# ANDEAN AGRICULTURE IN THE FACE OF CLIMATE CHANGE

UNEP

Frankfurt School
UNEP Collaborating Centre
for Climate & Sustainable Energy Finance

MEBA
microfinance for
ecosystem-based adaptation

Supported by:
Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

based on a decision of the German Bundestag

**Title:** Andean agriculture in the face of climate change.

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**Year:** 2014.

**Suggested citation:** UNEP-ROLAC / FS-UNEP Centre. (2014). Andean agriculture in the face of climate change. Microfinance for Ecosystem-based Adaptation (MEbA) project document. Panama.

# ANDEAN AGRICULTURE IN THE FACE OF CLIMATE CHANGE

Rocoto producers finishing a day's work, Villa Rica, Peru. Photograph C. Membreño

# Table of contents


Onion crops in the Berlín páramo, Santander, Colombia. Photograph C. Membreño

# Introduction



The objective of the *Microfinance for Ecosystem-based Adaptation* (MEbA) project is to provide access to microfinance products and services that enable rural and peri-urban communities in the Andean region of Colombia and Peru to make investments aimed at improving production practices, increasing income and conserving ecosystems. The goal is for the actions promoted by the project to increase the resilience of small farmers to climate change effects through the diversification of crops, income and activities, thereby decreasing their vulnerability. Given that climate change vulnerability is a product of multiple interrelated factors, the MEbA project is focused primarily on two particular aspects: guaranteeing the maintenance or enhancement of the ecosystem services on which these communities depend for their livelihoods, and providing options for the improvement of their socioeconomic conditions.

The project's emphasis on agriculture is due to the fact that this sector is the main source of income for the population of the Andean region. Because it is closely intertwined with climate, agriculture – and particularly subsistence and small-scale farming – is highly sensitive to the effects of climate change. Small farmers in the Andes currently lack access to financing options; this is partly due to the risks implied for credit institutions in serving this sector of the population. However, due the relative saturation and high competition in the urban microcredit market, expanding into the rural market represents an opportunity for microfinance institutions. Success will depend on the degree to which the different components of risk can be reduced.

Therefore, the MEbA project is aimed at, on one hand, reducing the climate and production risk of agricultural producers through access to adaptation options based on the sustainable use and management of ecosystem resources and services; and, on the other hand, reducing the credit risk of microfinance institutions (MFIs) through the incorporation of climate variables in their credit risk assessment methodology, and a portfolio of customers who are better prepared to face climate variations. Up until now, five MFIs have agreed to test out this new strategy: Bancamía, Contactar and Crezcamos in Colombia, and Fondesurco and Solidaridad in Peru.

In addition to the abovementioned components, which involve technical assistance and training for both the participating MFIs and communities in the Andean region, the MEbA project is also working with the governments of Colombia and Peru in the development of public policies that capitalize on the potential of public-private partnerships to catalyze climate change adaptation. Through the integration of best practices for agricultural production and maintenance of the natural infrastructure in climate change adaptation strategies and plans, the partner countries can enhance the resilience of their populations. When this is combined with greater capacity on the part of the microfinance sector to promote the replication and wide-scale adoption of sustainable alternatives, it can serve to reduce the adaptation-finance gap and improve the living conditions of small farmers in the Andean region.

# Objectives of this publication

The main objective of this publication is to provide a reference framework for the key themes and concepts involved in the MEbA project, particularly those related to climate change, adaptation, ecosystems and microfinance. It also aims to provide background information on the Andean region, its ecosystems and the agricultural activity practised there. Finally, it highlights the role of the microfinance sector in promoting climate change adaptation, with a particular emphasis on sustainable approaches. This publication will serve as the basis for campaigns and materials developed as part of the project to raise awareness among Andean region communities of the effects of climate change on their activities, as well as the potential alternatives for responding to these effects. It is also intended as a support tool to help the decision makers in the project's partner MFIs to develop financial products and related marketing materials. Finally, it is meant to complement the publication *Microfinance for Ecosystem-based Adaptation: Options, costs and benefits*, which describes 40 potential measures that could be implemented in the context of the project.

The first chapter focuses on the causes and consequences of climate change at the global level. It highlights the differences between climate change and climate variability, between adaptation and mitigation, between vulnerability, threats and risks, and between the different emissions scenario families. It provides an introduction to the effects of climate change on ecosystems and the contribution of land-use change to both ecosystem fragmentation and climate alterations. There is also a section dedicated to explaining how climate risk is characterized in the framework of the MEbA project.

The second chapter addresses the central theme of the publication. It describes the Andean region, its ecosystems, and the agriculture carried out there. It emphasizes the effects of climate change on agricultural activities and the ecosystem services that sustain them. Potential changes in the suitability of areas where potatoes and coffee are grown are considered in detail. It also analyzes the role played by agriculture in land-use change, the transformation of natural systems and climate change. In particular, it describes how good and bad agricultural practices can have positive and negative synergistic effects, respectively, on ecosystems and the climate.

The third chapter presents the different response options: in other words, it describes the current possibilities for climate change adaptation. It identifies different adaptation strategies and focuses on ecosystem-based alternatives. Through a few examples, it highlights the benefits of this approach for enhancing the resilience of productive activities and the population in the Andean region. It establishes the links between microfinance, climate, risk and ecosystem-based adaptation. It analyzes rural microfinance and the need to integrate climate risk in credit risk assessments. Finally, it presents the methodological approach of the MEbA project and provides a rough outline of the direction that the proposed microfinance products and services will take.

At the end of the publication there is a brief glossary with definitions of some of the key concepts addressed in this publication. Most are extracted from official documents, while others are based on the most commonly accepted definitions used in climate change and ecosystem terminology.

# 1 Climate change

## 1.1. The causes of climate change

Climate variations have occurred throughout history on time scales ranging from several years to millennia. Therefore, the climate has never been static. Nevertheless, there is now a scientific consensus around the existence of a global climate alteration, as evidenced by the observed increases in mean global air and sea temperatures, extensive melting of glaciers, and an increase in mean sea level (IPCC 2007a). This global climate alteration, called climate change, denotes a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period, typically decades or longer (IPCC 2014a). The Intergovernmental Panel on Climate Change (IPCC) stressed in its latest report (2014a) that it is extremely likely that human influence has been the dominant cause of climate change.

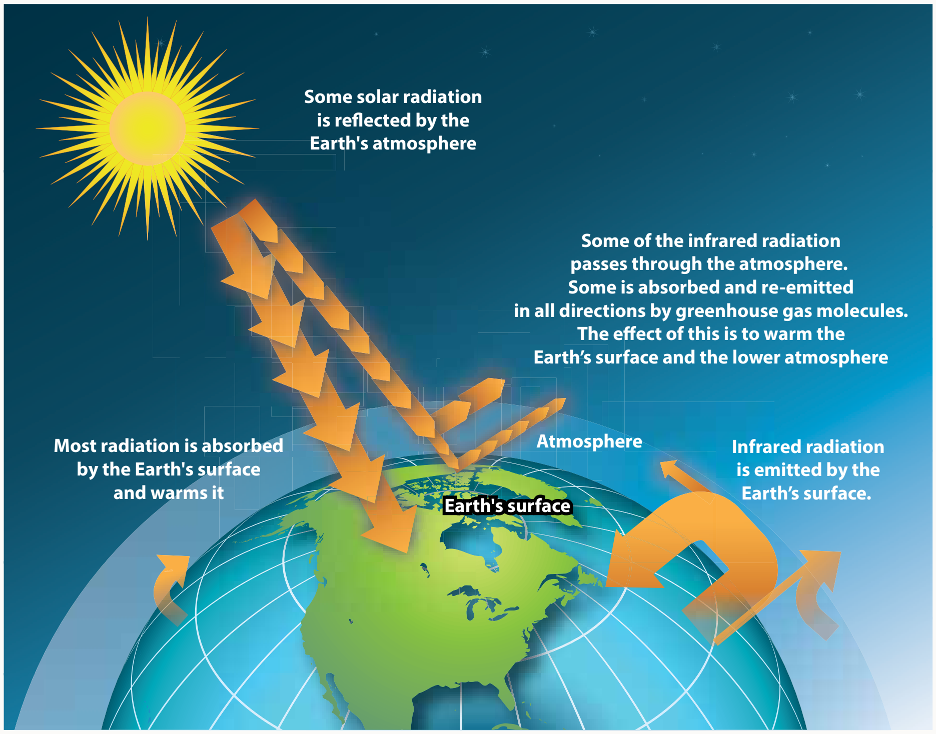



*Figure 1. The greenhouse effect. Source: US EPA (2012b).*

Climate change, as described in the IPCC definition, should not be confused with climate variability on other scales of time and space. Climate variability is a factor that has always existed as a consequence of different natural phenomena. One of the most significant examples of climate variability is El Niño-Southern Oscillation (ENSO) and its opposite event, La Niña. An El Niño event is marked by abnormally warm waters (more than 0.5°C above normal) on the western coast of South America for a period of more than three consecutive months. By contrast, La Niña is characterized by unusually cold ocean surface temperatures in the central and eastern tropical Pacific (WMO 2007; Comunidad Andina n/d). El Niño and La Niña influence seasonal temperatures and precipitation in many parts of the world, through the effects of tropical rains in the upper atmosphere. As a result, some areas suffer from drought while others receive heavy rainfall (CCAFS 2014).

Generally speaking, global warming and the subsequent changes in the current climate are due to the accumulation in the atmosphere of greenhouse gases (GHGs), which form a layer that prevents solar radiation from being reflected back into the atmosphere (see Figure 1). The greenhouse effect is in itself a natural phenomenon, essential for the existence of life on Earth: it keeps the planet from growing too cold at night, and without it, many life forms (including human beings) would not be able to survive. Consequently, in discussions of climate change, the greenhouse effect in itself is not at issue, but rather the exacerbation of the greenhouse effect caused by the overproduction of GHGs.

The primary GHGs include water vapour, carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), sulphur hexafluoride ($SF_6$) and chlorofluorocarbons (CFCs). Some have natural sources, while others are human-caused (anthropogenic). In addition, not all of them have the same capacity for retaining heat (global warming potential), nor do they remain in the atmosphere for the same length of time (atmospheric lifetime). As a result, as illustrated

| GHG | Global warming potential* (100 Years) | Atmospheric lifetime (Years) | Source (including but not limited to) |
|---|---|---|---|
| **Carbon dioxide ($CO_2$)** | 1 | Variable | Deforestation, use of fossil fuels (transportation, energy, agriculture). |
| **Water vapour ($H_2O$)** | ≥ 2 | Undefined | Natural source. |
| **Methyl bromide ($CH_3Br$)** | 5 | 0,7 | Pesticide, fumigant. |
| **Methane ($CH_4$)** | 21 | Between 9 and 15 | Natural gas and petroleum systems, rice cultivation, cattle farming, landfills. |
| **Methyl chloroform ($CH_3CCl_3$)** | 146 | 5 | Industrial degreasing solvent. |
| **Nitrous oxide ($N_2O$)** | 310 | 120 | Nylon production, cultivated soils, biomass burning. |
| **Carbon tetrachloride ($CCl_4$)** | 1400 | 26 | Fire extinguisher, refrigerant production. |
| **Sulphur hexafluoride ($CF_6$)** | 23 900 | 3200 | Electrical insulator. |
| **Chlorofluorocarbons CFCs (11, 12, 113, 114, 115) ($CCl_xF_x$)** | Between 85 and 4750 | Between 45 and 10 900 | Aerosol propellants, refrigerants. |
| **Sulphuryl fluoride ($F_2O_2S$)** | Unknown | Unknown | Fumigant (post-harvest). |

** Global warming potential is a measure of how much heat a greenhouse gas traps in the atmosphere, and is calculated in comparison with the amount of heat trapped by carbon dioxide (which has a value of 1).*

*Table 1. Primary Greenhouse Gases. Sources: California Environmental Protection Agency (2004), Held and Soden (2000), IPCC (2007b).*

in Table 1, their role in global warming varies considerably.

$CO_2$ is the GHG that has received the most attention, due to its accelerated increase since the Industrial Revolution until today (an increase of 70% between 1970 and 2004 alone). In addition to being released through natural causes, $CO_2$ is produced by the burning of fossil fuels (related to electricity generation, transport, agriculture and plastics production, among others); deforestation and forest degradation; the production of agrochemicals; and countless other economic activities that depend on the use of petroleum and its derivatives. As illustrated by Figure 2, the amount of carbon dioxide in the atmosphere is closely linked to the increase in global temperature. Methane is another gas with a high global warming potential, since it is 21 times more heat-absorptive than $CO_2$. Approximately 60% of methane emissions come from human activities such as agriculture, coal mining and landfills, while the rest is produced by natural sources, particularly wetlands, gas hydrates, termites and permafrost (Methane to Markets 2008; Carmona *et al*. 2005).

In short, the contribution of human activities to climate change is now a commonly accepted fact, supported by considerable scientific evidence.

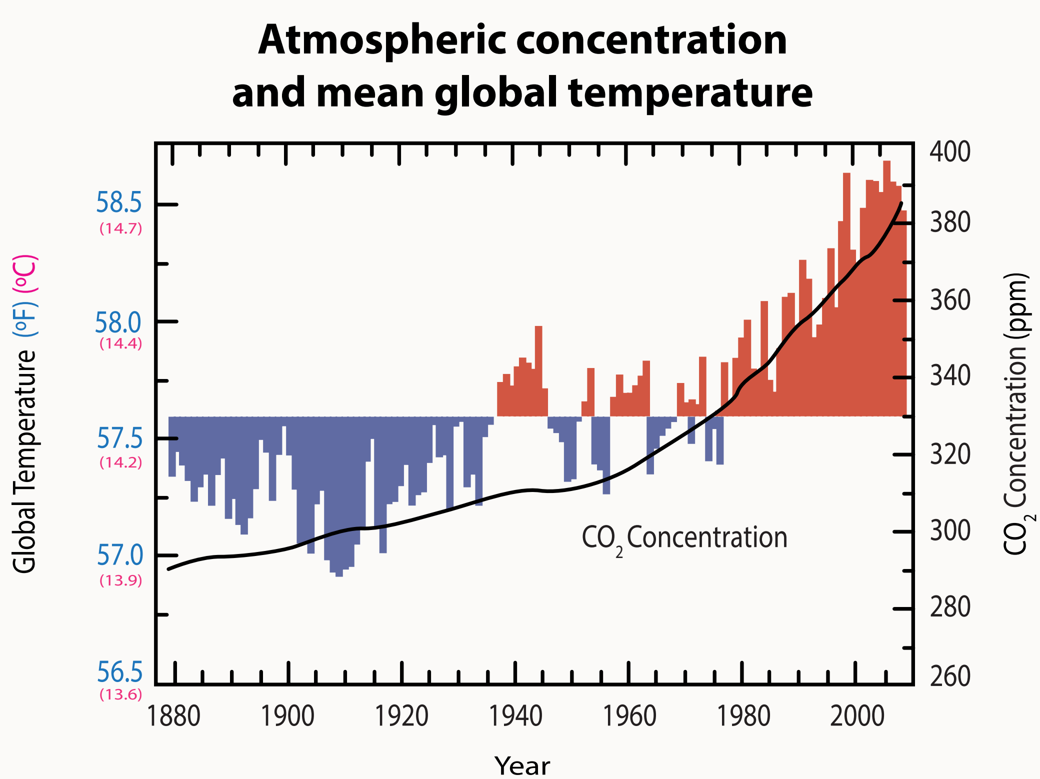
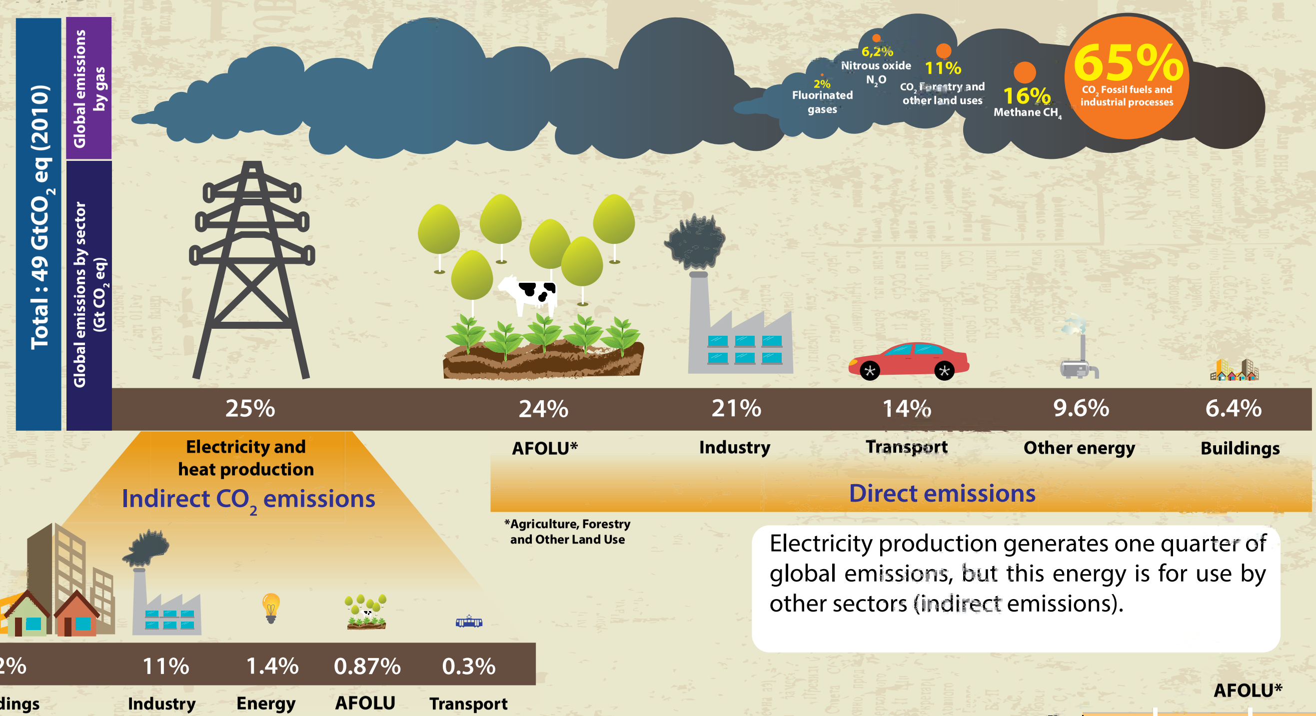
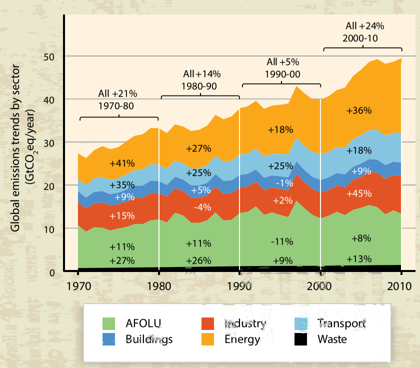



*Figure 2. Concentration of $CO_2$ in the atmosphere and global mean temperature. Source: Karl et al. (2009).*

# Global emissions and human activities



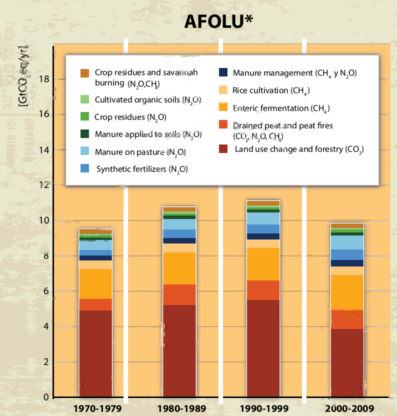

Electricity production generates one quarter of global emissions, but this energy is for use by other sectors (indirect emissions).




