs and RCPs. This gives an idea of the overall change but, as has been emphasized before, FIC/IEH methodology is applied on a local scale because very different changes appear at different points.

More details about FICLIMA downscaling technique can be found at:
www.ficlima.org/FICLIMA-statistical-downscaling-methodology.pdf

To work appropriately with uncertainties, rather than managing them initially to build a single "future" (for example, doing a weighted average of all the future projections), it is recommendable to select multiple "futures" and work with all of them to assess impacts.

<u>e) Full verification and validation studies must be performed</u>

Before producing future simulations, the downscaling tools need to be verified, and the CMs validated.

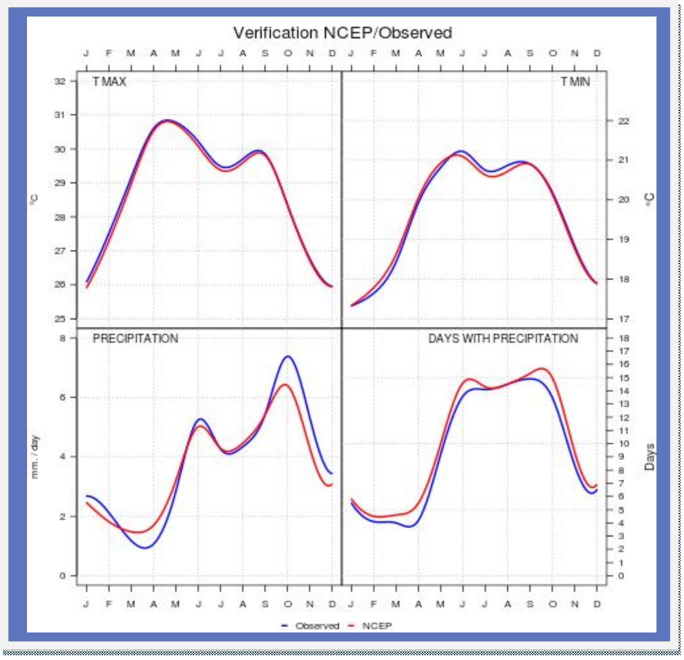
Verification procedures make it possible to assess whether the downscaling tool is able to "translate" low resolution atmospheric information (called "predictors") into high resolution surface effects (precipitation, temperature, etc, called "predictands"). The downscaling tool is applied to predictor observations, and the simulation thus obtained is compared to predictand observations. Verification must not only take averages into account, but also extreme values and other climatic characteristics.

Once the downscaling method has been successfully verified, the validation process makes it possible to assess whether a CM predictor simulation resembles the atmospheric configurations of that area. The downscaling tool is applied to the control run provided by each CM for the recent past (for example, 1960-2000), and this simulation is compared to observed climate.

Again, verification and validation have to be performed and analysed on a local scale: verification results for a given downscaling tool and validation results for a particular CM can be very different for points quite near each other. Local verification and validation results provide a lot of useful information for uncertainty quantification and for subsequently making suitable use of the scenarios.

These systematic, rigorous verification and validation procedures for all the downscaling tools and all the CMs available make it possible to identify the strengths and weaknesses of the different tools and CMs and seek complementarities between them.

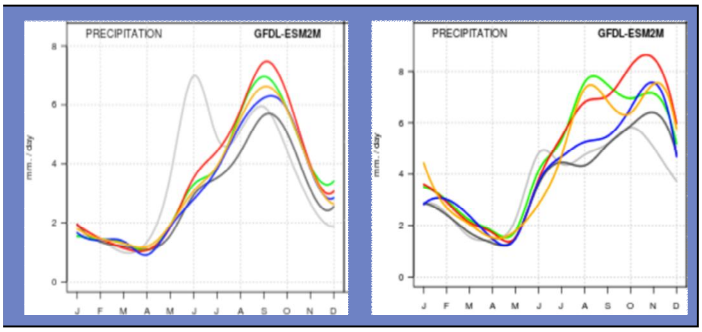
Figure 1.



Results of the verification process for temperature and precipitation for the period 1951-2011 in the IFAD Northern Horizons Project
Top graphics represent monthly averages of maximum and minimum temperatures for all the stations studied, and bottom graphics represent precipitation (observed data in blue and simulations obtained downscaling predictands observations in red). In both cases the results of the verification process are accurate and satisfactory.

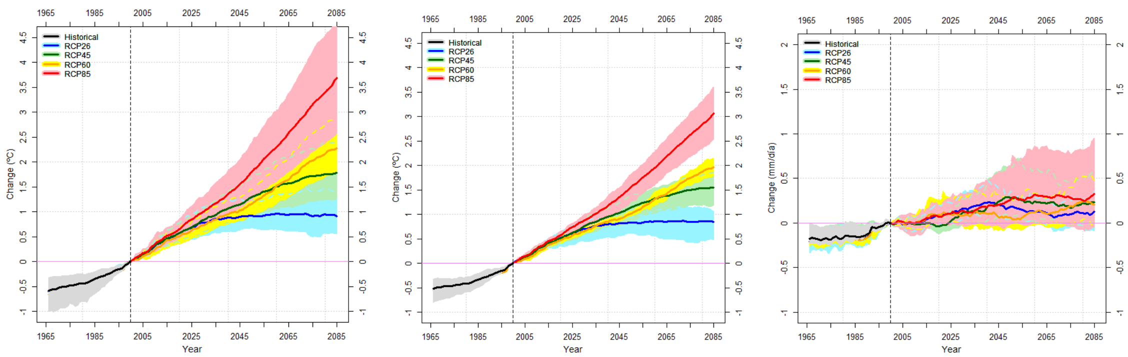
Figure 2.

