CLIMATE CHANGE AND COEXISTENCE WITH THE BRAZILIAN SEMIARID REGION

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Map of areas undergoing desertification in the Brazilian semiarid region: kindly provided by the Satellite Image Analysis and Processing Laboratory – Lapis, from the Federal University of Alagoas – UFAL (Project funded by the National Council for Scientific and Technological Development – CNPq; process: 311079/2017-2)

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SUMMARY

INTRODUCTION

In few sectors the need to adapt to climate change is as urgent as it is in Family Agriculture. On the one hand, this sector is largely dependent on climatic and environmental conditions; on the other hand, family farmers are among the populations most vulnerable to climate change, poverty, and food insecurity. Thus, increasing their adaptive capacity is essential.

Climate projections for the Northeast and the Semiarid regions indicate an increase in temperature, with expected negative impacts including reduced productivity of agricultural crops, lower farmers' income, as well as water and food insecurity. In this context, the projects of the International Fund for Agricultural Development (IFAD) in Brazil have implemented a series of adaptive solutions, technologies and innovative techniques for coexistence with the semiarid climate, such as rainwater collection and storage, greywater reuse, agroforestry systems, creole seed banks, in addition to training and technical assistance to poor farmers. By adopting these strategies to adapt to climate change large-scale, Family Agriculture plays a fundamental role in protecting soils, ecosystems and biodiversity, as well as in helping to sequester carbon, reduce poverty, and promote food and nutrition security.

Although poor farmers – especially women, young people, traditional peoples and communities, priority groups for IFAD's work – are the most vulnerable to the adverse effects of climate change, they are key in building a resilient future. IFAD, through its action in the Northeast, will remain as a partner for the implementation of climate-resilient solutions and innovations.

Hardi Michael Wulf Vieira
Program Officer of the International Fund for Agricultural Development – IFAD

Chapter 1
Agriculture and Climate Change

“Senhor, eu pedi para o sol se esconder um tiquinho
Pedir pra chover, mas chover de mansinho
Pra ver se nascia uma planta no chão”
(Súplica Cearence – Luiz Gonzaga)

Favorable climatic conditions are crucial to successful agriculture, from preparing the soil and sowing to selling the produce. Each crop has specific soil and air humidity, temperature, and water requirements for the different stages of its development. Even with all the technological innovations used in the sector, rain and temperature are still very important factors for the agricultural production process, and they account for a significant portion of productivity. Climate is the “input” of which farmers have the least ability to have control. For this reason, knowing the climatic variations in advance facilitates decision-making, which minimizes risks and increases the chances of having higher productivity and income.

Several studies have shown that the climatic conditions of the planet are changing rapidly, especially in the last forty years[1]. This process, called climate change, has been causing damage to the agricultural sector with negative effects on global food security. Losses in agriculture reduce food availability and diversity, which aggravates undernutrition, mainly among the poorest families[1]. Therefore, understanding climate change is key for planning farmers' activities.

Climate change is the long-term change in the global or regional climate. According to the Intergovernmental Panel on Climate Change (IPCC), it is considered climate change when the historical pattern of a given variable – temperature, for instance – has been changing over a long period (decades or centuries)[2]. For a better understanding of this concept, it is important to highlight the difference between climate and weather. The latter refers to short-term manifestations – in days or weeks, for example – of climatic variables (temperature, rainfall, cloudiness, etc.). Climate, on the other hand, is a long-term, global, or regional pattern of weather; in other words, the "average" of climate variables over several years[3].

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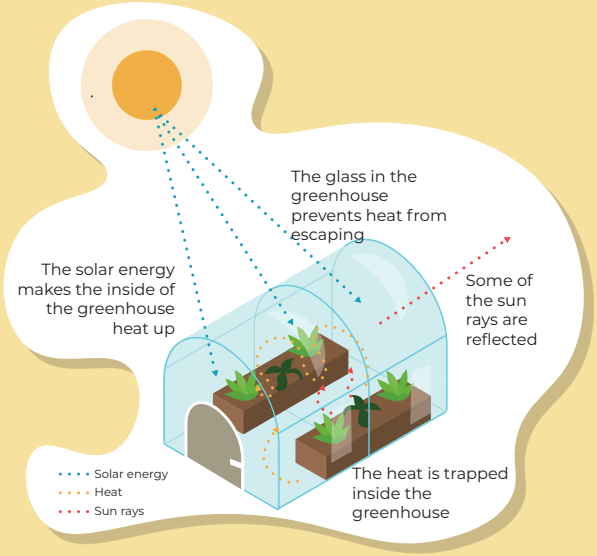
GREENHOUSE EFFECT