Despite efforts to reduce emissions, they have continued to grow. It is key to promote individual changes in consumption patterns and greater collective awareness to conserve, restore and reforest ecosystems.

Source: US EPA (2014), IPCC (2014b).

The AFOLU sector (agriculture, forestry and other land use) occupies second place in global emissions. This demonstrates the significant potential for improving production practices and restoring forests.



## Climate change and changes in land use

Just like the living beings that it sustains (microorganisms, plants, trees), the soil represents a major reservoir of carbon. In fact, the world's soils contain twice as much carbon as the atmosphere and three times as much as is stored by living organisms (IPCC 2001a). However, when it is improperly managed, soil can act as an emitter of $CO_2$. A change in land use, such as the clearing of an area of land for agriculture, increases GHG emissions and thereby contributes to climate change. It is currently estimated that changes in land use generate 24% of global $CO_2$ emissions (IPCC 2014b).

Land use also determines certain essential characteristics of the Earth's surface such as humidity, water and temperature regulation, and flows of mass (water vapour or $CO_2$) and energy (heat). As patterns of land use change, these characteristics are altered, causing changes in climate conditions: "When terrestrial ecosystems are substantially altered (in terms of plant cover, biomass, phenology, or plant group dominance), either through the effects of climate change or through other mechanisms such as conversion to agriculture or human settlement, the local, regional, and global climates are also affected" (IPCC 2014a). For example, large-scale clearing of forests and the subsequent decrease in evapotranspiration can result in decreased cloud formation and rainfall and an increase in droughts. Meanwhile, the degradation of plant cover in upper river basins can lead to more severe impacts through floods and drought in lower areas. On the other hand, changes in climate affect plant cover through their effects on temperature, precipitation patterns and solar radiation, which influence the development of plant species.

# 1.2 Consequences of climate change

## Climate change scenarios

Assessment of the future impacts of climate change is primarily based on the use of emissions scenarios commonly known as the SRES scenarios (since they were first published in the IPCC Special Report on Emissions Scenarios, or SRES). These scenarios explore different alternative development paths in terms of energy use, population growth and economic development, among other factors. The interaction of these variables gives rise to GHG emissions trends which are incorporated into General Circulation Models (GCMs) to estimate potential climate changes.

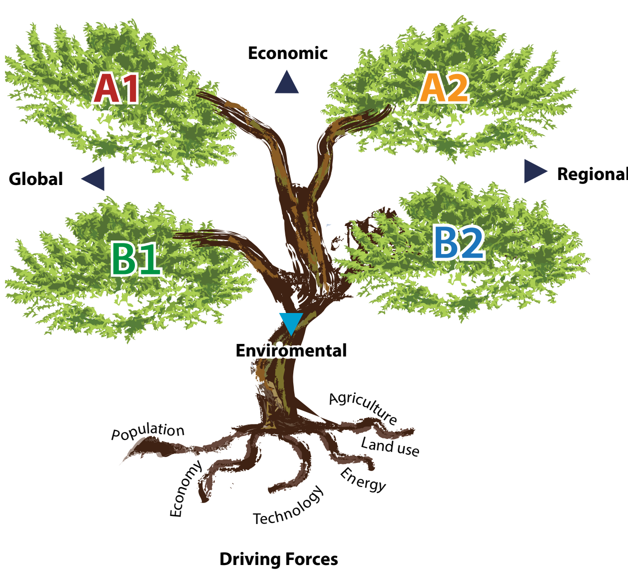



*Figure 3. Dimensions and families of emissions scenarios. Source: IPCC (2001b).*

These future emissions scenarios are formulated on the basis of four dimensions (see Figure 3) in which A represents increasingly globalized development, B represents regionalized development, 1 refers to economic growth and 2 refers to environmental protection, giving rise to four main families[1] of scenarios used to foresee tendencies in emissions:

A1: Very rapid demographic and economic growth but with rapid introduction of more efficient technologies.

A2: A very heterogeneous world with an underlying theme of preservation of local identities, and where per capita economic growth and technological change are fragmented and slow.

B1: More efficient energy use and more pronounced technological development.

B2: A world with a continuously increasing population but at a lower rate than in scenario family A2, with an emphasis on local solutions towards social, economic and environmental sustainability.

The use of scenarios and their application in different General Circulation Models is essential for a better understanding of the global distribution of climate change impacts, as well as for the development of adaptation and mitigation policies and programmes. However, the current resolution of global models (roughly 200-300 km) does not allow to perform impact assessment studies at the national level, much less at a sub-national level, since the impact models are applied at much higher resolutions (crop modelling, hydrological modelling, etc.). As a result, in recent years efforts have been made to develop and implement statistical and dynamic downscaling techniques, in order to generate regional climate change scenarios.

Emissions scenarios are not an exact science and have a significant level of uncertainty, since they are based on assumptions regarding socioeconomic, demographic and technological evolution across an extremely long time horizon. Some of the main sources of uncertainty around climate change scenarios are: (1) uncertainty with regard to emissions; (ii) uncertainty around the magnitude and direction of climate change; (iii) uncertainty associated with climate models; and (iv) uncertainty around downscaling (in the creation of regional scenarios). All of this means that scenarios must be used with caution and awareness of their limitations for decision making.

## Main consequences and changes, current and future

Climate change manifests itself in a gradual but continuous increase in the temperature of the Earth's surface and of the oceans, changes in precipitation patterns, a rise in sea levels, and changes in the frequency and intensity of extreme weather events (UNEP 2010). More precisely, the following changes have been observed:

The global mean temperature increased 0.4°C between 1992 and 2010;

All of the 10 warmest years in recorded history have occurred since 1998;

The global sea level has risen about 17 centimetres in the last century;

The number of storms in Latin America and the Caribbean between 2000 and 2009 was 12 times greater than during the period between 1970 and 1979;

Mountain glaciers are retreating almost everywhere in the world (UNEP 2010; UNEP 2011; NASA 2014).

[1] Unlike the other families (A2, B1 and B2), the A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: intensive use of fossil fuels (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

The IPCC Fifth Assessment Report (2014a) establishes that in recent decades, changes in climate have caused, and will continue to cause, impacts on natural and human systems on all continents and across the oceans. Table 2 presents examples of the potential impacts of climate change on different systems and resources.

| System or resource | Impact |
|---|---|
| **Freshwater resources** | • A decrease of at least 20% in renewable water resources for every 1°C of increase in temperature and 7% increase in world population;<br>• Reduction of surface water and groundwater resources in dry subtropical regions;<br>• Variation in the frequency of flooding;<br>• Increased frequency of meteorological and agricultural droughts in dry regions. |
| **Terrestrial and inland water systems** | • Alteration of the structure, composition and functioning of ecosystems;<br>• Alteration of the range, abundance and behaviour of plant and animal species;<br>• Changes in the distribution of freshwater species;<br>• Tree mortality and forest dieback |
| **Coastal systems and low-lying areas** | • Submersion, flooding and erosion of low-lying areas.<br>• Coral bleaching and mortality;<br>• By the year 2100, hundreds of millions of people vulnerable to coastal flooding and displacement. |
| **Marine systems** | • Increase in species richness at mid and high latitudes, decrease at tropical latitudes;<br>• 9% decrease in global open-ocean net primary production by 2100;<br>• Warming and acidification of oceans. |
| **Food security and food production systems** | • Decrease in crop yields in tropical and temperate regions;<br>• Impacts on all aspects of food security, including food access and price stability. |
| **Urban areas** | • Heat stress, extreme precipitation, inland and coastal flooding, landslides, air pollution, drought and water scarcity pose risks in urban areas for people, assets, economies and ecosystems. |
| **Rural areas** | • Impacts on water availability, food security and agricultural incomes. |

*Table 2. Projected impacts of climate change. Based on IPCC (2014a).*

These changes and their impacts on human and natural systems will have repercussions on the global economy. These include the costs related to damage to property and infrastructure caused by extreme weather events and productivity losses due to lost working days, crop failure, interruptions in energy production or the transportation of goods, and so forth. In general terms, the IPCC estimates that the world economy could suffer losses of between 0.2% and 2% of gross domestic product (GDP) during the 21st century if temperatures rise two degrees Celsius as compared to recent levels. Economies that are strongly tied to highly climate-sensitive resources (such as agriculture, for example) and areas prone to suffering extreme weather events are expected to be more severely impacted. In 2009, the Central Reserve Bank of Peru calculated the effect of climate change on the national economy, that is, the impact that climate variations (in temperature and precipitation levels) will have on the economic growth rate. It was estimated that in 2030, Peru's real GDP will be 6.8% lower than it would have been without climate change (Ministerio Peruano de Economía y Finanzas 2014).

## Climate change and ecosystems

Living beings are intimately linked to the local climate. Even small changes in air temperature or soil humidity can have significant effects on the capacity of plants, animals or microorganisms to survive or reproduce in a given environment. These changes can also modify the rhythm of their biological activities (e.g. flowering, migration). Climate characteristics such as light intensity, precipitation and temperature have a considerable influence on the development of plants, since they affect photosynthesis, the process through which plants obtain energy (Boshell *et al.* 2011). For

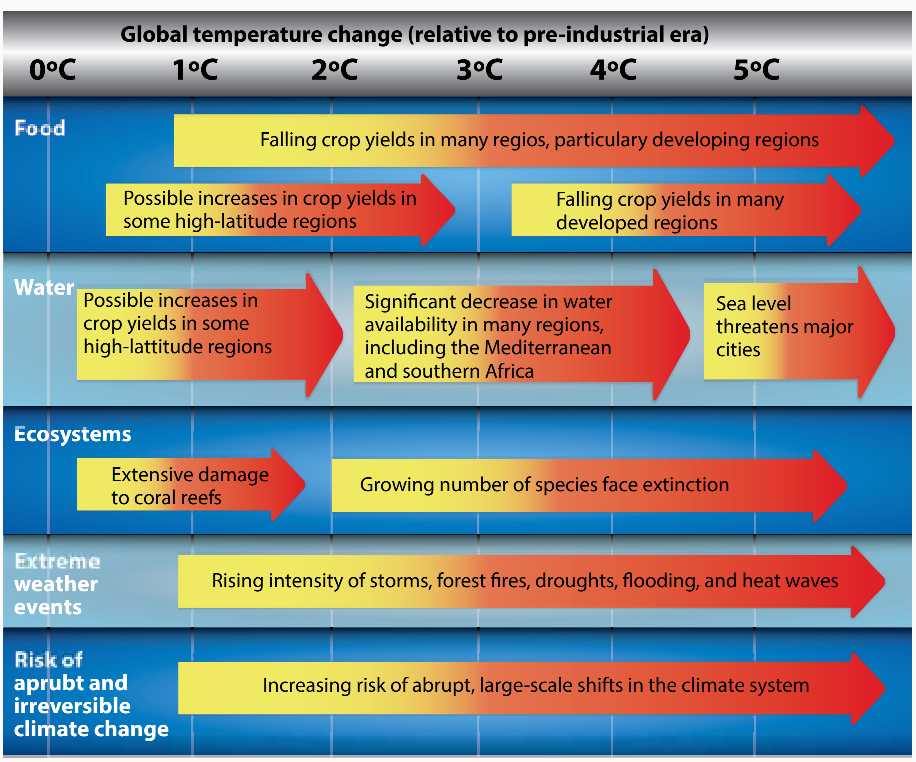



*Figure 4. Projected climate change impacts. Adapted from Stern (2006).*

example, the optimal temperature for the growth of citrus fruits is between 20°C and 30°C, with zero tolerance for frost. In addition, citrus crops are highly sensitive to water deficit, since any shortage of water during the development of the tree leads to a decrease in the yield, size and juice of the fruit. As a result, citrus crops grow in tropical environments at altitudes no higher than 2000 metres above sea level (Ecocrop 2012). Moreover, while each species is individually affected, impacts can also have repercussions through the intricate web of life that ecosystems comprise. Basically, climatic properties such as the intensity and frequency of precipitation and temperature levels largely determine the types of ecosystems in a given region and the biological diversity that they support.

The Earth's climate varies in accordance with geophysical features, such as distance from the equator, elevation above sea level, orientation to the sun and wind, proximity to the ocean and atmospheric circulation, to name a few. In certain ecosystems, such as tropical forests, the biotic components themselves (types of flora, fauna and human communities, as well as their interactions) contribute significantly to the local climate. In fact, areas with forest cover are generally more temperate than deforested areas. For example, in cities, a phenomenon known as urban heat islands is observed. In these areas, the average temperature tends to be higher than in nearby rural areas, due to a combination of factors like buildings, asphalt paving and the lack of green spaces.

Climate change has the potential to alter the composition of ecosystems as we know them, through impacts on their functions and the provision of services. For example, climate change could force certain species to higher latitudes or elevations, where temperatures are more propitious for their survival.

## 1.3 Risk, vulnerability and adaptation

Changes in the composition of the Earth's atmosphere and the consequent changes in climatic conditions pose a risk to natural, human and financial systems. Risk refers to the probability of occurrence of hazardous events and their economic, environmental and social consequences (IPCC 2014a). Unlike impact, which reflects the real consequences on human or natural systems, risk describes a still uncertain impact. In its most recent report, the IPCC uses the term risk primarily to refer to the risk of climate change impacts. An example would be the possibility of the occurrence of a hydrometeorological event resulting in a reduction of income for agricultural producers or an increase

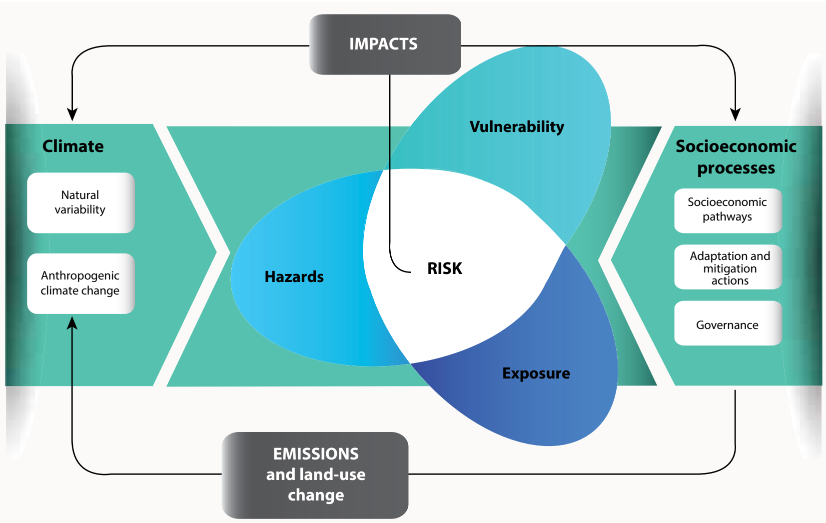



*Figure 5. Interactions among the components of risk. Source: IPCC (2014a)*

in their production costs (UNEP-Frankfurt School 2013). Risk can have several meanings, depending on the context in which it is used. For example, it has different connotations in disaster management, climate change adaptation, or finance.

According to the IPCC (2014a), risk results from the interaction of vulnerability, exposure and hazard (see Figure 5). Vulnerability is understood as the propensity or predisposition of a person or system to be adversely affected by the effects of climate change. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (adaptive capacity). The greater the sensitivity of a system, the greater its vulnerability. Conversely, the greater its adaptive capacity, the less vulnerable it will be. People (or systems) who are socially, economically, culturally, politically, institutionally or otherwise marginalized are especially vulnerable to climate change (IPCC 2014a).

Exposure refers to the presence of people, livelihoods, species, ecosystems, infrastructure and economic, social or cultural assets in places and settings that could be adversely affected by climate change (IPCC 2014a). For example, it may refer to the location and environmental conditions in which a crop is found: the agroclimatic zone, the soil's capacity for retention of water, or areas prone to erosion. Variations in vulnerability and exposure result from "non-climate" factors such as multidimensional inequalities generated by divergent development processes.

Finally, a hazard is defined as the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC 2014a).