Validation results of the GFDL-ESM2M Climate Model (USA) for precipitation in two stations of the IFAD Northern Horizons Project
The light grey curve corresponds to the observed annual precipitation cycle, and the dark grey to the simulation obtained by downscaling the CM control run. In Santa Rosa de Copán (left), where there is a clear relative summer drought ("canícula"), this CM is not useful because it does not reproduce this important climatic event. In San Pedro Sula (right), which doesn't have a clear canícula, validation results are fairly good, and this CM can be used to produce scenarios.



Verification and validation results have to be analysed on a local scale. Colour curves in Figure 2 represent projections for 2041-2070 under different RCPs (**future projections are also different for different points.**)

Figure 3.

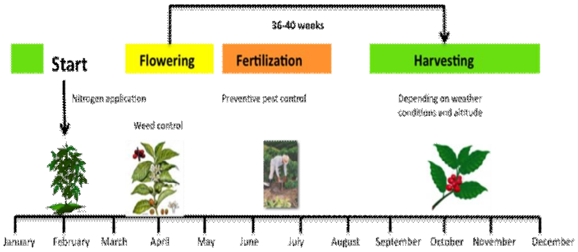


Changes in annual mean maximum temperature, minimum temperature and daily precipitation expected throughout the 21st century (30-year moving averages) in the IFAD Northern Horizons Project. Thick lines represent the average for all the stations and Climate Models. Shaded areas represent the interval between the 5th and 95th percentiles. Temperature changes in °C. Precipitation changes in mm/day. It is expected that maximum and minimum temperatures will increase gradually over the entire century for all emission scenarios. For mid-century, maximum temperatures are expected to increase up to 2ºC in the most extreme RCP, while expected increases for minimum temperatures are a bit lower. Precipitation is expected to increase slightly over the whole century, reaching values of about 0.25 mm/day (approximately 90 mm/year, a bit less than 10%) by mid century.

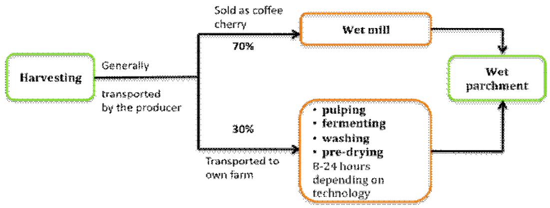
STEP 2: Mapping the productive system or value chain and identifying the "critical elements" particularly vulnerable to climatic events

The productive system or value chain is the subject of the analysis. Therefore, it is mapped in order to obtain the information necessary for the analysis. Mapping includes information on different stages, scheduling, the crop situation in the project area and the main actors involved in the different stages of the productive system or chain and their interrelations.

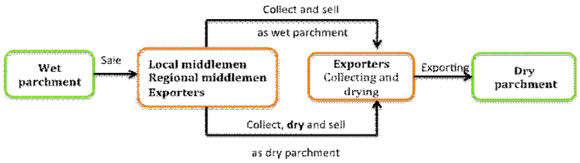
This exercise starts with meetings with the most relevant national institutions related to the productive system/value chain and climate change issues in order to identify the primary sources of information and present their views on the methodology. The first step is to carry out interviews with technical staff and organisations from each sector in the areas of interest and consult secondary sources in order to map the workings of each productive system/value chain as completely as possible.



Schedule of the coffee production cycle in Northern Honduras



Parchment coffee production routes in Northern Honduras



Collecting and drying in Northern Honduras

Example of two critical coffee value chain elements in the IFAD Northern Horizons Project

The coffee value chain was divided into the following phases in order to identify its critical elements: flowering, ripening, harvest and post-harvest.

In the flowering stage, the main critical element identified was **"the process of flowering induction"**. The onset of flowering is important because it affects the subsequent phases in the chain. If flowering takes place earlier or later, the subsequent phases will also occur earlier or later, and at those times they may lack the temperature and rainfall conditions necessary for proper development. On the other hand, a delay in flowering may also mean later harvesting, with the consequent impact on the coffee price received by the grower.

In the ripening stage, the main critical element identified was ***"the level of vulnerability to pests and diseases".*** During ripening, the plant is vulnerable to pests and diseases that reduce the amount and quality of beans and force the grower to allocate resources in order to combat them. Excessive humidity along with high temperatures favours the emergence and proliferation of fungi, such as rust. Moreover, if the temperature is not low enough during the coldest months (November to January in Honduras), vulnerability to diseases also increases.

After describing the productive system/value chain components and how they work, the "critical elements" most vulnerable to climatic events are identified. A critical element is any aspect of the productive system or value chain that may eventually have a significant impact on product quantity or quality, and which is particularly sensitive or vulnerable to climatic events.