A **natural phenomenon** that maintains the temperature of the planet at levels suitable for the existence of life (around 15 °C). However, **the greenhouse effect has become more intense** since the late 19th century as a result of human activities (burning fossil fuels – oil and coal – and deforestation, for example) leading to **climate change**. An analogy can be made with a glass greenhouse, similar to those used for agricultural production, to better grasp this phenomenon. According to Ronaldo Decicino[4], "some gases that make up the atmosphere (carbon dioxide – CO_2, methane – CH_4, water vapor – H_2O, among others) work like the glass of a greenhouse, which lets the sunlight into its interior and traps this heat inside the greenhouse". Hence, "the greenhouse effect occurs when part of the solar radiation reflected by the Earth's surface is absorbed by these gases". As a result of this process, "the greenhouse effect prevents the heat emitted by the sun from returning to space. Thus, the heat that the Earth receives during the day keeps the temperature high even at night"[4].

Several studies have shown that the continuous increase in greenhouse gas (GHG) emissions, particularly CO_2, is the main driver of climate change. The most recent IPCC report (2022) has concluded that if GHG emissions from human activities continue at the same pace as in recent years, in the next two decades the global temperature is expected to increase by an average of 1.5 °C[1].



One of the main manifestations of climate change is global warming, that is, the continuous increase in the global average temperature over time. According to the Sixth IPCC Report published in 2021, in the decade 2011-2020 the global surface temperature increased by approximately 1.1 °C compared to the period from 1850 to 1900. Different regions of the planet are already facing or will suffer very distinct impacts. Data from the World Meteorological Organization point out that, while the average global temperature increased at a rate of 0.07 °C per decade between 1981 and 2019, South America and Africa, for instance, had an increase of 0.24 °C and 0.31 °C, per decade, respectively, in the same period[3]. This warming trend has also taken place in Brazil in recent years, as presented in the following graph (Figure 1). In the period 1985-2015, the average temperature rose by approximately 0.15 °C every ten years.

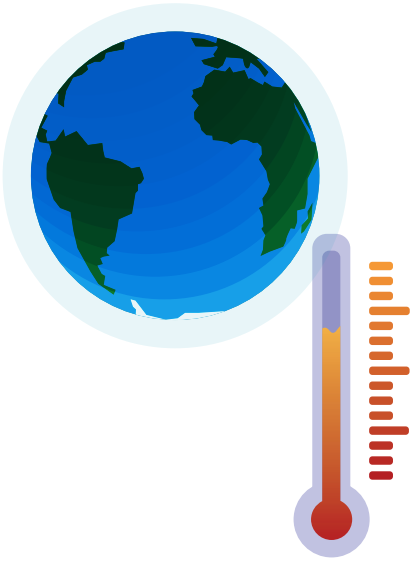
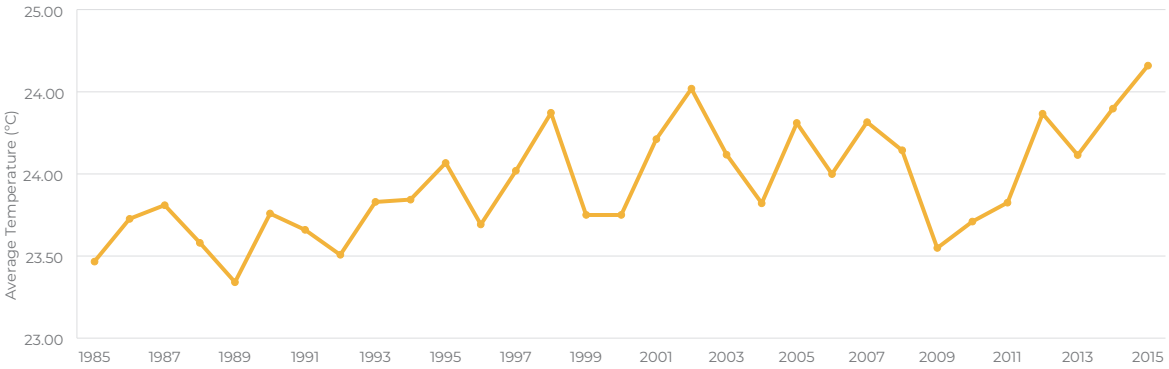


Figure 1. Average temperature in Brazil between 1985 and 2015



Source: Prepared by the author based on data from the Global Meteorological Forcing Dataset for Land Surface Modeling[5].