The risk associated with climate change forces countries and communities to put an end to "business-as-usual" and to adopt both adaptation and mitigation measures, in order to prevent, reduce or moderate potential harm or disturbances, as well as to exploit beneficial opportunities (IPCC 2001a). Climate change mitigation refers to actions to prevent the increase of the amount of GHGs in the atmosphere. Mitigation involves, on one hand, the reduction of emissions and, on the other, the sequestration and storage of carbon. For example, greenhouse gas emissions can be reduced through more efficient energy use, by changing fuels (natural gas instead of coal), by using renewable energy sources (solar, wind, geothermal), by improving transportation (rapid transit systems, bike lanes), and by changing consumption patterns (saving electricity). The simplest and most efficient way to sequester and store carbon is by conserving primary forests, restoring degraded forest areas, and reducing rates of deforestation and forest degradation.

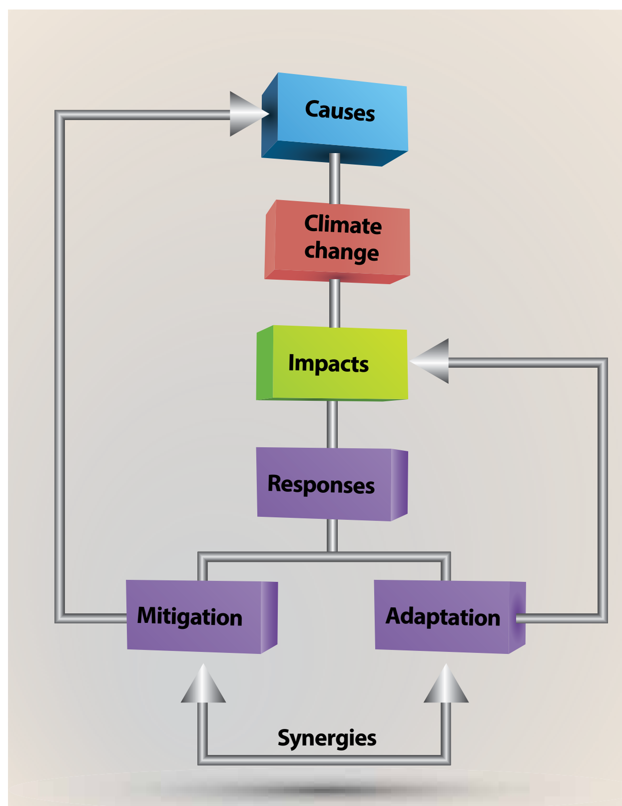



*Figure 6. How mitigation and adaptation measures impact on the response to climate change. Source: Developed by the authors.*

Adaptation is aimed at decreasing the negative impacts of climate change through adjustments in human, natural, social and economic systems, and taking advantage of the potential opportunities that may arise from these changes (see Figure 6). There are various different types of adaptation (see Section 3.1). However, all types of adaptation focus on reducing the vulnerability of natural and human systems and increasing their resilience – in other words, their capacity to “cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation” (IPCC 2014a). Climate change adaptation can encompass many aspects, from specific interventions (drought-resistant crops, the construction of flood walls), to regulatory aspects (building codes, land-use planning), to complex processes like the relocation of human settlements and the restoration of ecosystems.

## Climate risk in the context of the MEbA project



In order to offer a simple interpretation of climate risk for agricultural production and livelihoods in the Andean region, the Microfinance for Ecosystem-based Adaptation (MEbA) project team decided to draw a distinction between two traits of climate risk in the context of the project, namely (i) threats: climate factors over which humans have little control, and (ii) impacts: the consequences of the manifestation of climate threats on the system of interest. Based on the publication *Microfinance for Ecosystem-based Adaptation: Options, costs and benefits,* Table 3 provides examples of specific threats and impacts in the Andean region.

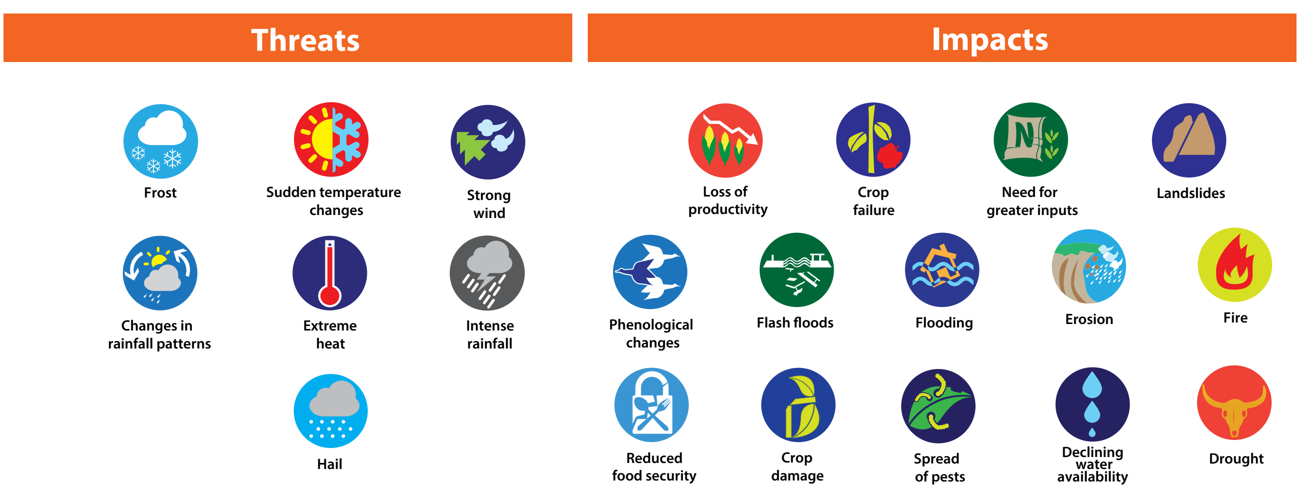
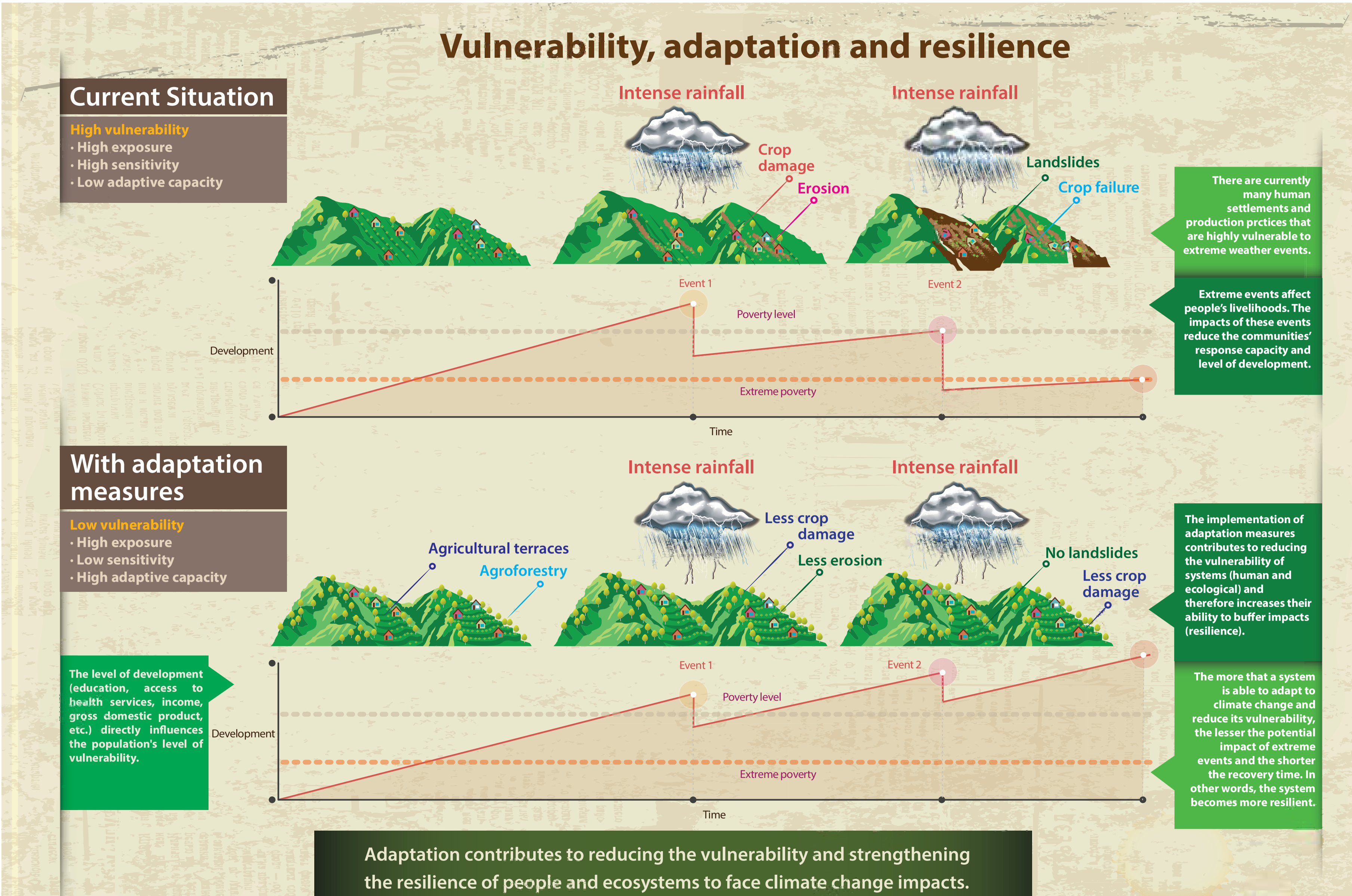



*Table 3. Examples of specific threats and impacts in the Andean region. Source: UNEP-Frankfurt School (2013).*




Source: *Developed by the authors.*

2

# Andean agriculture and climate change



The Tropical Andes mountain range – which includes the Northern and Central Andes – covers an area of 1 542 644 km$^2$, stretching from western Venezuela to the border between Bolivia, Chile and Argentina, with altitudes ranging from 600 to 6542 metres above sea level (Josse *et al*. 2009). The Andean population in Colombia, Ecuador and Peru is estimated at 45 million inhabitants, with each country accounting for 50%, 25% and 25% of the total, respectively (CIAT 2013). It is one of the regions with the highest degree of biodiversity in the world, and a rich source of natural resources for agriculture and livestock grazing. With barely 1% of the world's total land mass, the region is home to more than 45 000 vascular plant species (of which 20 000 are endemic) and 3400 species of vertebrates (1567 endemic) (Herzog *et al*. 2011; Myers *et al.* 2000).

## 2.1. Climate and ecosystems of the Andes

Most of the Andean region of Colombia is characterized by precipitation levels between 1000 and 2000 mm/year, and temperatures that vary significantly at different ranges of altitude. The lower altitudes have annual mean temperatures above 24°C, while the areas at altitudes above 2000 metres have average annual temperatures lower than 16°C, and below 8°C in high mountain areas. For its part, the Ecuadorian Andean climate can be divided into three distinct climate areas: the eastern slopes of the Ecuadorian Andes have a climate that is wet and warm to temperate; the western slopes are also markedly wet, particularly the northern part, where average annual precipitation levels are more than 2000 mm/year; and the central area is drier and colder. Finally, the climate in the Peruvian Andean region exhibits clearly marked seasons: the period between April and October is dry, with high day-time temperatures and very low night-time temperatures, while the period from November to March is characterized by intense rainfall (CIAT 2013).

In accordance with the Köppen climate classification system, which divides the world's climates into five major types and 27 sub-groups based on annual and monthly averages of temperature and precipitation, there are three major climatic types and 10 subtypes represented in the Tropical Andes (see Table 4).

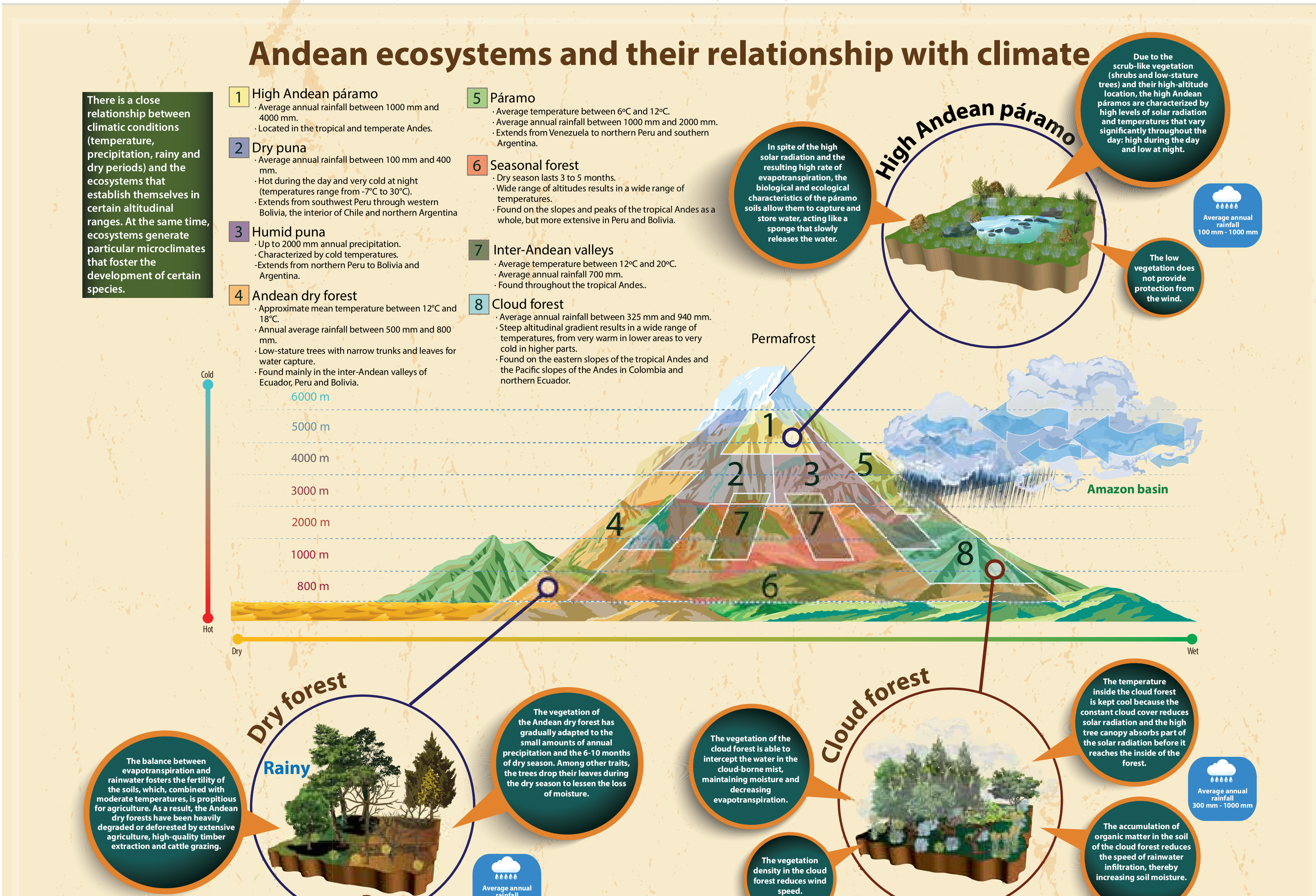
| Type and name | | Description | Subtype and name | | Description |
|---|---|---|---|---|---|
| A | Tropical | Temperatures in the coldest season rarely drop below 18ºC. Occurs in Venezuela, Colombia, Ecuador and Peru. | f | Rainforest | Warm and rainy all year round, no seasons. |
| | | | m | Monsoon | Short dry season followed by rainy season with heavy rainfall. Monsoon forests. |
| | | | w | Tropical savannah | Warm all year, dry season. |
| B | Dry | Low precipitation. Potential water loss through evaporation and transpiration much greater than the amount of water entering through the atmosphere. Occurs in Venezuela, Colombia, Ecuador, Peru, Bolivia and Chile. | S, h | Hot steppe | Mild winters, warm summers. |
| | | | S, k | Cold steppe | Cold winters, temperate or warm summer. |
| | | | W, h | Hot desert | Mild winters, warm summers, very scant precipitation. |
| | | | W, k | Cold desert | Very cold winters, warm summers, very scant precipitation. |
| C | Temperate | In coldest months temperatures range between 18°C and -3°C. Occurs in Venezuela, Colombia, Ecuador and Peru. | f, b | Marine west coast | Cold or temperate winters and cool summers. Precipitation evenly distributed throughout the year. |
| | | | s, b | Cool-summer Mediterranean | Cold or temperate winters and dry, cool summers. Most rain falls in the winter or between seasons. |
| | | | w, c | Oceanic subpolar | Dry, cold winters. |

*Table 4. Köppen climate classification for the Tropical Andes region. Based on Pidwirny (2006).*

It is believed that this wide climatic variation within a relatively limited territory contributes to the region's high level of biodiversity. In fact, the Tropical Andes encompass 133 types of ecosystems[2] grouped into nine major bioclimatic belts (Cuesta *et al.* 2012; Herzog *et al*. 2011; Josse *et al.* 2009):

1. Páramo (between 3500 m and 4200 m);
2. Humid puna (between 2000 m and 6000 m);
3. Dry puna (between 2000 m and 6000 m)
4. High Andean páramo/Superpáramo (between 4200 m and 4500 m);
5. Cloud forest (between 1000 m and 3500 m, except for southern Peru and Bolivia, where it begins at 600 m);
6. Andean seasonal forest (between 800 m and 3100 m);
7. Andean dry forest (between 800 m and 4100 m);
8. Inter-Andean valleys (between 1900 m and 3500 m); y
9. Aquatic habitats (various altitudes, generally below 800 m).