The critical elements are selected based on productive system/value chain activities and actors, particularly in the crop cycle, to determine the most climate-sensitive stages.

Community and smallholder farmer/fisherfolk perceptions on how climate change has influenced their productive systems play a key role in the identification of these critical elements. A broad, participatory consultation process where local actors contribute their input is required at a community level.

A desk review of similar studies in other countries is carried out and discussed with national experts in workshops in order to validate the critical elements selected and jointly determine how they are affected by climatic events.

STEP 3: Analysing the vulnerability of the critical elements identified and the impacts of future climate on them

The future climate scenarios generated and the definition of critical elements are the basis for analysing the potential future climate impacts on the productive system/value chains.

For the analysis a set of indicators based on climate information (rainfall, temperature, etc) must be constructed, to measure how every critical element is affected by climate. The indicators are programmed into a computer and applied to the rainfall or temperatures observed. Results obtained are discussed in workshops in rural communities with farmers, cross-checking their qualitative perceptions with the quantitative results obtained by applying the indicators to the observations. Farmers and experts are also consulted to ensure that the results reflect what has actually happened in the field.

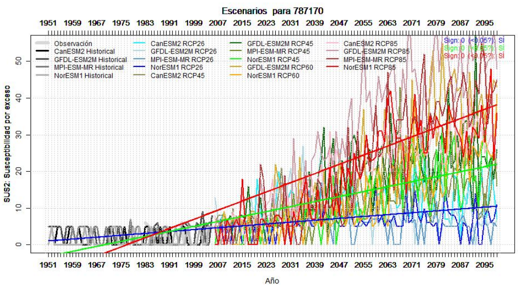
Once verified, these indicators are applied to the generated scenarios, making it possible to determine the temporal evolution of the indicators and its implications for the productive systems/value chains through different climate models and RCPs. The use of as many models and RCPs as possible makes it possible to reduce uncertainties when applying the climate change predictions to each of the critical elements.

This method of translating climate phenomena into information useful to the productive system/value chain analysis is necessary in order to evaluate the impact of future climate on the agri-food sectors and make recommendations for minimizing undesirable impacts.

Example of indicators and analysis of vulnerability in the coffee value chain in the IFAD Northern Horizons Project

Two main indicators were identified for measuring vulnerability to pests and diseases:

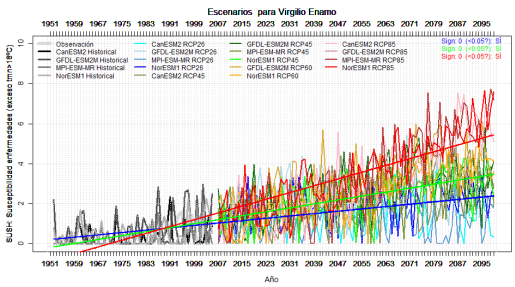
Vulnerability to Diseases Indicator. It measures the excess of humidity linked to high temperatures which is the main cause of coffee plant diseases in the project area.
It was formulated as the *"number of days between July 1st and October 30th when daily average temperatures are above 24ºC and accumulated rainfall during that day and the four previous days exceeds 30 mm."*



The scenarios applied to this indicator show very significant changes. For instance, by 2040-2060 the number of days when these conditions are met will increase from 3 to 15 (for intermediate RCPs) and therefore vulnerability to diseases including rust and other fungi will be much higher, as will vulnerability to pests such as the berry borer and other insects. This will cause higher harvest losses and increased costs to deal with those pests and diseases.

Indicator of Pests and Diseases Due to Absence of Cold: The cold stops the development and spreading of fungi, which means that if the temperature does not drop enough during the coldest months, this pest reduction does not take place.

The indicator was formulated as the "*number of degrees by which the average temperature in the coldest natural month (30 consecutive days) exceeds 18ºC*". The higher the indicator value, the more likely it is that pests and diseases will remain in viable condition during the coldest months.



The scenarios generated for this indicator show significant changes, which imply higher sensitivity to pests and diseases.

The conclusion drawn is that vulnerability to pests and diseases will tend to be higher; fungal, viral and bacterial diseases will be more frequent, strong and widespread, as will insect infestations. Consequently, the impact on both production volume and quality will be relevant. All these analyses are performed on a local scale, for each of the stations or grid points of the study area, and conclusions and recommendations are also local.

STEP 4: Making recommendations regarding each of the critical elements to minimize negative impacts and reinforce positive impacts

The results of the analysis are discussed with the rural communities affected and national experts in order to jointly analyse the potential future climate impacts on the productive systems/value chains and propose adaptation actions for each area that minimize negative impacts and boost opportunities.

For example, in the case of the IFAD Northern Horizons Project, one of the most general recommendations coming from coffee growers in certain areas is to improve crop shading in order to reduce the negative impact of higher temperatures. This will affect everything from flowering (earlier timing or flower amount) to the proliferation of pests and diseases, and also harvesting (influencing harvest accumulation). Coffee growers and experts consulted also proposed improved ventilation within the coffee plantation through appropriate sowing density and efficient plant management.

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