Climate change and its various manifestations, such as global warming and extreme events (droughts, frosts, storms, etc.), represent enormous challenges that governments and society need to deal with. These phenomena, whose occurrence and intensity are accelerated by human activities, have the potential to make other problems already faced globally even more severe: the extinction of plant and animal species, hunger, migrations, the emergence and spread of diseases and pests, as well as inequalities of both income and access to clean water and energy. Consequently, various sectors, together with the government and civil society, need to make efforts so that climate change and its negative effects are minimized.

Several studies indicate that poor and developing countries will have great impacts in terms of income and well-being reduction due to the expectations of global warming in the coming decades[6]. In some locations in Africa, Asia, and both Central and South America, poorer and more marginalized groups including women, family farmers, in addition to traditional peoples and communities deeply feel the negative effects of climate change[1].

Geographic location imposes even bigger rises in temperature on naturally hot locations, approaching (or exceeding) their biophysical limits[1]. Furthermore, these regions have less favorable economic, technological, institutional, and even political conditions, which lowers their ability not only to react to climate change but also to try to reduce losses. Being heavily dependent on the agricultural sector for income generation is another big issue[6]. Agriculture, as it depends directly on favorable weather conditions, is one of the most affected economic sectors

IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

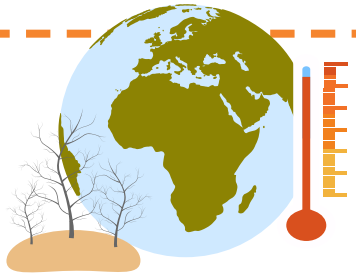
1.Temperature increase, beyond certain limits, reduces crop productivity. In addition, the combined effect of increased temperature and long periods of drought leads to reduced moisture of soil and air, causing further yield declines..

2. With greater climate variability and more extreme events, the planning capacity in agriculture is impaired, causing significant economic losses.

These two effects combined tend to reduce the agricultural product supply, which can lead to an increase in their prices and, thus, jeopardize the food security of the population, especially of the poorest families[7] [8].

NEXUS BETWEEN CLIMATE CHANGE, AGRIFOOD SYSTEMS, AND FOOD AND NUTRITION SECURITY

Changes in the global climate have already been reducing the productivity of many agricultural crops and undermining the conditions necessary for food production[8]. The lower availability and diversity of food tends to increase hunger and impair access to diets of good nutritional quality, which compromises populations' health, especially those in the poorest regions of the planet. Up to 183 million more people are projected to go hungry under climate change scenarios globally, with poorer consumers facing greater risks[9]. Researchers project approximately 530,000 deaths worldwide associated with poor diet as a result of climate change by 2050[10]. Furthermore, agricultural production systems are responsible for around 22% of global GHG emissions[11]. To face the challenges posed by this nexus between climate change, agrifood systems, and food and nutrition security, it is more and more necessary to rethink the way food is produced, distributed, and consumed. On the production and marketing side, some alternatives include increasing soil organic matter and erosion control, pasture management, genetic improvements for heat and drought tolerance, crop diversification, and food transport in more efficient and less polluting ways. On the consumption side, conditions must be created for the adoption of nutritionally adequate diets by consuming less meat and, at the same time, reducing food waste[9].



RESILIENCE

According to the IFAD, “resilience describes the extent to which social or ecological systems can maintain, recover and improve their integrity and functionality when subjected to external disturbances”[12]. The IPCC, in turn, explains that resilience refers to “the ability of a socio-ecological system to cope with a dangerous event or disturbance, either responding or rearranging itself in a way that it maintains its function, identity and essential structure while keeping the ability to adapt, learn and transform”[13]. From a socioeconomic point of view, it can be said that individuals, households, and communities are more resilient when they are able to avoid poverty and/or improve their life conditions in face of various adverse events, including climate change and extreme events[14].