2 Of the 133 ecosystems catalogued in the Tropical Andes, 77 are found in Peru, 69 in Bolivia, 31 in Ecuador, 22 in Colombia and 21 in Venezuela (Josse et al. 2009).




*Source: Based on Herzog et al. (2011).*

Ecosystems provide numerous tangible benefits or "ecosystem services" that can be divided into four types (Millennium Ecosystem Assessment 2005):

- **Supporting services:** Soil formation, nutrient cycling, primary production.
- **Provisioning services:** Food, fresh water, fuelwood, fibre, biochemicals, genetic resources.
- **Regulating services:** Climate regulation, disease regulation, water regulation, water purification, pollination.
- **Cultural service:** Spiritual and religious, recreation and ecotourism, aesthetic, inspirational, educational, sense of place, cultural heritage.

These services sustain human economies and livelihoods, whether directly or indirectly. For example, thanks to various ecosystem services (pollination, biological pest control, maintenance of soil structure and fertility, water services), agricultural activity provides food, fodder, bioenergy and certain pharmaceutical products essential for human well-being. In the Andes, it is estimated that 40% of the population depends directly on the Andean ecosystems for their daily activities (Josse *et al.* 2009).

Over the past 50 years, the impact of humans and their means of production on ecosystems and their services has been more rapid and extensive than in any comparable period in human history. In fact, 60% of the ecosystem services examined for the Millennium Ecosystem Assessment (2005) are being degraded or used unsustainably. In the case of the Andes, the extensive human use of the humid puna for agriculture and mineral extraction, the increase in cattle grazing and intensification of mineral extraction in the dry puna, and the increase in logging facilitated by the recent expansion of road construction in cloud forest areas (to provide just a few examples), have affected the capacity of Andean ecosystems to withstand and recover from disturbances, making them more vulnerable to the impacts of climate change (Herzog *et al*. 2011).

## 2.2. Andean agriculture

Agricultural production is one of the most important traditional economic activities in the Andean region, and accounts for 13%, 9.9%, 7% and 6.5% of GDP in Bolivia, Ecuador, Peru and Colombia[3], respectively (World Bank 2013). Based on the area sown (hectares), production (tons) and yield (tons/hectare), the main crops in the region are *arracacha* (a root vegetable, sometimes referred to as the "Andean carrot"), bananas, barley, beans, coffee, cucumbers, lettuce, maize, oranges, papayas, peas, plantains, potatoes, rice and sweet potatoes (Zapata Caldas *et al*. 2011). Although the bulk of agricultural production is geared to the domestic market, some is exported to international markets, as reflected by the 95 million euros in agricultural exports from the Andean region in 2012 (European Commission 2013). The main agricultural export crops in Peru are mandarin oranges, quinoa and blueberries, while Colombia's main exports are coffee and bananas (Rubiano 2012).

Andean agriculture, practised at altitudes ranging from 1500 metres to over 4000 metres, has successfully adapted over the centuries to the topography of the land as well as the particular climatic conditions of the region, thanks to traditional knowledge, a high degree of crop diversity, and various alternative production techniques, which include:

3 There is no data available for Venezuela.

- The use of biological indicators to predict weather conditions;
- The development of different farming tools, such as the "foot plough" or chakitaklla;
- The use of a system of ridges and furrows (waru waru), in order to maximize the agricultural potential of the terrain by preserving the moisture of the soil and preventing its erosion (see Figure 7);
- Agricultural terraces to increase agricultural area and reduce slopes;
- Crop rotation and mixed crop systems, as well as the use of pest-repellent plants

(Jiménez Noboa *et al*. 2012)

Andean agriculture is primarily organized around peasant farming and family farming, characterized by small scales of production (smallholdings) scattered across a range of altitudes (Cuesta *et al.* 2012). In fact, it is estimated that 80% of families in the peasant communities of Cusco and Puno, Peru, own parcels of land of between 0.5 and 3 ha, considered smallholdings. Meanwhile, between 50% and 90% of Colombian producers of cereal crops, coffee, cacao, bananas and plantains are small farmers, with farms of less than 10 ha each (Lau *et al*. 2011). As a result of the significant level of pendular migration among the male population of the region, due to the large number of men who leave to work in places outside their permanent place of residence, women play a decisive role in agriculture and the administration of family economies in general. In the case of family farming in communities in the Puno region, for example, it is estimated that women and children participate in 56% of agricultural activities, especially those involving seed management, sowing, field work and post-harvest activities.

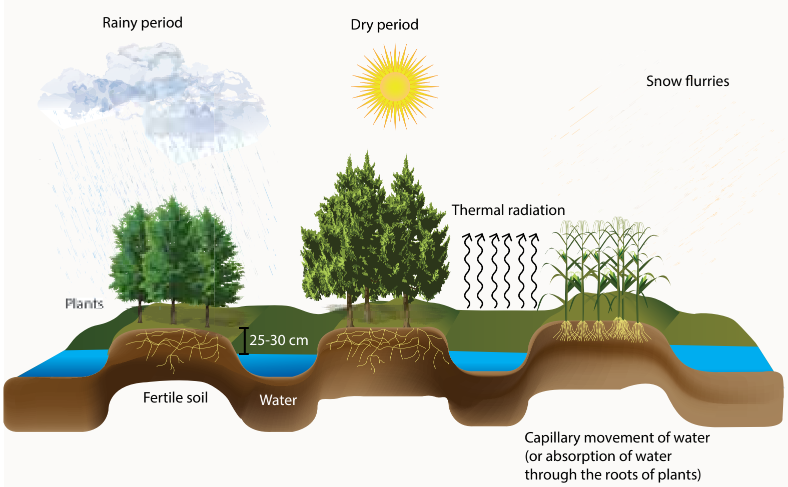



*Figure 7. Functioning of a waru waru.*

# Land-use change, agriculture and climate change

The land area of the Tropical Andes devoted to agriculture has increased in recent years, at the expense of the region's forested area. In Colombia, agricultural land increased from 37.5% to 39.5% of the total land area in a period of nine years (2002-2011), while in Peru, the area of agricultural land remained stable during the same period, at 16% (World Bank 2014). In Colombia, during the period of 2005-2010, 55.5% of the land deforested was converted to pasture, which reflects an increase in comparison with the period of 2000-2005 (39.7%) (see Table 5).

Changes in land use result in local changes in air temperature and precipitation. According to a study published in 2010, although there is still not a well-defined general pattern, it can be stated that when agricultural land is converted to tropical forests, precipitation tends to increase. On the contrary, the conversion of tropical forests or grasslands to agricultural land tends to lead to a decrease in precipitation (Rodríguez-Eraso *et al.* 2010).

Moreover, land-use change is responsible for more than 70% of GHG emissions in Peru, Ecuador and Bolivia, three times more than those produced by the burning of fossil fuels (PNCC 2003). The practice of slash-and-burn forest clearing, which accounts for 85% of the loss of tropical forest cover, contributes to this situation, as much of the carbon stored in the wood and leaves of the trees, as well as in the fallen leaves on the forest floor, is rapidly converted into $CO_2$ when burned and released into the atmosphere. A study conducted in Bolivia shows that slash-and-burn practices also affect soil quality. The study found that the lands of peasant farmers (with up to 30 hectares of land) suffered a decrease in humus and nitrogen content for up to five years after clearing, subsequently becoming stable for many years (Krüger and Gerold 2003).

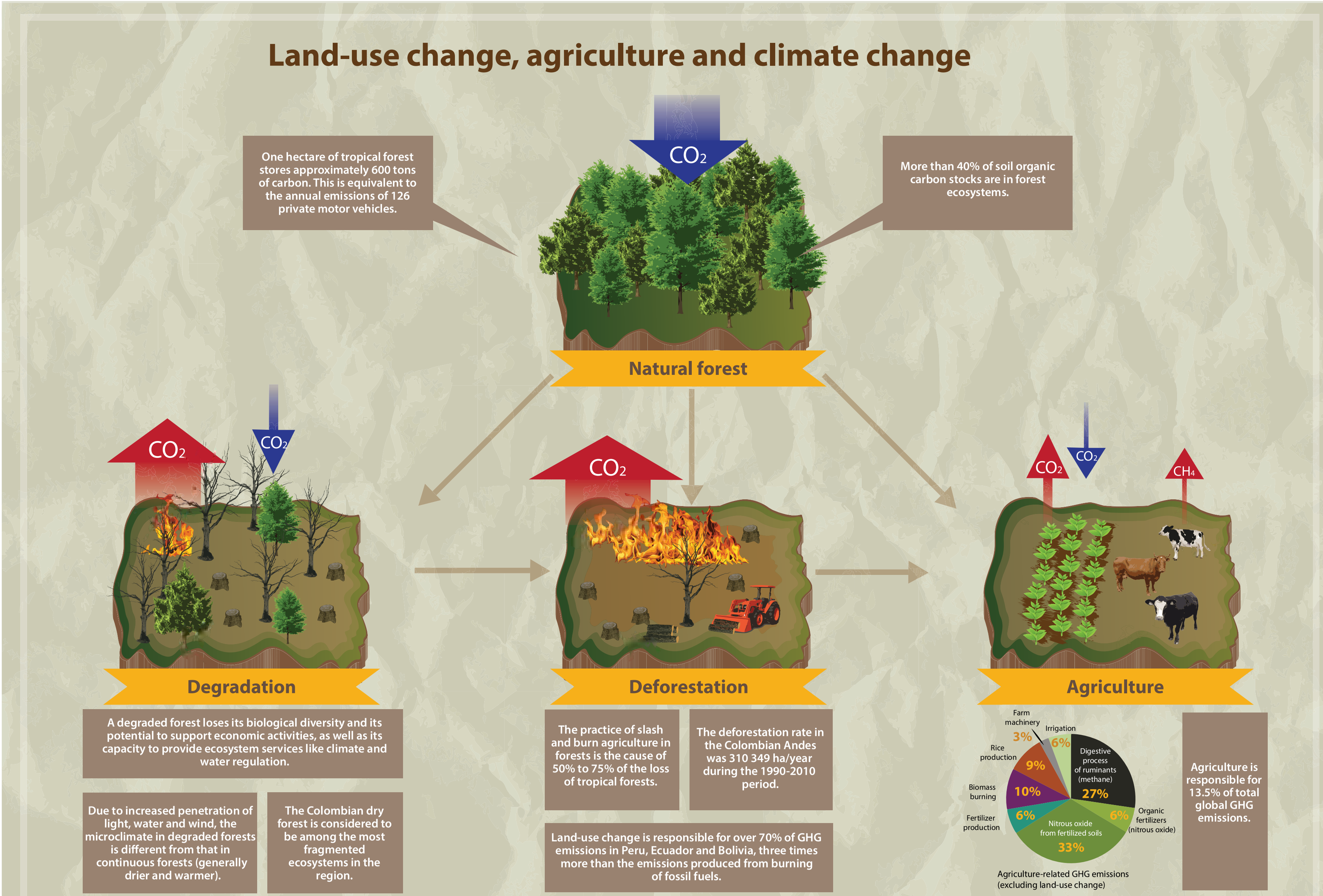
| New land cover | 2000-2005 | | 2005-2010 | |
|---|---|---|---|---|
| | Area converted (ha) | % Area converted | Area converted (ha) | % Area converted |
| Urban areas | 9585 | 0.6 | 123 | 0.0 |
| Temporary crops | 6989 | 0.4 | 2197 | 0.2 |
| Permanent crops | 3750 | 0.2 | 873 | 0.1 |
| Pasture | 625 833 | 39.7 | 663 901 | 55.5 |
| Mixed agricultural areas | 194 064 | 12.3 | 104 852 | 8.8 |
| Tree plantations | 40 | 0.0 | 144 | 0.0 |
| Grassland | 19 256 | 1.2 | 19 539 | 1.6 |
| Shrubland | 77 125 | 4.9 | 129 648 | 10.8 |
| Secondary vegetation | 552 495 | 35.1 | 241 764 | 20.2 |
| Burned areas | 5296 | 0.3 | 3531 | 0.3 |
| Other areas without vegetation | 3785 | 0.2 | 7670 | 0.6 |
| Aquatic vegetation | 1700 | 0.1 | 11 192 | 0.9 |
| Bodies of water | 14 950 | 0.9 | 10 898 | 0.9 |
| No information available | 60 084 | 3.8 | | 3.8 |
| Total | 1 574 953 | 100.0 | 1 196 331 | 100.0 |

*Table 5. Classification of change in forest cover due to deforestation in Colombia (for the periods 2000-2005 and 2005-2010). Source: SIAC (n/d).*

Slash-and-burn forest clearing is not the only practice that affects ecosystems and the climate. Monocultures (single-crop cultivation), intensive fertilizer use and intensive soil tillage also contribute to the deterioration of local ecosystems. These practices reduce the quality of soils as well as the number of species and varieties, and thereby have a negative impact on agricultural production.

On the other hand, it is believed that good agricultural practices play a key role for climate change mitigation and the health of ecosystems (see Figure 8).


*Figura 8. Effects of good and bad agricultural practices. Developed by the authors.*




*Source: Developed by the authors based on documents from: www.stateofthetropics.org; www.fao.org; www.minambiente.gov.co and www.asb.cgiar.org.*

## 2.3. The impact of climate change on Andean ecosystems

In recent decades, various climate factors in the Tropical Andes have begun to exceed historically documented thresholds. The air temperature in the region has increased significantly in the last 60 years (+0.11°C/decade) and at an even faster rate since 1975 (+0.34°C/decade) (Herzog *et al*. 2011). While recognizing the uncertainties around current General Circulation Model climate simulations, it is nonetheless believed that this trend will continue for the next 30 or 40 years, with considerable effects on the agricultural sector in the region (Bradley *et al*. 2006; Herzog *et al*. 2011).

In terms of precipitation, the comparison of a series of 17 GCMs based on SRES scenarios, carried out by Mulligan and Rubiano in 2010, showed that one of the biggest global changes in precipitation by the year 2050[4] will occur in the Andes, with increases of several hundred millimetres a year in the northern Andes, the western Amazon and the Colombian plains, and decreases of several hundred millimetres a year in the southern Andes, the Guiana Shield and eastern Brazil. According to a study conducted in 2013 by the International Centre for Tropical Agriculture (CIAT), in Colombia, the most significant decreases in total precipitation are foreseen in the Santanderes region, while increased precipitation is expected in the Cauca Valley, Cauca, Quindío, Nariño, Tolima and Huila regions. In the case of Peru, climate models foresee major increases in annual precipitation in the north (roughly 80 mm/year in the decade of the 2030s and 180 mm/year in the 2050s), but less severe increases in the south (a maximum of 40 mm/year in the 2030s and 120 mm/year in the 2050s).

In addition to variations in precipitation and temperature, changes are also predicted in the type, frequency and intensity of extreme weather events, such as intense rainfall and cold and heat waves (UNFCCC 2007). A study published in 2012 foresees a 10% increase in precipitation extremes for every one degree of temperature increase in the tropics (O'Gorman 2012). More than changes in average temperature, which occur gradually, extreme weather events pose a significant risk to agricultural producers, since they occur suddenly and allow very little time to react. According to the 2009 Atlas of the Dynamics of the Andean Region, 355 000 km$^2$ of Andean agricultural land are exposed to frost (54% in Peru, 28% in Bolivia, 10% in Colombia and 7% in Ecuador), while 120 000 km$^2$ of agricultural land in Colombia and 35 000 km$^2$ in Peru are exposed to flooding caused by intense rainfalls (Secretaría General de la Comunidad Andina 2009).

These changes in temperature, precipitation and extreme weather events are affecting and will continue to affect ecosystems and their services, which will in turn lead to consequences, both positive and negative, for human well-being and productive activities like agriculture. In the next section, we will focus on the impact of climate change on the ecosystem services of greatest relevance to Andean agriculture.

### Water supply and water regulation

Agriculture is one of the productive activities with the greatest demand for water, and its competitiveness depends on whether this resource is available when it is needed for the development of crops, livestock and trees (Ortiz 2012). In the Andes, agricultural activity accounts for between 40% and 80% of water consumption (Mulligan and Rubiano 2010).

Water provisioning and water regulation are among the main services provided by ecosystems in the upper altitudes of the Andean region. Millions of

[4] The comparison was made using the A2a scenario for the year 2050. For more information, consult the study at http://publicaciones.fedepalma.org/index.php/palmas/article/view/1537/1537.

people depend on water from the Andes for their daily activities. In the complex geology of the Andes, water regulation through groundwater is limited. Therefore, the options for regulation in the mountains are generally few and fragile, limited to the storage and regulation of water in the form of snow (at higher levels of altitude), natural regulation in lakes and ponds (throughout the mountain range), and storage in the soils of high Andes ecosystems (páramo, puna and forest) (De Bièvre and Acosta 2012). In the latter case, the storage of water in the surface or subsurface soil is made possible by soils with a high content of organic matter and preserved plant cover. As a result, changes in land use and the effects of climate change on the watersheds and ecosystems of the páramo and high mountain regions have contributed to the deterioration of the region's water regulation capacity.

It is predicted that a warmer climate will alter the water cycle in the region in the following ways: 1) higher rates of evaporation, ii) a greater proportion of liquid precipitation (rain) instead of solid precipitation (snow), iii) possible changes in the amount and seasonality of precipitation, iv) a probable reduction in reserves of soil moisture and groundwater, and v) greater frequency of droughts or floods (Beniston 2005; Pérez et al. 2010). These changes will undoubtedly influence the water balance of river basins, with considerable impacts on agriculture. In fact, researchers foresee reduced availability of water in dry seasons, as well as a decline in water quality due to increased sediment loads.

In the Andes, long-term observations have detected a 30% retreat in the total ice mass over the last 30 years, which has affected the majority of glaciers at lower altitudes and of smaller size (<0.5 km$^2$) (Urrutia and Vuille 2009; Vuille *et al*. 2003). During these 30 years, Mount Huascarán in Peru has lost 40% of its ice cover (1280 hectares), while the Chacaltaya Glacier in Bolivia has shrunk by 82%, as a consequence of increases in temperature and $CO_2$ levels and the thinning of the ozone layer, among other factors (Simms and Reid 2006). The melting of the glaciers will also have major repercussions on access to water for local agricultural producers. At the time of melting, the circulation and availability of water will increase. However, as areas of ice cover continue to disappear, dry seasons will become more acute and there will be less water available both for human consumption and for agriculture and other productive activities (Bradley *et al*. 2006). Together with the predicted increase in the intensity of precipitation, the melting of glaciers could increase the threat of disasters, affecting crops in the inter-Andean valleys and upper Amazon basin (Chevallier *et al.* 2004; Kaser *et al.* 2003; Mark and Seltzer 2003; Juen *et al*. 2007; Poveda 2009; Cuesta *et al.* 2012).

## Soil formation

Soil formation is an essential ecosystem service that, in turn, sustains numerous others. It not only serves as the basis for 90% of human food, as well as fodder, fibre and fuel, but also offers services that go beyond productive functions: it provides storage, filtering and transformation of many substances, including water, carbon and nitrogen; it serves as habitat and a source of genetic resources; and it is also a platform for human activities. Soils also play a significant role in the reduction or mitigation of risks related to extreme weather events.

Altitude and therefore the climate significantly affect the inherent fertility of soils and the rate of erosion due to runoff. Many characteristics of soil fertility (organic matter content, pH) vary considerably with altitude, while the propensity of soil to erode increases dramatically with elevation (Pérez *et al.* 2010). Climate change impacts in the form of more severe rainfall and glacial retreat, as well as the expansion of the agricultural frontier at higher altitudes, will make agricultural systems more vulnerable to soil erosion. In a survey carried out by Mulligan and Rubiano (2010), for which they interviewed 70 water experts from seven Andean countries, soil erosion was identified by 71% of the respondents as the highest agricultural priority in the region. Deforestation, overgrazing and poor farming practices also lead to irreversible losses of organic matter from the soil. In addition, studies have shown that the loss of chemical elements from the soil due to deforestation can result in increased nutrient concentrations in surface water bodies, thus posing a risk for aquatic ecosystems and for humans who depend on them for their daily activities (Lindell *et al*. s/f).

## Biodiversity

Biological diversity, or biodiversity, refers to the variability among living organisms, and includes diversity within species, between different species, and between different ecosystems. Although biodiversity is not an ecosystem service in itself, it is the basis for the supply of services such as provisioning services (food, fibre, fuelwood), regulatory services (pollination), supporting services (soil formation) and cultural services (recreation, ecotourism).

As mentioned earlier, the Tropical Andes is one of the world's regions with the highest degree of biodiversity. A large number of the species found in the region are endemic and have limited distributions, as they have adapted to specific altitudinal and latitudinal ranges and environmental conditions. Given the predictions of temperature increases greater than in other parts of the world, and the prevalence of species that are intrinsically more sensitive, the Tropical Andes is considered to be one of the most ecologically vulnerable regions in terms of impacts on biodiversity (Herzog *et al*. 2011).

Over the last 50 years, there has been an unprecedented loss of natural habitats resulting from land use conversion and climate change. The main consequences of this loss are the probable changes in the presence and abundance of species as well as the high probability of profound changes in their distribution (Herzog *et al.* 2011).

Observations and projections for mountain regions indicate changes in the distribution of ecosystems or biomes, with apparent vertical displacement towards higher altitudes. As an example, Figure 9 simulates the changes in mountain vegetation that could be caused by the impact of climate change (in a scenario of +3.5°C and +10% precipitation) on humid tropical ecosystems. In terms of the displacement of ecosystems, the speed with which climatic conditions are changing forces species to

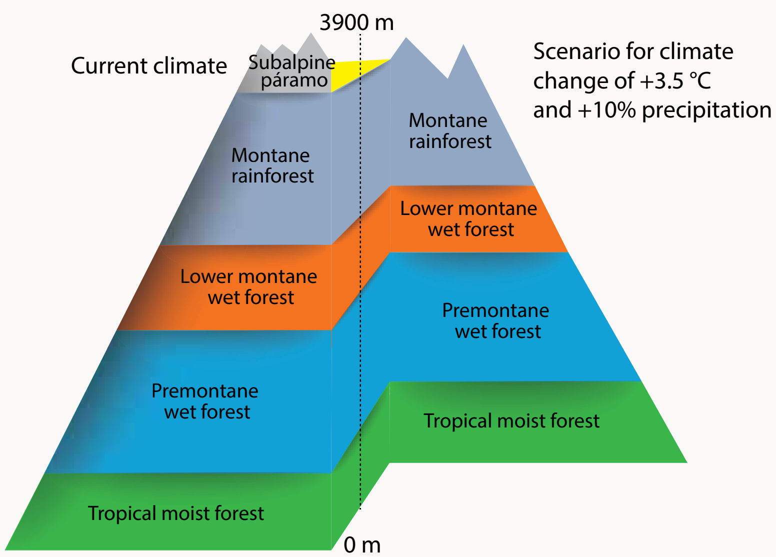



*Figure 9. The impact of climate change on vegetation in mountain regions. Adapted from Slaymaker et al. (2009).*

migrate rapidly. If they do not migrate, it is likely that the population of numerous Andean species will decline or a new group of species will emerge (La Marca *et al*. 2005; Pounds et al. 2006; Herzog *et al*. 2011). A study by Cuesta Camacho (2007) estimates that 35% of bird species and 60% of plant species in the Andean páramo regions could become extinct or critically endangered.

## 2.4. The impact of climate change on Andean agriculture

Climatic characteristics (temperature, precipitation, $CO_2$ and solar radiation) determine certain essential factors for the optimum development of each plant species, such as the length of the life cycle, photosynthesis and evapotranspiration. For example, the ambient temperature affects the length of the life cycle of a plant or a crop; that is, it modulates the time (days or months) that passes between the germination of the seed and harvesting.

A time reduction in the life cycle of a crop can be counterproductive in some species, since they may not complete each of their stages (Boschell *et al*. 2010). As a result, the climate geographically delimits the regions where certain crops can be produced, as well as the quantity and quality of yields. Andean vegetation and crops are adapted to the climatic conditions of the region. However, now that the range of natural climatic variability has begun to surpass historically documented thresholds, significant effects on the region's agricultural sector are expected. In fact, agriculture is one of the sectors that will be most affected by climate change. The main impacts expected include changes in areas suitable for certain crops; the expansion of the agricultural frontier towards higher altitudes and the related conversion of high Andes ecosystems like páramos and wetlands into crop-growing areas; changes in crop yields; and changes in the distribution of pests and diseases.

It is estimated that by 2050, in the majority (>60%) of areas currently used for agriculture, 80% of Andean crops will be affected by climate change (CIAT 2013). However, the precise effects are still uncertain: they will be distributed unequally throughout the region and will affect different crops in different ways. It is expected that some warm-climate crops (those that are optimally suited to production in the lower altitudes of the Andean region), such as cassava, cacao, sugar cane and bananas, will become increasingly suited to lower regions. On the other hand, high Andes crops like potatoes and quinoa will become less climatically suited to the regions where they are currently grown and more suited to higher altitudes. Using the example of projected maize cultivation in Peru in 2030 and 2050, Figure 10 indicates a major potential loss of climatic suitability in the lowest areas of the Andean region on the Amazonian side (marked in red on the map). As the altitude rises, losses become slighter, and as it continues to rise, conditions become more favourable for this crop (marked in green).

Using SRES emissions scenarios A1B and A2 for the periods 2010-2039 and 2040-2069, Zapata Caldas *et al*. (2011) assessed the probable impacts of climate change on the 25 most important crops in the Tropical Andes. They concluded that tomatoes would be the most severely affected crop in the region due to loss of climate suitability, followed by wheat, beans, coffee and potatoes. In economic terms, the countries that would be most seriously impacted are Colombia and Venezuela, while Ecuador and Peru would benefit from the changes with regard to at least one of the crops assessed. In the case of Peru, the positively affected crops would be potatoes and beans, with profits of USD 87.9 million and USD 2.2 million, respectively.

The increased climatic suitability of certain crops at higher altitudes and the process of glacier retreat are the main reasons for the upward expansion of mountain agriculture over the last 50 years. In Peru, grazing and crop growing have risen some 300 metres higher in certain areas as a readjustment to increased temperatures and changes in precipitation, with potatoes being grown at a record high altitude of 4500

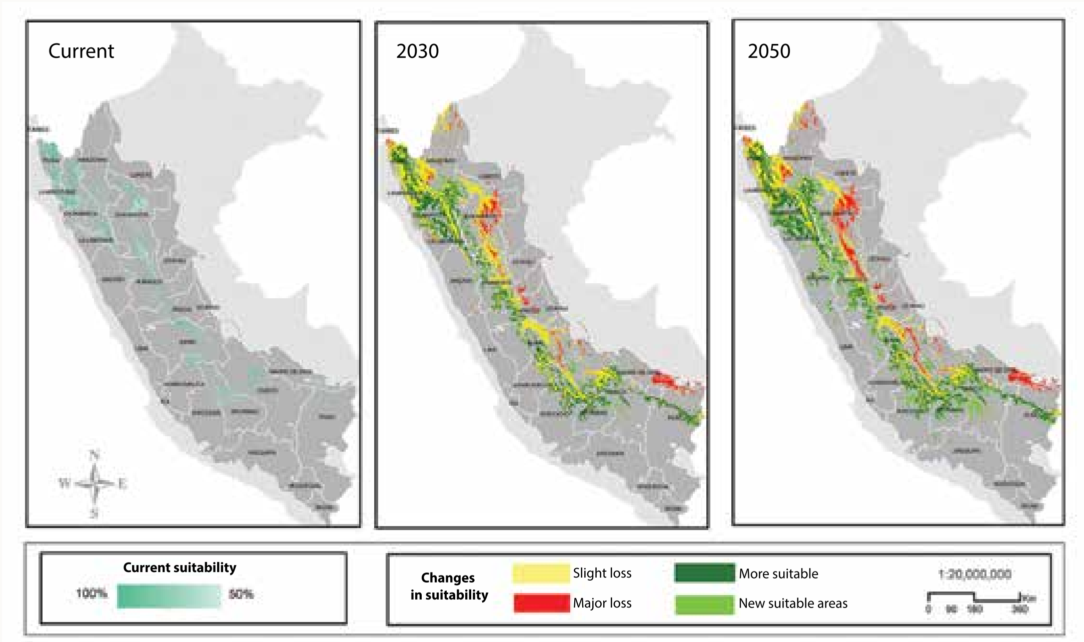



*Figure 10. Changes in climate suitability for maize cultivation for 2030 and 2050 scenarios in the Andean region of Peru. Source: CIAT (2013).*

metres (Herzog et al. 2011). The migration of coffee growing to higher altitudes has also been observed in Colombia (in Cauca, specifically) (Ramírez-Villegas et al. 2012).

Projections indicate that, generally speaking, the trend towards an increasing upper altitudinal limit for agriculture will continue throughout the next century, leading to a total increase of at least 500 metres across the region. However, while the migration of crops to higher altitudes is considered a viable adaptation strategy in some cases, it can also result in potentially negative effects. These include competition for resources between new and native crops; the extinction of mountain-top species for which there are no longer escape routes available to move into; competition between agricultural areas and conservation areas (such as páramos); and greater exposure to extreme weather events like frost, droughts and hailstorms (IPCC 2001a; Ramírez-Villegas et al. 2012).

Changes in climatic conditions could also have an impact on crop yields (the amount of food or other crops produced per unit of area cultivated). A study conducted by the National Planning Department of Colombia (2011) predicts a significant increase in average crop yields of cotton and irrigated rice in Colombia in the coming decades, while sugar cane crop yields could increase moderately. On the other hand, a moderate decrease in coffee and plantain productivity is expected, and no significant effects are foreseen on banana, maize and potato crops (CIAT 2013). At a regional level, the Inter-American Development Bank (IDB) estimates that Andean agricultural output could decline by 12% to 50% as a result of climate change (Ortiz 2012).

Moreover, since plants, fungi, bacteria and insects have climatic thresholds within which they develop better, regional and local climate change, along with the migration of some species to higher altitudes, have favoured the spread of pests to areas that were historically free of them. In addition, the simplification of landscapes in terms of biodiversity and ecological complexity increases the vulnerability of agricultural systems to diseases, limits their capacity for recovery, and is positively correlated with the increase in certain pests, as has been demonstrated with the Guatemalan potato moth (Poveda et al. 2012).

## Box 1. Potatoes

Cultivated for millennia throughout the Andes mountain range, the potato is one of the staple foods of the region's population. Potatoes represent 11% of Peru's GDP and 9.63% of Colombia's agricultural production. They are considered an important source of income for poor farmers in Colombia, Ecuador and Peru (CIAT 2013).

The combination of rising temperatures and changes in the distribution of precipitation is expected to have a favourable impact on potato yields, particularly at higher altitudes. Therefore, the outlook for the year 2050 reflects gains in the climatic suitability of potato crops in areas ranging from central Peru towards the south, while a significant area – probably at lower altitudes – will be negatively affected (Colombia year 2020, SRES-A2). The displacement of cultivation of this crop towards higher altitudes, especially areas above 3000 metres, where native potato species are normally grown (Cusco, Apurímac, Huancavelica), is a common adaptation strategy in the region.

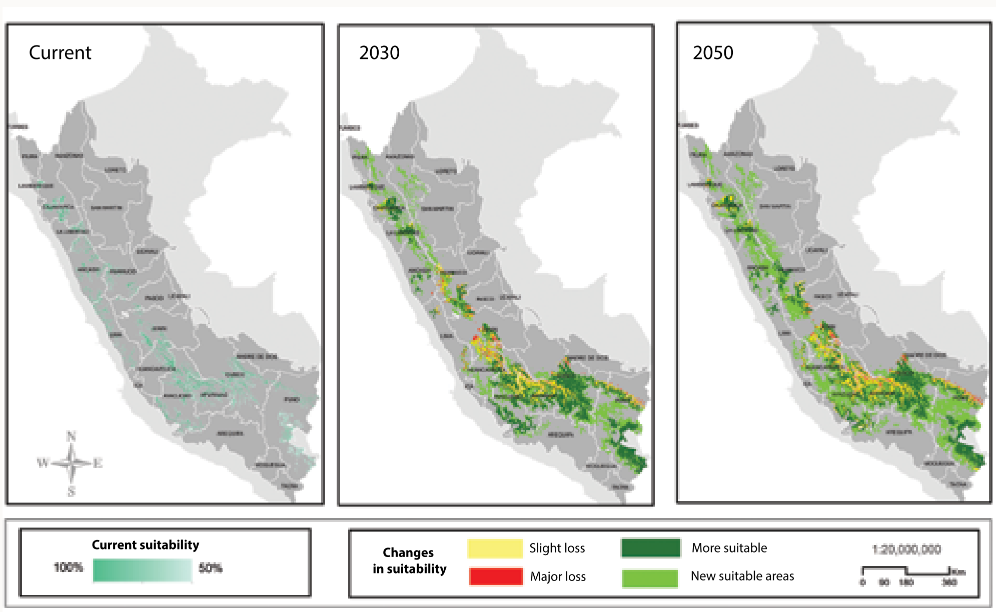



*Figure 11. Changes in climate suitability for potato cultivation for 2030 and 2050 scenarios (Peru).*

The increased diversification of crops is a recognized adaptation strategy in the case of potatoes, and helps reduce the risks associated with high-altitude agriculture. It has been observed that the common potato (*Solanum tuberosum subsp. tuberosum*) can withstand temperatures below 3ºC, while other Andean species (especially *S. tuberosum sub. andigena, S. stenotomum, S. chaucha, S. goniocalyx*) and species of so-called "bitter" potatoes (*Solanum juzepzuckii, Solanum curtilobum, Solanum ajanhuiri*) can withstand temperatures as low as -5ºC.

At the same time, however, rising temperatures and humidity will favour the development of late blight – the most potentially damaging disease for potatoes – which could spread to areas located above 3000 metres (where it is currently non-existent). The potato moth, which is currently found in coastal areas and inter-Andean valleys, could also spread to new areas as a result of changes in temperature.

*Sources: CIAT (2013), PROEXPORT and SAC (2012), Devaux et al. (2010), Zapata Caldas et al. (2011).*

## Box 2. Coffee

With annual production in 2012/2013 of 595 500 tons, Colombia ranks as the world's fourth largest coffee producer (after Brazil, Viet Nam and Indonesia), while Peru occupies ninth place with annual production of 258 000 tons.

The optimum temperature for the development of *coffea arabica* fluctuates between 15ºC and 24ºC (between 500 and 2800 metres in terms of altitude). Higher temperatures can interfere with the flowering of the plants or cause the berries to mature too quickly, which negatively impacts their yield and quality. This decrease in yield and quality associated with rising temperatures is one of the main risks facing Andean coffee producers. Studies indicate that the mean temperature in Colombia's coffee-growing regions has increased by approximately 1ºC in the last 30 years, with increases of 2ºC in some mountainous areas. If this trend continues, it is estimated that 84.7% of the area where coffee is currently produced in Colombia will be affected by temperature changes of approximately 2ºC to 2.5°C. A study conducted by CIAT (2013) foresees a shift in climate suitability for coffee crops towards higher altitudes in Colombia (see Figure 12). In 2030, in the municipality of Puente Nacional (Santander), a change in growing areas is expected, with a slight loss in climate suitability, while a number of new areas will become suited to coffee growing, including the municipalities of Altamira, Garzón and Guadalupe in the department of Huila and the municipality of San Juan de Pasto in the department of Nariño.