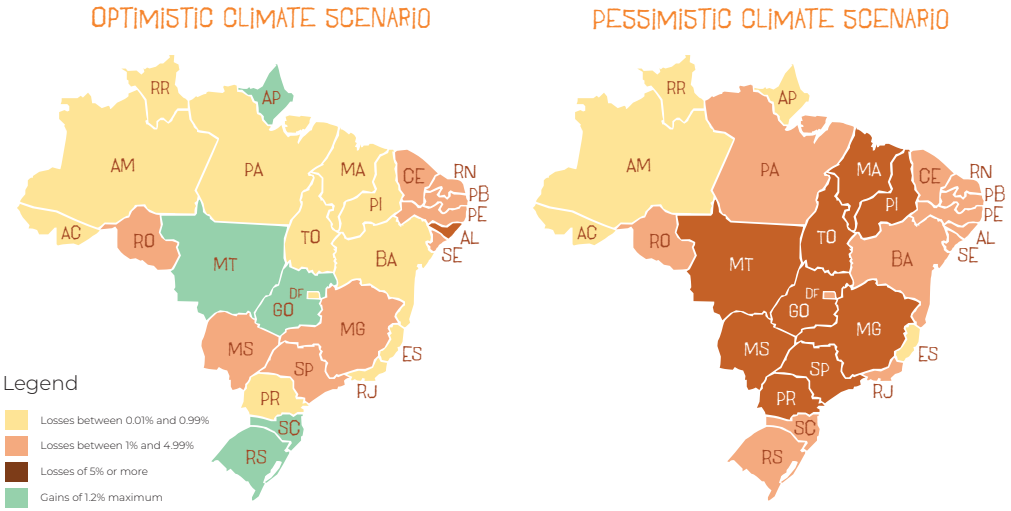
There is a lot of research on the impacts of climate change upon the Brazilian agriculture. Most predict a drop in productivity of the main crops produced in the country, with more intense negative effects in the long term, even in more optimistic climate scenarios. Consequently, the national Gross Domestic Product (GDP) is expected to fall by the end of the 21st century, with annual losses ranging from 0.4% (optimistic scenario) to 1.8% (pessimistic scenario)[15]. Some researchers claim that there can be serious regional consequences, with greater negative impacts in the poorest regions, such as the North and Northeast ones, as shown in Figure 2[15] [16] [17].

Therefore, the regionalized debate of all issues involving climate change is essential. In Brazil - a country of continental dimensions with high environmental and socioeconomic heterogeneity - there are different levels of vulnerability. The Brazilian agriculture also presents contrasts that can cause greater or lesser negative impacts, depending on the size of the agricultural enterprise. Farmers with large production scales, and easy access to technologies and credit are less exposed to climate change. On the other hand, family farming, which is responsible for producing big part of the food consumed in Brazil[1], tends to face greater difficulties. According to information from the IFAD, family farming faces difficult access to good quality land and technical assistance services and to rural extension, as well as lack of financial resources, which are all factors that boost the negative effects of climate change.

1 Data from the 2017 Agricultural Census, organized by researcher Calixto Rosa Neto and his collaborators[18], indicate that family farming has a significant share in national fruit production (for example, 81.2% of the strawberries are produced by Family farming; 79.3% of the grapes; 67.1% of the pineapples; 48.5% of the bananas), in temporary crops (69.6% of the amount of cassava is harvested by family farming; 23.1% of the beans; 12.5% of the corn; 10.9% of the rice), horticulture (64.5% of the lettuce is produced by family farming), and livestock (64.2% of the cow milk is produced by family farming; 12.4% of chicken eggs). More details can be obtained from: *https://bit.ly/3L6FrfQ*.

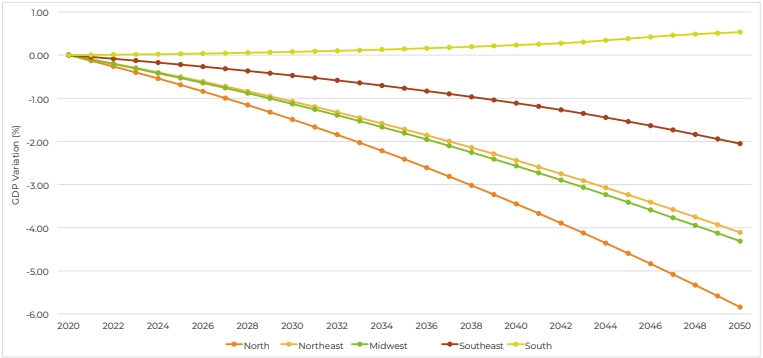
Figure 2. Estimates of regional impacts as a result of climate change

A. Percentage change in agricultural productivity of Brazilian states in climate change scenarios*



(*)Average difference between the projected productivity value of beans, corn, soybeans, sugarcane, oranges, and coffee in 2100 and their current levels
Source: prepared by the author based on the results of Souza and Haddad (2022)[15].

B. Percentage change in GDP of Brazilian regions as a result of falling agricultural productivity in a climate change scenario, 2020-2050



Source: prepared by the author based on the results of Nazareth et al. (2022)[17].