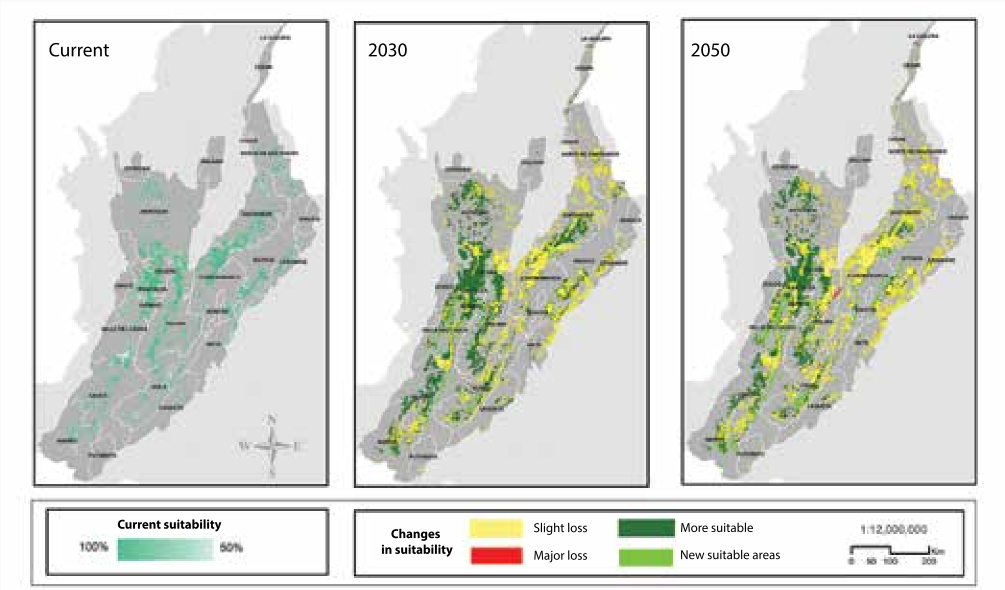



*Figure 12. Changes in climate suitability for coffee cultivation for 2030 and 2050 scenarios (Colombia).*

In the meantime, the predicted rise in temperatures as an effect of global warming will generate favourable conditions for the spread of pests and diseases, modifying their current distribution pattern. In fact, coffee grown in areas above 1500 meters is considered one of the crops most severely affected by pests and diseases. A prime example is *Hemileia vastatrix*, the fungus that causes a disease known as coffee rust that is devastating to *coffea arabica* crops and requires specific levels of temperature, humidity and rainfall to develop. Chalfoun *et al.* (2001) observed that today, outbreaks of coffee rust (also known as roya disease) appear earlier than was observed in the 1980s and 1990s, pointing to a possible link with the increase in mean minimum temperature during winter.

*Sources: Méndez (2009), Centro de Comercio Internacional (2010), CIAT (2012), EcoCrop (2012), Lau et al. (2012), Ramirez-Villagas et al. (2012).*

Coffee trees under natural shade, Santander, Colombia. Photograph C. Membreño

3

# 3. Alternatives

## 3.1. Adaptation strategies for agriculture

Given the exposure and sensitivity of Andean ecosystems to climate change and the importance of agriculture for the well-being of the population, the impacts of climate change are considered to pose a threat to the foundations of development in the region. While the need to mitigate the effects of climate change through the reduction or sequestration of greenhouse gas emissions remains imperative, there is also a need to adapt to current and future changes. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change adaptation as adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. Adaptation measures represent changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change.

Adaptation is not a new phenomenon. Throughout human history, societies have adapted their production systems to climate variability. These adaptation strategies have had different facets. In natural (unmanaged) systems, adaptation is generally autonomous and reactive: it is the process through which species and ecosystems respond to changing conditions – for example, when a species migrates to higher areas to find climate conditions propitious for its development. In human systems, or natural systems managed by humans, adaptation measures are carried out by private or public actors and can be anticipatory (proactive) or reactive; in other words, they may serve to prepare for the risks and opportunities of climate change (anticipatory) or to cope with its effects (reactive).

Whether reactive or anticipatory, climate change adaptation is closely linked to the reduction of the vulnerability of communities, regions, sectors or activities. Adaptation combines activities aimed at confronting the current risks posed by growing climate variability and emerging trends; managing risk and uncertainty; and developing adaptive capacity. There are numerous approaches to adaptation, which focus on the role of communities, on infrastructure to reduce the risk of extreme events, or on new technologies (UNFCCC 2007). There is also growing recognition of the role that healthy ecosystems can play to enhance resilience and help people adapt to climate change. Table 6 outlines different types of climate change adaptation that focus on water resources and agriculture.

| Type of adaptation | Description | Benefits | Constraints | Example |
|---|---|---|---|---|
| Institutional, legal | Strengthening institutional capacities at all levels, including the definition of responsibilities and powers and the allocation of resources. | • Incorporates adaptation in the planning and land use management processes.<br>• Strengthens institutional capacities. | • There is a high degree of uncertainly for decision making in terms of the range and intensity of climate change.<br>• Requires political will, leadership, accountability, political/social justice, and social empowerment. | • Climate Change Adaptation Through Effective Water Governance Project in Ecuador (PACC). |
| Infrastructure | Improving the resilience of infrastructure (both new and existing). | • Improves disaster risk management.<br>• Synergies with mitigation, for example, in energy and transport infrastructure. | • High investment and maintenance costs.<br>• May have implications on land use, water quality and biodiversity (maladaptation). | • Changes in infrastructure for perennial crops (irrigation, drainage). |
| Technology | The use of innovation to improve existing processes and systems for greater efficiency. | • Increases resilience through the use of appropriate technology that permits better management of ecosystems and their services. | • May contribute to increasing competition for resources.<br>• Requires capacity building for the use and management of these technologies.<br>• High cost of implementation on significant scales. | • Implementation of early warning systems.<br>• Research on new crop varieties . |
| Financial | The provision of financial resources and incentives for risk sharing and transfer or improving the social and ecological bases of vulnerable systems. | • Reduces the impact (mainly economic) of adverse weather conditions on human development levels. | • Requires the existence of an effective financial structure.<br>• Tends to be inaccessible for the most vulnerable groups. | • Index insurance.<br>• Microfinance. |
| Ecosystem-based adaptation (EbA) | The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at local, national, regional and global levels. | • Generates social, economic, environmental and cultural benefits while contributing to the conservation of biodiversity. | • Requires structural changes in productive and development activities.<br>• Lack of information and dissemination of successful initiatives. | • Agroforestry systems.<br>• Family orchards.<br>• Soil restoration.<br>• Biological corridors. |
| Community-based adaptation | A process led by the community, based on its own priorities, needs, knowledge and capacities, which empowers people to plan for and overcome climate change impacts. | • Creates a sense of ownership, generates awareness and commitment to adaptation projects.<br>• Provides local solutions that are accessible for the community | • Requires will, organization and local capacity.<br>• Does not explicitly emphasize the need to conserve the ecosystem services on which the most vulnerable livelihoods depend. | • Community training in the maintenance of tree nurseries, participatory management, environmental governance, and seed collection and management. |

*Table 6. Comparison of different types of adaptation. Developed by the authors based on various documents.*

Generally speaking, an adaptation measure is more effective in reducing the vulnerability of social and ecological systems when it is implemented in conjunction with a wide portfolio of complementary measures. For example, the reduction of vulnerability to floods is more effective if, in addition to the construction of a flood wall (infrastructure), efforts are made to re-establish flood plains (EbA) and a land use policy is implemented to prohibit or limit the building of settlements in areas prone to flooding (institutional). Moreover, the multifaceted nature of climate change impacts (economic, social, political, environmental) highlights the need for the mainstreaming of adaptation. In other words, adaptation measures should not be seen as specific, isolated actions or additional efforts, but rather, climate change adaptation goals, strategies, policies, measures or operations should be integrated into national and regional development policies, processes and budgets, at all levels and all stages.

Adaptation should not be viewed as a specific project, but rather as an iterative and accumulative learning process, in which experiences are incorporated in the design and implementation of new actions. For this reason, the implementation of adaptation projects is normally carried out in different stages, which include information gathering, awareness raising, the planning and design of the measure, the implementation of the measure itself, and monitoring and evaluation (see Figure 13).

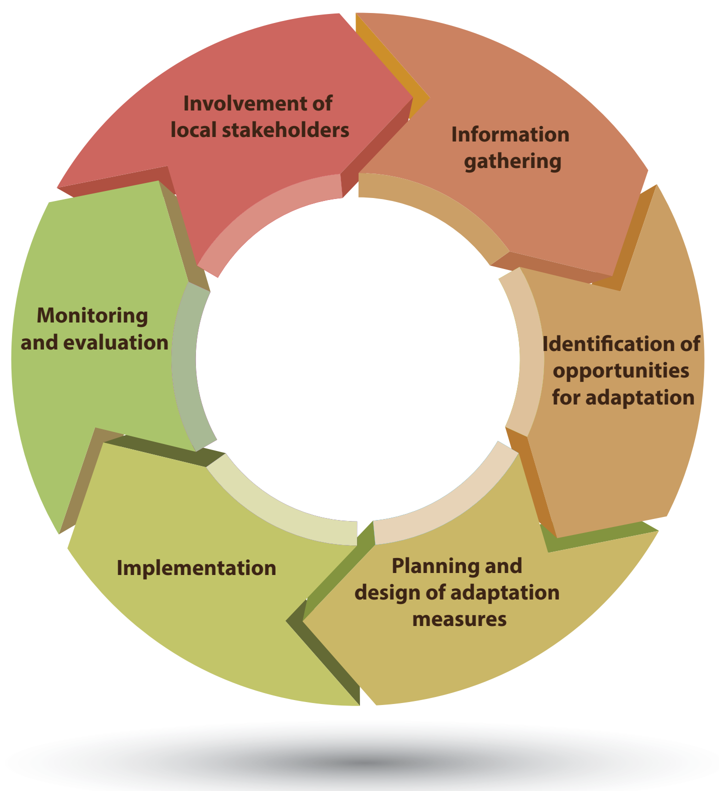



*Figure 13. Stages of the adaptation process. Source: Developed by the authors.*

## 3.2. Ecosystem-based adaptation

On one hand, the synergistic effects of climate change, production patterns and practices, and economic development are the main causes of the alteration and degradation of ecosystem services, and it is very likely that these effects will continue to intensify in the future (Millennium Ecosystem Assessment 2005). On the other hand, healthy and well-managed ecosystems can help to increase the resilience of communities and help them to adapt to climate change. In view of this connection, ecosystem-based adaptation (EbA) has emerged as an interesting option to face climate change.

### Box 3. Case study on Ecosystem-based Adaptation in the Peruvian Andes

The Nor Yauyos Cochas Landscape Reserve, located in the regions of Lima and Junín in the Peruvian Andes (2780 to 5750 metres above sea level), is the pilot site for the implementation of the Mountain Ecosystem-based Adaptation Project, commissioned by the Ministry of Environment of Peru.[1]

The most extensive ecosystems on the reserve, which provide the largest number of services to the population, are wetlands and puna grasslands/shrublands. In particular, they provide water and pasture, and are therefore a fundamental means of support for livestock production, the region's main economic activity. As a consequence, they are also the ecosystems most pressured by extensive livestock grazing, and potentially the most seriously threatened by the adverse effects of climate change.

Three sets of climate change adaptation measures are being implemented in the reserve:

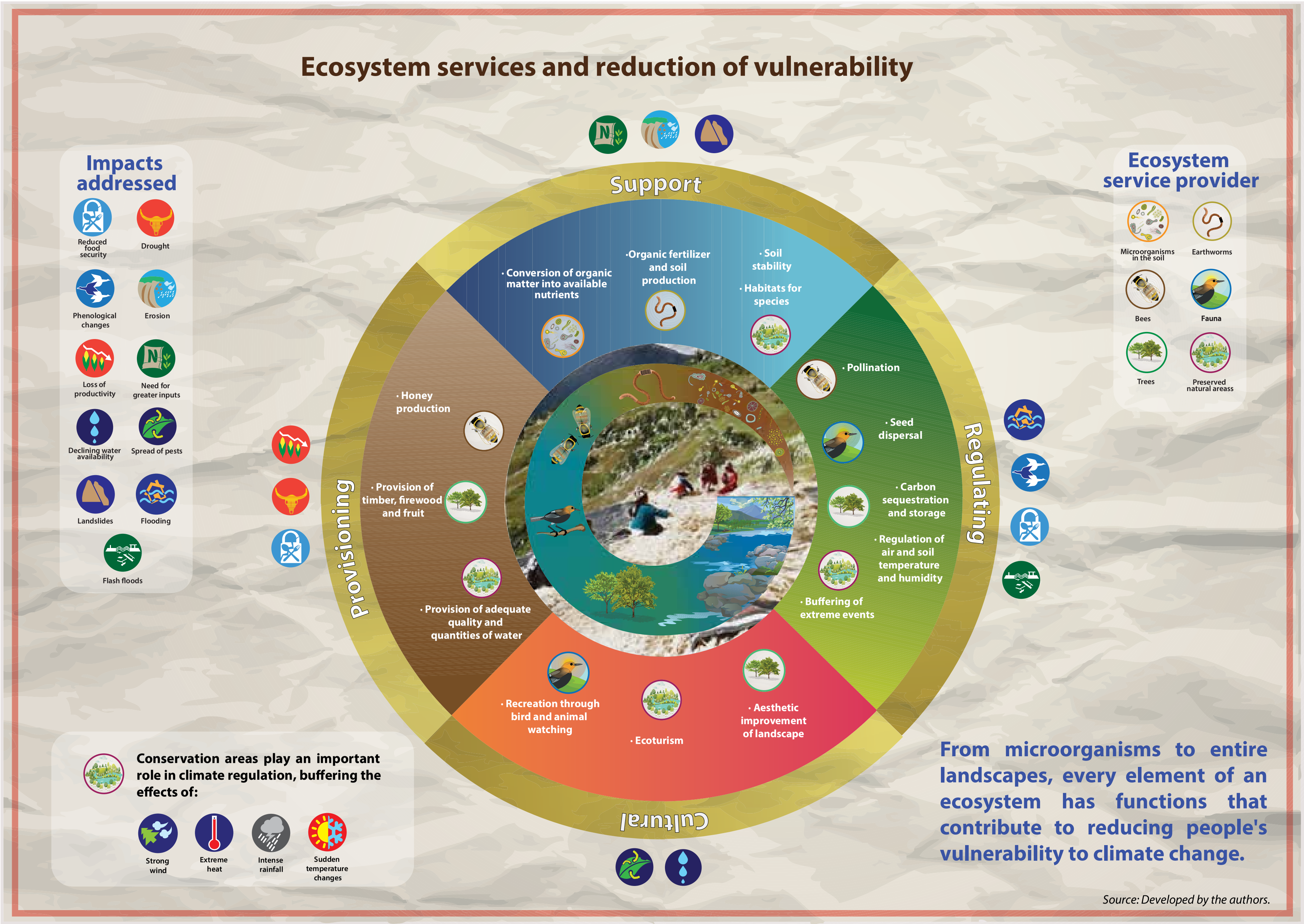
- **Vicuña management in the district of Tanta.** Involves the conservation of natural grasslands for vicuña grazing and the shearing of the animals for fibre production. Promotes the recuperation of puna grasslands and wetlands.
- **Community-based management of natural grasslands.** Includes livestock management and zoning to promote conservation areas. Reduces pressure on the grasslands and wetlands.
- **Improvement of ancestral water infrastructure in the districts of Miraflores and Canchayllo.** Includes the conservation of the headwaters of micro-watersheds. Promotes proper water regulation.

These measures, prioritised using different methods, approaches and processes, are aimed at reducing the pressure of livestock grazing on grasslands and wetlands by developing sustainable livestock management within the reserve.

In the meantime, the water produced by the reserve's ecosystems is used for electricity production and agricultural activities downstream, which also benefits the populations in faraway areas. Therefore, maintaining the health of the reserve's ecosystems ensures the future provision of water for the economic activities of these populations.

*Source: Proyecto de Adaptación basada en Ecosistemas de Montaña. Parte del Programa Global Ecosystem based Adaptation (EbA). Retos y oportunidades de adaptación al Cambio Climático en la Reserva Paisajística Nor Yauyos Cochas, Perú. Proyecto EbA Montaña, 2014. http://www.pnuma.org/eba/Brochure_EbA%20Montana_Final.pdf*

1 The Mountain Ecosystem-based Adaptation Project (EbA) is a collaborative initiative of the United Nations Environment Programme (UNEP), the International Union for the Conservation of Nature (IUCN) and the United Nations Development Programme (UNDP), funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of Germany (BMUB). In Peru, the programme is commissioned by the Ministry of Environment (MINAM) and is implemented in the Nor Yauyos Cochas Landscape Reserve with the support of the National Service of Natural Protected Areas (SERNANP). The activities under the IUCN's responsibility are implemented in partnership with The Mountain Institute (TMI) in the communities of Canchayllo and Miraflores.


Ecosystem services and reduction of vulnerability
Impacts addressed
Reduced food security
Drought
Phenological changes
Erosion
Loss of productivity
Need for greater inputs
Declining water availability
Spread of pests
Landslides
Flooding
Flash floods
Support
· Conversion of organic matter into available nutrients
·Organic fertilizer and soil production
· Soil stability
· Habitats for species
Regulating
· Pollination
· Seed dispersal
· Carbon sequestration and storage
· Regulation of air and soil temperature and humidity
· Buffering of extreme events
Cultural
· Recreation through bird and animal watching
· Ecoturism
· Aesthetic improvement of landscape
Provisioning
· Honey production
· Provision of timber, firewood and fruit
· Provision of adequate quality and quantities of water
Ecosystem service provider
Microorganisms in the soil
Earthworms
Bees
Fauna
Trees
Preserved natural areass
Conservation areas play an important role in climate regulation, buffering the effects of:
Strong wind
Extreme heat
Intense rainfall
Sudden temperature changes
From microorganisms to entire landscapes, every element of an ecosystem has functions that contribute to reducing people's vulnerability to climate change.
Source: Developed by the authors.

EbA measures are generally cost-effective. In addition to their role in reducing the vulnerability and increasing the resilience of biodiversity, they usually generate valuable additional benefits, such as:

- **Disaster risk reduction.** Healthy ecosystems play an important role in the protection of infrastructure and human security, acting as natural barriers or reducing agro-climatic risks. For example, conservation and maintenance of plant cover in mountainous regions can reduce the risk of landslides and flooding during intense rainfall.

- **Sustenance of livelihoods and food security.** The maintenance and sustainable management of ecosystems guarantee the provision of crucial services for people's well-being and livelihoods. For example, a healthy agro-ecosystem contributes to feeding the community while also providing economic resources.

- **Carbon sequestration.** EbA strategies can complement and enhance climate change mitigation actions. The sustainable management of forest ecosystems contributes to carbon capture and storage, in addition to maintaining ecosystem services like the provision of food, fibre and water.

- **Water availability.** Managing, restoring and protecting ecosystems can also contribute to the provision of water for various uses; for example, by improving water quality and increasing groundwater recharge.

  (Lhumeau and Cordero 2012).

In the framework of the Microfinance for Ecosystem-based Adaptation (MEbA) project, the following five criteria were used to identify EbA options that can be promoted through microfinance products:

1. Reducing pressure on ecosystems and the services they provide.

2. Enhancing the social or economic resilience of human populations vulnerable to climate change.

3. Reducing risks associated with climate events in production activities.

4. In their implementation, protecting, restoring or using biodiversity and ecosystems in a sustainable manner.

5. Having a positive impact on individuals' economy in the short term.

## Box 4. Agricultural terraces

**Impacts addressed:**

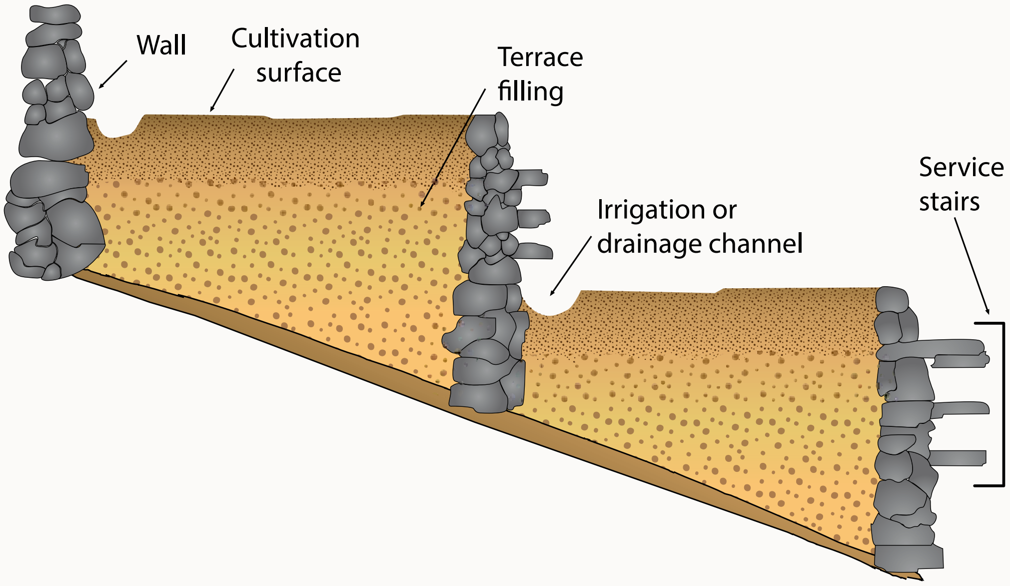
- Landslides
- Reduced food security
- Erosion

**Scale of measure:**
Collective – Aimed at groups with common interests.

**Focus:**
Investment – Results in higher yields or additional income in the short term.
Support – Intended to increase the resilience of the system, contributing to greater stability in the face of climate or market fluctuations over the medium and long term.

**Estimated time for results:**
Up to 1 year.

**Description:**
The ancient Andean technique of terracing consists of making cuts in steep slopes to establish cultivation surfaces that are supported by stone walls. Because the terraces are positioned perpendicular to the flow of water, they allow the water to infiltrate the soil slowly, thereby raising the soil moisture content. At the same time, they reduce erosion and retain soil. In addition to this, they also increase the cultivation surface. Altieri (1999) reports that after terraces were restored in a project in Peru, the first yields increased by between 43% and 65% for potatoes, maize and barley, compared with conventional hillside cultivation.




*Source: UNEP and Frankfurt School (2013).*

## Box 5. Crop diversification

**Impacts addressed:**

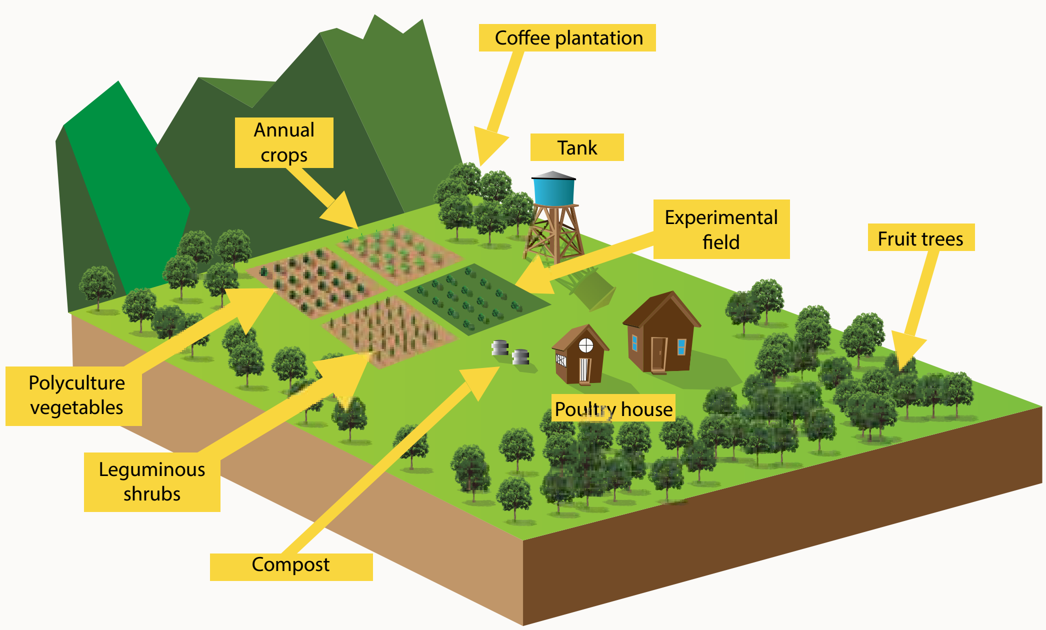
- Reduced food security
- Crop failure
- Spread of pests

**Scale of measure:**
Individual - Intended for family units or persons striving to meet their own needs.

**Focus:**
Investment – Results in higher yields or additional income in the short term.

**Estimated time for results:**
Up to 1 year.

**Description:**
Crop diversification refers to growing various agricultural products on a single plot, especially two or more crops in alternating rows. Depending on the mix of crops, diversification can achieve several objectives, including controlling herbivorous insects and more efficiently using horizontal and vertical spaces in a plot. Diversified systems are generally more resilient than monoculture systems.




*Source: UNEP and Frankfurt School (2013).*

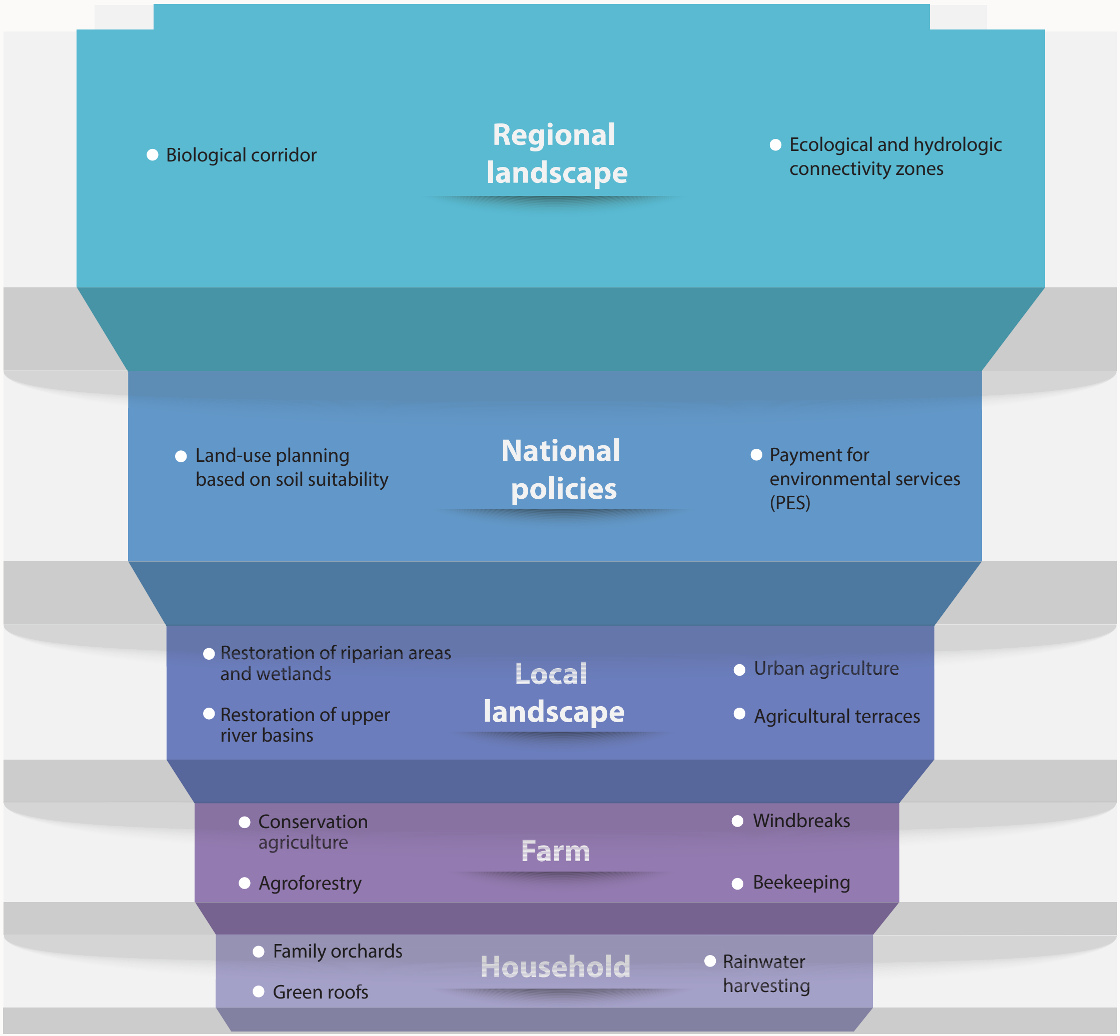



*Figure 14. Examples of Ecosystem-based Adaptation measures at different scales. Source: Developed by the authors.*

EbA measures include different activities for the sustainable management of ecosystems, such as integrated water management for the regulation of water flows, the restoration of ecosystems (wetlands, forests) for disaster risk reduction (protection against flooding), and the diversification of agricultural production to cope with changing climate conditions (adaptation of crops and livestock to climate variability) (see Boxes 4 and 5). It should be stressed that ecosystem-based adaptation goes beyond local-level and landscape-scale strategies. In fact, an ecosystem approach can be mainstreamed into the design of sectoral policies and a long-term vision of adaptation. In accordance with national capacities and circumstances, EbA concepts can be integrated into pertinent higher-scale instuments, such as adaptation policies, plans and strategies at the national and regional level. Examples include national action strategies on biological diversity, biological corridors, disaster risk reduction strategies, and sustainable land management strategies (see Figure 14).

## 3.3. The role of microfinance in promoting ecosystem-based adaptation

Since its creation in the late 20th century, microfinance has been viewed as a tool for combating poverty. The concept that gave rise to the microfinance industry was the idea that the provision of small loans to populations with limited resources could help them to raise their socioeconomic level and overcome poverty. Over the years, this concept has expanded, and now microfinance institutions (MFIs) offer a range of products and services in addition to loans, including savings accounts, national and international transfers as well as micro-insurance. The microfinance industry believes that the socioeconomic improvement of its customers will translate into social empowerment in the future.

### Microfinance approaches

As in any other field, there are various different approaches and concepts in the field of microfinance. In the early 1980s, competition arose between two main microcredit approaches – subsidized and commercial – but today commercial microfinance predominates. The basic idea is that the potential for development with the use of financial products and services can only be fully exploited through market mechanisms.

In the meantime, there are also different approaches in terms of how to reach end-customers. Due to the growing diversification of customer segments, business models for serving them also vary. Added to this diversification of market segments, there is also greater competition among financial service providers seeking to penetrate markets that are still not saturated. With regard to credit, for example, there is a distinction between the provision of individual loans and loans to groups of debtors with a shared responsibility for repayment. In terms of competition, banks and banking networks that are downscaling their operations now compete with regulated and non-regulated microfinance institutions. The emerging area of electronic financial services promises to provide innovative solutions in the near future, as increasing connectivity in developing countries puts technology-based solutions within reach of most institutions in the field (Alexandre *et al*. 2011).

There are also different approaches to segmenting the market to serve end-customers. Improper segmentation can cause shortfalls in fulfilling an organization's objectives, in performing against the competition, and in satisfying the needs of customers. Customer segments can be defined by their characteristics: level of debt, business size, number of assets, employees or sales. Another example of segmentation is geographic, where urban and peri-urban markets compete with rural markets. Due to differences such as greater population density, greater ease in serving customers thanks to better infrastructure, and a perception of lower risk, urban and peri-urban markets are more attractive to financial institutions and are usually better served than rural markets (Cainey and Hagens 2008).

### Microfinance in Colombia and Peru

The Andean region of Colombia and Peru is inhabited by a population that has limited economic resources and is highly dependent on agriculture. This places the Andean population at a high level of vulnerability to climate change. Both the IPCC and the Climate Change Knowledge Network (CCKN) have stated that low-income populations will suffer most from the effects of climate change and are in the worst conditions for adaptation. One of the main reasons for this high degree of vulnerability is the limited availability of economic resources. A positive link has been identified between economic resources and adaptive capacity. This means that any attempt to find a way for the poor to reduce their vulnerability must

| | Perú | Colombia |
|---|---|---|
| **Number of MFIs**[*1,*] | 72 | 42 |
| **Number of borrowers**[1,*] | 3.7 million | 2.4 million |
| **Borrowers as % of the population**[1,*] | 12.2% | 5.0% |
| **% of the population (15+ years) with a bank account in a formal institution in the last year**[1]**:** | 20% (2011) | 30% (2011) |
| **% of the population (15+ years) with savings in a formal institution in the last year** [1]**:** | 9% (2011) | 9% (2011) |
| **Loans granted**[2] | 10.7 billion (USD) | 6.75 billion (USD)* |
| **Deposits**[2] | 9 billion (USD) | 5.5 billion (USD)* |
| **Number of depositors**[2] | 4.6 million | 6.1 million |

* Data from MFIs that report to MIX. Table updated in September 2014 with most recent data available. In the case of Colombia, the Bancolombia portfolio was not included in order to facilitate comparison.
1 Source: CGAP microfinance portal.
2 Source: MIX Market.

*Table 7. The microfinance industry in Colombia and Peru.*

begin with promoting access to resources geared to build adaptive capacity (IFAD 2013).

In the 1980s, when the municipal savings and credit unions known as Cajas Municipales de Ahorro y Crédito (CMACs) (assisted by GTZ – now GIZ – and IPC)[5] initiated the microfinance movement in Peru (FEPCMAC 2012), it could be seen that when marginalized populations were provided with access to financial resources, they found a way to lift themselves out of poverty and improve their standard of living. This relationship observed between the provision of funds and improvement in people's quality of life demonstrates that microfinance is an effective tool for combating poverty.

To date (September 2014) a global portfolio of USD 94.5 billion in microfinance credit has been reported (MIX Market 2014). Peru specifically was named for the sixth consecutive year as the country with the best microfinance environment in the world (CGAP, 2014). The country has 72 MFIs that serve 3.7 million borrowers (12.2% of the population), who have been granted a total of USD 10.7 billion in loans.

For its part, Colombia was ranked in seventh place in the same classification by *The Economist Intelligence Unit*. The country has 42 MFIs that serve 2.4 million borrowers. This figure represents 5% of the population, who have received USD 6.75 billion in loans, maintaining deposits of USD 5.5 billion (CGAP 2014; MIX Market 2014; EIU 2013).

[5] IPC – Internationale Projekt Consult (Consultora de Proyectos Interdisciplinarios - FEPCMAC)

## Microfinance and climate

While most rural customers are exposed to climate risks because they depend directly or indirectly on agricultural activities, the analysis of this type of risk is generally not included in the credit risk methodology of MFIs. Their methodologies are often based on individual credit assessments, carried out by a loan officer or customer advisor, verified through an in situ visit and based on decentralized decision-making structures.

Agricultural microfinance is not only susceptible to the same risks as any other financial sector, but must also, due to its nature, deal with agriculture-specific risks. This means that in addition to the typical risks, such as moral hazard (when the fulfilment of the obligation is in doubt), adverse selection (when the estimation of the economic capacity of the borrower to pay back the loan is incorrect) or principal-agent problems (due to differing interests between the parties), risks inherent to agricultural activities (weather, crop productivity) must also be taken into account. Box 6 analyzes the concept of risk in the context of microfinance and agriculture.