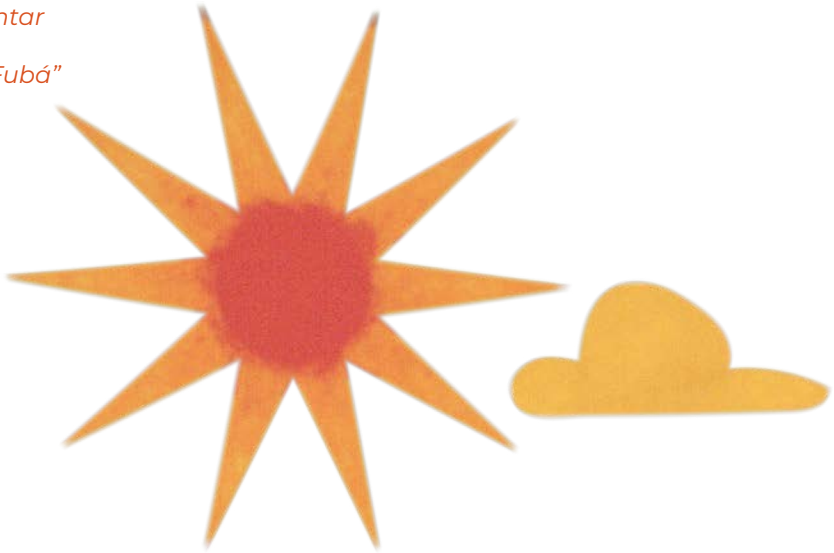
The negative effects of climate change reported in the surveys intensify hardships already faced in rural areas, as demonstrated by some reports from family farmers in Ceará and Bahia states::

> Many animals end up dying due to lack of water and also due to high temperatures. The harvest was poorer than expected, because of little rain. And as the temperature is very high, the crops end up burning to death." *(Ana Fabrícia Lira de Araújo, 29 years old, resident of the municipality of Quiterianópolis , Ceará state).*
>
> "Climate changes have directly influenced food production in our territory, since with the variations in the rainfall cycles we are producing less and less each year because of lack of water. We have already planted beans and corn and were not able to harvest as expected because a good winter was projected but that changed without warning." *(Mateus de Castro Ferreira, 25 years old, resident of the Tremembé indigenous community, municipality of Itapipoca, Ceará state).*
>
> "With the absence of rain in most of the winter season, the production of various agricultural products has decreased, and with that, we have to buy more expensive [produce] to complement [our diet]." *(Livânia Rodrigues de Oliveira, 38 years old, resident of the municipality of Quiterianópolis, Ceará state).*
>
> "We've already had a lot of losses, mainly in agricultural production, because we don't do irrigation and all the water comes from the rain, and with [its] decrease, production drops drastically, with recurring losses in the region. Even plantations more adapted to our climate have been feeling the changes in temperature recently. When we plant, and it is time to harvest, we have nothing to harvest, because there was no production, even at the right time, because there wasn't the right amount of rain, which makes everyone really anguished." *(Maria Estelina da Rocha, 48 years old, resident of the municipality of Casa Nova, Bahia state).*

In this context, the next two chapters of this booklet aim to: (i) present information on regional climate changes in the recent past and in future climate change scenarios based on current scientific knowledge; (ii) explain the concept of coexistence with the semiarid climate and its importance for improving the living conditions of the population of the semiarid region, as well as its synergy with sustainable development and actions for adapting to climate change.

CHAPTER 2
CLIMATE CHANGE IN THE BRAZILIAN SEMIARID REGION

"Aquela seca medonha fez tudo se atrapalhar
Não nasceu capim no campo para o gado sustentar
O sertão esturricou, fez os açude secar
Morreu minha Vaca Estrela, já acabou meu Boi Fubá"
(Vaca Estrela e Boi Fubá – Patativa do Assaré)



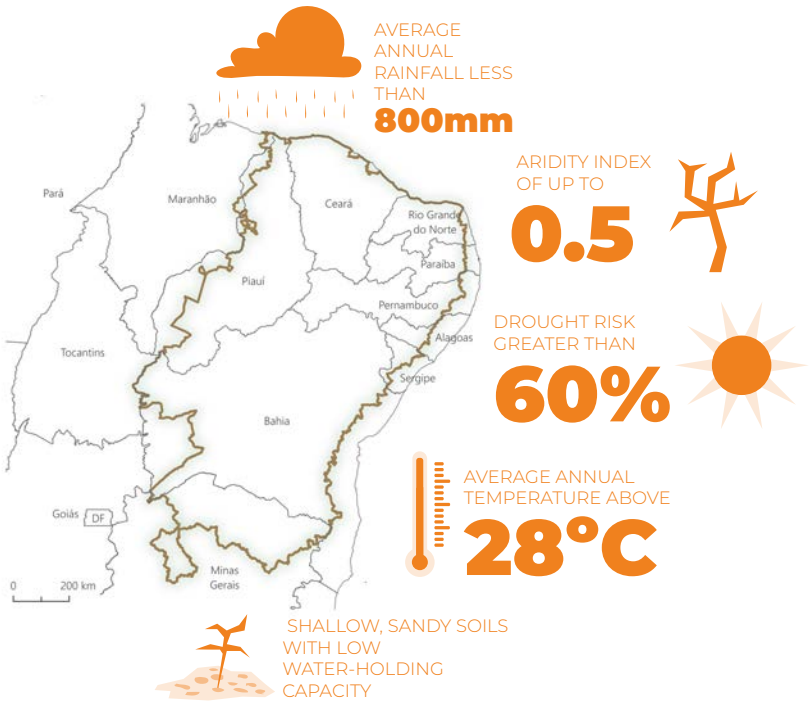
Arid and semiarid regions represent about 40% of the Earth's surface and are located, mostly (90%), in poor or developing countries. It is a consensus among scientists that climatic instabilities in these areas account for the variability in food production and agricultural income, which, in general, causes economic difficulties and worsens situations of poverty and social inequality[19]. Adverse weather conditions in semiarid regions are expected to worsen due to climate change[1].