However, the complexity of the interrelations between climate and the development phases of a plant, for example, is not manageable at the level of an individual assessment, conducted by business personnel with little training. Larger and more complex amounts of data and levels of knowledge are required. This is why the inclusion of climate risks, and consequently of climate change, in the daily activity of the microfinance industry requires more sophisticated data management solutions. In general, the management of data related to both the market (prices of inputs and products) and climate projections (changes in temperature and precipitation) plays a more important role in agricultural microfinance than in an urban/commercial context.

Moreover, in order to identify customers' needs and develop tailor-made products, it is crucial to understand their current situation. This entails identifying which climate risks have most affected the target population in each area of operation, as well as identifying the effects of these risks. This information can be obtained by gathering data from the daily operations of MFIs. Once the risks have been identified, it is possible to develop products that are better adapted to the needs of their customers.

Given the nature of microfinance – a high volume of transactions involving small amounts of funds – there is significant potential for the replication of small-scale actions geared to ecosystem-based adaptation, which together can achieve substantial large-scale changes. Success will depend on the way in which efforts simultaneously tackle the need to standardize administrative, operational and organizational processes and to provide specific solutions to address individual production risks of customers. The promotion of the well-being of the ecosystems in their immediate environment and the improvement of production practices guarantees a sustainable solution that goes beyond the known borders of the industry.

Better management and development of this emerging market can be supported and fostered through one or several of the following solutions aimed at helping customers adapt to climate change:

1. **Proper market segmentation**. Identifying the shared needs of groups of customers makes it possible to offer microfinance services that cover common requirements (for example, for groups of customers who share similarities in the crops they grow, the climate risks they face and the production methods they use, or who form part of the same community). This will make it possible to create value for customers by giving them the opportunity to choose the option best suited to their needs from a series of previously approved products.

2. **New credit methodologies**. The incorporation of more data, including both market data and data related to climate projections and the phenological development of typical crops, can be achieved through the use of information and communications technology (ICT) solutions. As smart devices become increasingly accessible, the amount of data available will consistently continue to grow. A better understanding of the market could enhance the provision of products and services of value to the target customers.

3. **Awareness raising.** Increased awareness of the existence of feasible strategies for ecosystem-based adaptation will result in greater demand for these types of alternatives. MFIs can strengthen their target market through tailored operations and solutions.

4. **Training.** Through strategic cooperation with educational and technical service providers, MFIs can promote improvements in production processes and build capacity.

5. **Verification and monitoring.** Through the data provided by methodologies adjusted for climate variables and clear criteria on the practices promoted, MFIs can guarantee their investors triple bottom line returns (environmental, social and economic benefits) in a transparent manner.

## Box 6. Risk in the context of microfinance and agriculture

Generally speaking, risks in agriculture are associated with the challenges and risks of agricultural production and marketing from the perspective of the farmer (real sector view), while risks in agricultural finance reflect the challenges and risks of lending to farmers from the viewpoint of a financial institution (financial sector view). Both types of risk are interlinked, and agricultural production risks determine to a large extent the financial sector risks of agricultural lending. In fact, the high risks in agricultural finance are commonly quoted as the main constraint inhibiting financial institutions from lending to agriculture.

According to Baquet *et al*. (1997), there are five main sources of agricultural risks that can be defined as follows (OECD 2009):

- **Production risk:** Concerns variations in crop yields and in livestock production due to weather conditions, diseases and pests.

- **Market risk:** Related to variations in commodity prices and quantities that can be marketed.

- **Financial risk:** Refers to the ability of farmers to pay bills when due, to have money to continue farming, and to avoid bankruptcy.

- **Legal and environmental risk:** Concerns the possibility of lawsuits initiated by other businesses or individuals and changes in government regulation related to the environment.

- **Human resources risk:** Relates to the possibility that family or employees will not be available to provide labour or management to the farming business.

Among the risks that more specifically affect agriculture, there are production risks (due to bad weather, pests and diseases), as well as market risks. In recent years, climate change has appeared as an additional risk category.

In the meantime, risks in agricultural financing can generally be grouped into three categories:

- **Principal credit risks:** These essentially refer to the ability and the will of the borrower to repay the loan. In the case of both small farmers and small enterprises in general, this ability represents a risk since these sectors tend to be characterized by a high degree of informality and low levels of education and financial literacy, and few are able to produce financial statements.
- **Specific risks related to agriculture:** The high production and market risks that can ultimately affect the ability of small farmers to repay their loans.
- **Political risks:** The risks related to government interference in the sector, given the strategic importance of agriculture for ensuring the population's food security.

*Source: Maurer (2010)*

## The MEbA project

The MEbA project seeks to address each of the abovementioned solutions through the transfer of knowledge to partner MFIs. The mission of the MEbA project is to provide options for sustainable management of ecosystems and their services through microfinance products and services. The central objective is to enhance the resilience to climate change of vulnerable populations in the Andean region of Colombia and Peru, which are primarily comprised of small farmers.

The project's basic approach focuses on integrating a better understanding of climate risk variables in the credit methodology of MFIs. On one hand, it seeks to improve financial risk management to increase understanding of the market and thereby increase the incentive to penetrate it. The information generated will not only allow for improved risk management by the MFIs, but will also be valuable for the customers. On the other hand, farmers will be presented with options for ecosystem-based adaptation that will allow them to reduce their climate and production risks through better agricultural practices, income diversification and maintenance of the ecosystem services that sustain their activities. In the future, risk-adjusted pricing, tailor-made products and enhanced services based on the smart use of climate data may become available through the consolidation of initiatives promoted by the project.

The MEbA project serves to achieve the integration of financial products with the promotion of development for the rural population and the added value that the positive impacts of EbA activities last beyond the term of the loan. For small farmers, an important benefit is the greater access to financial resources. In addition, the possibility of reducing production risk not only benefits farmers through improved crop yields and income, but also contributes to decreasing the financial risk of the MFIs due to more stable financial flows of repayment. The MFIs additionally benefit from expanding their market participation and reaching populations that they did not formerly serve.

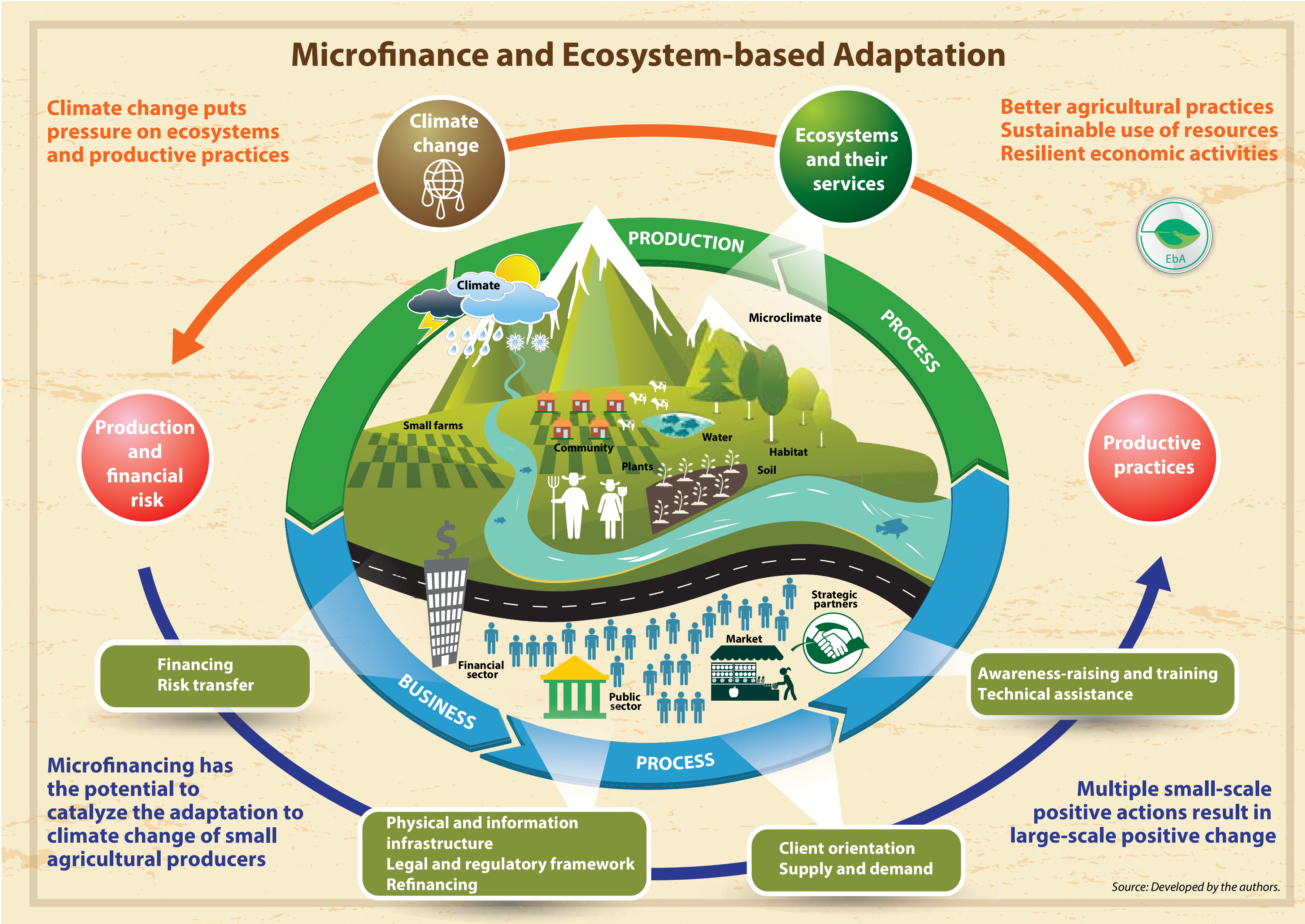
In the future, the availability of more data and greater knowledge of target customers should lead to greater sophistication of the market. Incentives for EbA can be promoted via risk-adjusted pricing: if the customer's individual risk is more accurately assessed and their current and future adaptive capacity (for example, after the successful implementation of an EbA measure) is taken into account, prices can be adjusted more adequately. In simple terms, more resilient clients should receive more accessible loans.

In order to capitalize on this opportunity and decrease the production risks inherent to agriculture, MFIs are being supported in the design of financial instruments that promote the development of small farmers and reduce the climate risks they face. This translates into the development of MEbA financial products. When MFIs promote the use of EbA measures, they are not only helping their customers, by offering options to reduce their vulnerability, they are also helping themselves, by improving the possibilities of loan repayment and expanding their customer base.

## MEbA products and services

MFIs know their customers' needs and their behaviour with regard to loans and other financial services they offer. On this basis, MFIs will have the tools required to offer products that better suit the needs of their customers while promoting sustainable adaptation.

MEbA products and services are microfinance instruments that aim to promote or support EbA strategies. Because they are similar in nature to the financial products already offered for the agricultural sector, MFIs can promote MEbA products and services in the same way they currently promote agricultural loans. MEbA products and services will be classified in segments based on the term of the loan and the type of activity it will finance. The existing types of products in which EbA options will be included are:




*Source: Developed by the authors.*

1. **Working capital loans (short-term):** Loans to finance investment in working capital such as inputs, seeds and organic fertilizer, among others. Repayment will be made on the basis of a crop harvest – that is, during a single growing season.
2. **Fixed asset loans (medium-term):** Longer-term loans to finance investment in fixed assets such as equipment, machinery and tools, among others. These are loans made on the basis of several economic activities, and so their repayment is typically scheduled over the course of several seasons.
3. **Community loans (short-to-medium-term):** Loans for community investments.
4. **Additional services ("MF+"):** Training and capacity building for customers or groups of customers, offered by the institution itself or through information exchange with strategic partners, aimed at promoting sustainable productive activities.
5. **Others:** Once greater experience has been accumulated, products like micro-insurance, savings plans and others could be considered, but these will depend on the introduction of the initial products.

## Public policies

While the actions promoted by MFIs can have significant positive effects on the quality of life of their customers and the maintenance of ecosystem services, a policy framework is needed to support the continuous and coordinated participation of the private sector in adaptation. This is due to the fact that the public financing available is not sufficient to meet the needs of vulnerable populations for protecting their economic activities from potential negative impacts or taking advantage of the market opportunities that emerge as a result of climate change. Public-private partnerships are key, and the more that the different roles and responsibilities are explicitly laid out in national, sectoral and local plans and policies, the easier it will be to bridge the financing gap and attend to the needs of the most vulnerable.

The MEbA project is working with different government actors in Peru and Colombia to promote the inclusion of the microfinance sector as a strategic partner to help catalyze sustainable climate change adaptation processes. Given the innovative approach and potential for replication of the actions promoted by the project, the governments of these countries have been receptive to providing greater space for collaboration with MFIs in the public policy instruments being developed in the areas of climate change, agriculture and the environment. These kinds of partnerships can lead to greater access to information, training and financing to improve the current and future conditions of small farmers.

On an international level there is also scope for fostering greater private sector involvement to promote sustainable schemes such as ecosystem-based adaptation. Forums like the 20th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COP 20), hosted by Lima in 2014, are key opportunities for reaching common positions that strengthen the links between governments and financial actors, with the shared goal of improving the environmental, social and economic returns on their investments.

# Conclusions



Climate change is the result of the model of economic growth in recent centuries. The economic activities of humans (from the production of food to the provision of financial services) depend to a large extent on the use of fossil fuels (fertilizers, transport, electricity). The burning of hydrocarbons and land-use conversion to other purposes (such as agriculture) produce emissions of greenhouse gases, primarily $CO_2$.

Plans of action to confront climate change require measures aimed at both mitigation (to reduce emissions) and adaptation (to prevent negative impacts and take advantage of opportunities). Adaptation measures focus on reducing the vulnerability of people, infrastructure and livelihoods. Vulnerability is determined by a population's environmental and socioeconomic conditions, as well as the climate risks to which it is exposed. In this context, ecosystem-based adaptation is a sustainable alternative to enhance the resilience of rural populations, and specifically small farmers.

There are positive and negative synergies between climate change and land-use change. The conversion of forests to other land uses is the second leading cause of global GHG emissions, surpassed only by electricity production. In addition to reducing emissions, the improvement of agricultural practices reduces pressure on ecosystems and the services they provide, which are essential for agricultural production. Investments made today will have lasting effects on food security and equitable development in the Andean region. In addition, the diversification of income sources and economic activities strengthens the socioeconomic resilience of communities. Strategies for the conservation of the natural environment and diversification of production are key for the development of communities in the face of climate change. Sustainable development in rural areas is not possible without taking into account the positive or negative impacts of production practices in environmental, social and economic terms.

Agriculture in the Andean region of Colombia and Peru can suffer significant impacts from the manifestation of climate risks in production systems. One example of this is the change in areas suitable for the cultivation of crop varieties currently grown. Adaptation is an iterative and accumulative process, in which it is essential to develop capacities at multiple levels, from the formulation of public policies to the application of technological solutions and traditional knowledge.

There are ecosystem-based adaptation options that can be promoted through microfinance products and services, but they require training, technical assistance and knowledge transfer, and the products must be geared to the customer's needs. Due to the service it provides to the most vulnerable populations, the microfinance industry is a strategic ally for promoting sustainable adaptation processes and establishing partnerships to strengthen the sector. By contributing to the reduction of climate risk through sustainable agriculture, MFIs will gain a more resilient portfolio of customers and reduce the financial risks of investing in the rural sector. The MEbA project offers technical assistance for the development of microfinance products and services geared to ecosystem-based adaptation.

# Glossary

This glossary was compiled from the sources consulted for the preparation of this publication and other available resources, particularly GEO-5 (UNEP 2012), the IPCC (2014a) and the CBD (2009).

**Adaptation**
Adjustment in natural or human systems to a new or changing environment, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (UNEP 2012).

**Adaptive capacity**
The ability of a system [human or natural] 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 (IPCC 2014a).

**Agro-ecosystem**
Agro-ecosystems are ecosystems in which humans have exercised a deliberate selectivity on the composition of living organisms. Agro-ecosystems are distinct from unmanaged ecosystems as they are intentionally altered, and often intensively managed, for the purposes of providing food, fibre and other products; hence they inherently have human community, economic and environmental-ecological dimensions (FAO 2008).

**Climate**
Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (IPCC 2014a).

**Climate change**
A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2014a).

**Climate variability**
Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC 2014a).

**Ecosystem**
A dynamic complex of plant, animal and micro-organism communities and their non-living environment, interacting as a functional unit (UNEP 2012).

**Ecosystem-based adaptation (EbA)**
The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change (CBD 2009).

**Exposure**
The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC 2014a).

### Global warming potential (GWP)

An index, based upon radiative properties of well mixed greenhouse gases, measuring the radiative forcing of a unit mass of a given well mixed greenhouse gas in today's atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide. The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation. By convention, the GWP of $CO_2$ is 1 (IPCC 2014a).

### Greenhouse effect

A process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of the gases (UNEP 2012).

### Hazard

The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC 2014a).

### Impact (climate change)

The effects of climate change on natural and human systems (IPCC 2014a).

### IPCC SRES scenarios

Six future-emission scenarios based on four scenario families, A1, A2, B1 and B2, where A represents globalized development, B represents regionalized development, while 1 refers to economic growth and 2 refers to environmental stewardship (UNEP 2012).

### Mainstreaming (adaptation)

The integration of adaptation objectives, strategies, policies, measures or operations such that they become part of the national and regional development policies, processes and budgets at all levels and stages (UNEP 2010).

### Mitigation (climate change)

The implementation of policies to reduce greenhouse gas emissions and enhance sinks (IPCC 2014a).

### Resilience

The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC 2014a).

### Sensitivity

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate 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) (IPCC 2014a).

### Vulnerability

The degree to which a system is susceptible to, and 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 change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2007).

Coffee producers, Villa Rica, Peru. Photograph C. Membreño

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MEBA
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Supported by:

Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

based on a decision of the German Bundestag