In Brazil, the semiarid region corresponds to 1.03 million km², which is equivalent to 12% of the country's total area. It is the most po pulous semiarid region on the planet,

a, na qual vivem cerca de 27 milhões de habitantes. De acordo com a Suin

which about 27 million people live. According to the Superintendence for the Development of the Northeast – Sudene (Resolution Condel/Sedene N° 150, 12/13/2021)[20], the 1,427 municipalities that make up the Brazilian semiarid region are distributed across all states in the Northeast region as well as in the North of Minas Gerais, as shown in Figure 3.

Figure 3. Brazilian semiarid region and some of its natural features

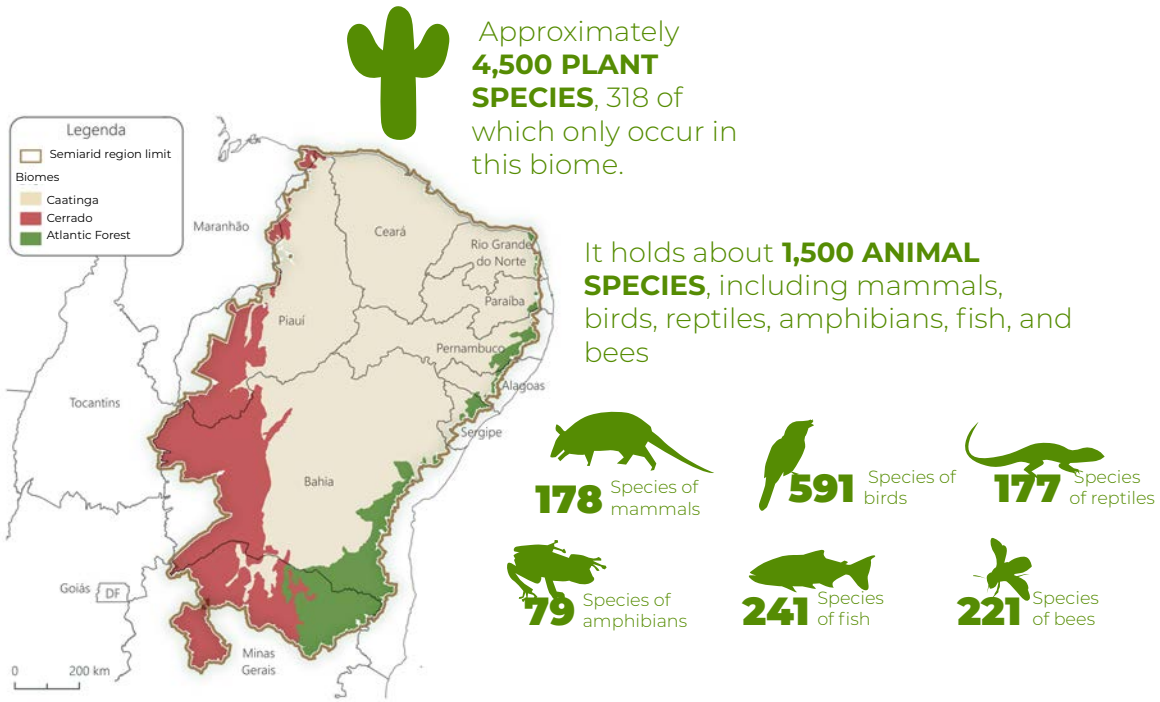


Source: Brazilian Institute of Geography and Statistics (2019)[21] and Ministry of Science, Technology and Innovation (2021)[15]

The predominant biome in the Brazilian semiarid region is the Caatinga, although there are also stretches of the Atlantic Forest and Cerrado (Figure 4). It is a genuinely Brazilian biome, known for being the most biodiverse in the world among the semiarid regions.

"White forest is the meaning of the name Caatinga given by the Tupi-Guarani Indians [to this vegetation] in allusion to the appearance it has when water becomes scarce. The look of its vegetation in the dry season is, in fact, an exemplary survival strategy. The lighter shade of the bark reflects the light, preventing the trunk from heating up. (...) Among the peculiar characteristics of the Caatinga is also the loss of leaves by most plants, which gives them an aspect of a dead landscape. However, this is another one of its clever ways to avoid losing water through transpiration" (Fernando Sinimbu Aguiar, analyst at the Brazilian Agricultural Research Corporation – Embrapa)[23].

Figure 4. The Brazilian semiarid biomes and the diversity of the Caatinga

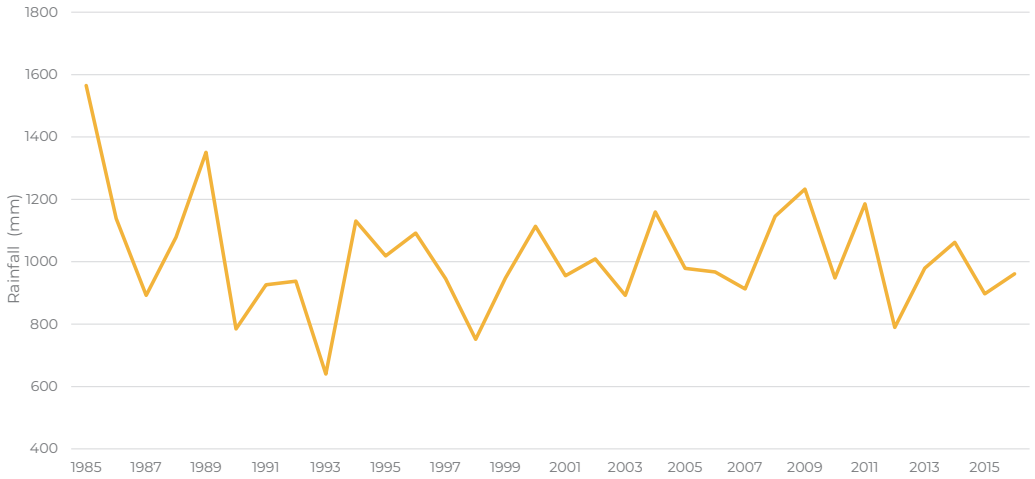


Source: Brazilian Institute of Geography and Statistics (2019)[21] and Ministry of Science, Technology and Innovation (2021)[15]..

A socioeconomic characteristic of the Brazilian semiarid region to be highlighted is the predominance of family farming. Out of the 1.8 million agricultural establishments in the region, 79% of them are family farms[24]. This segment, which primarily accounts for the local food supply, faces a lot of difficulties for being heavily dependent on weather conditions, especially rainfall. Moreover, access to water and land has always been strictly limited, leading to serious situations of socioeconomic inequality and poverty, which can worsen as a result of the negative effects of climate change[25].

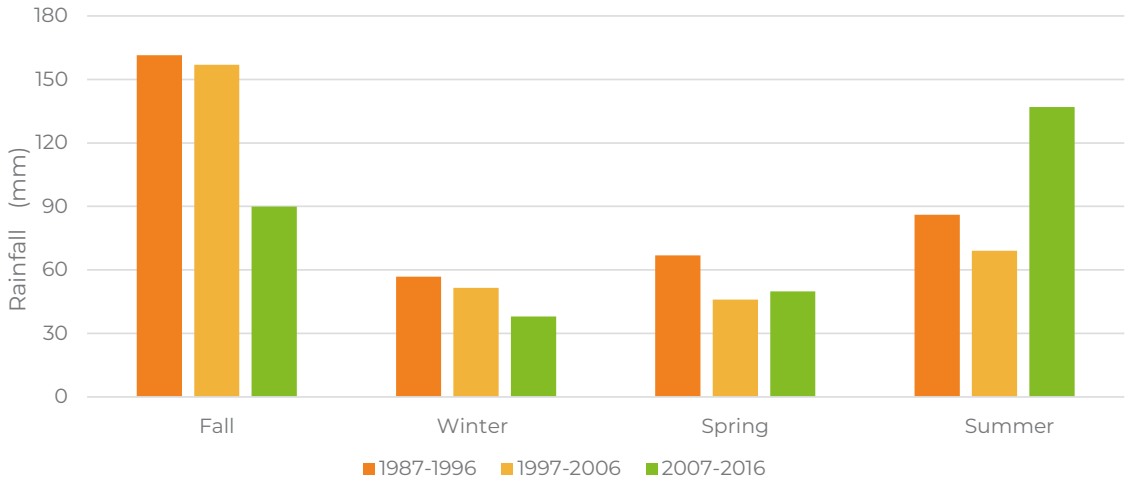
Historically, the Brazilian semiarid region has gone through long periods of drought, characterized by a marked reduction in rainfall during the rainy season. From the 1950s to 2020, there have been at least eight periods of drought in the region; one of the most intense ones started in 2011 and lasted until 2016. Both the average annual rainfall and the seasonal average in the rainy season have been decreasing over the last 30 years, whereas the average number of consecutive dry days increased in the same period[5].

Figure 5. Annual accumulated rainfall in the Brazilian semiarid region from 1985 to 2016



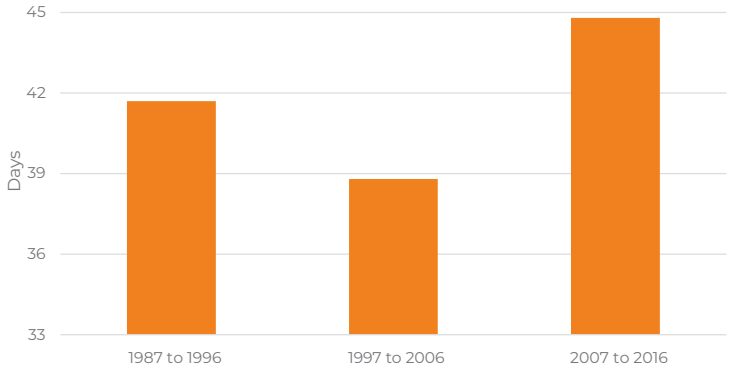
Source: Prepared by the author based on data from the Global Meteorological Forcing Dataset for Land Surface Modeling[5].

Figure 6. Average rainfall throughout the seasons in the Brazilian semiarid region; ten-year averages from 1987 to 2016



Source: Prepared by the author based on data from the Global Meteorological Forcing Dataset for Land Surface Modeling[5].

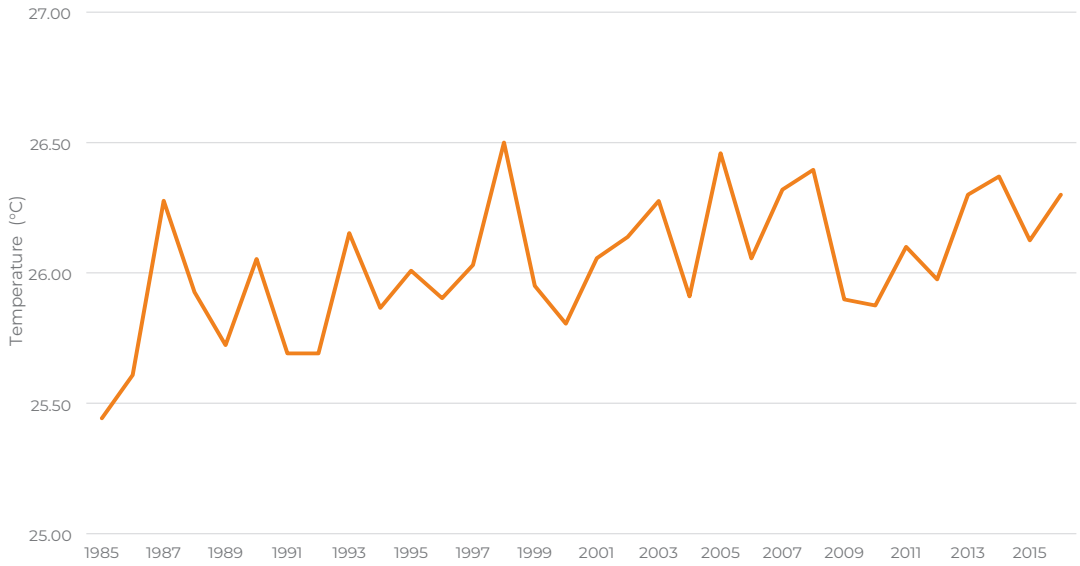
Figure 7. Annual number of consecutive dry days in the Brazilian semiarid region; ten-year averages from 1987 to 2016



Source: Prepared by the author based on data from the Global Meteorological Forcing Dataset for Land Surface Modeling[5].

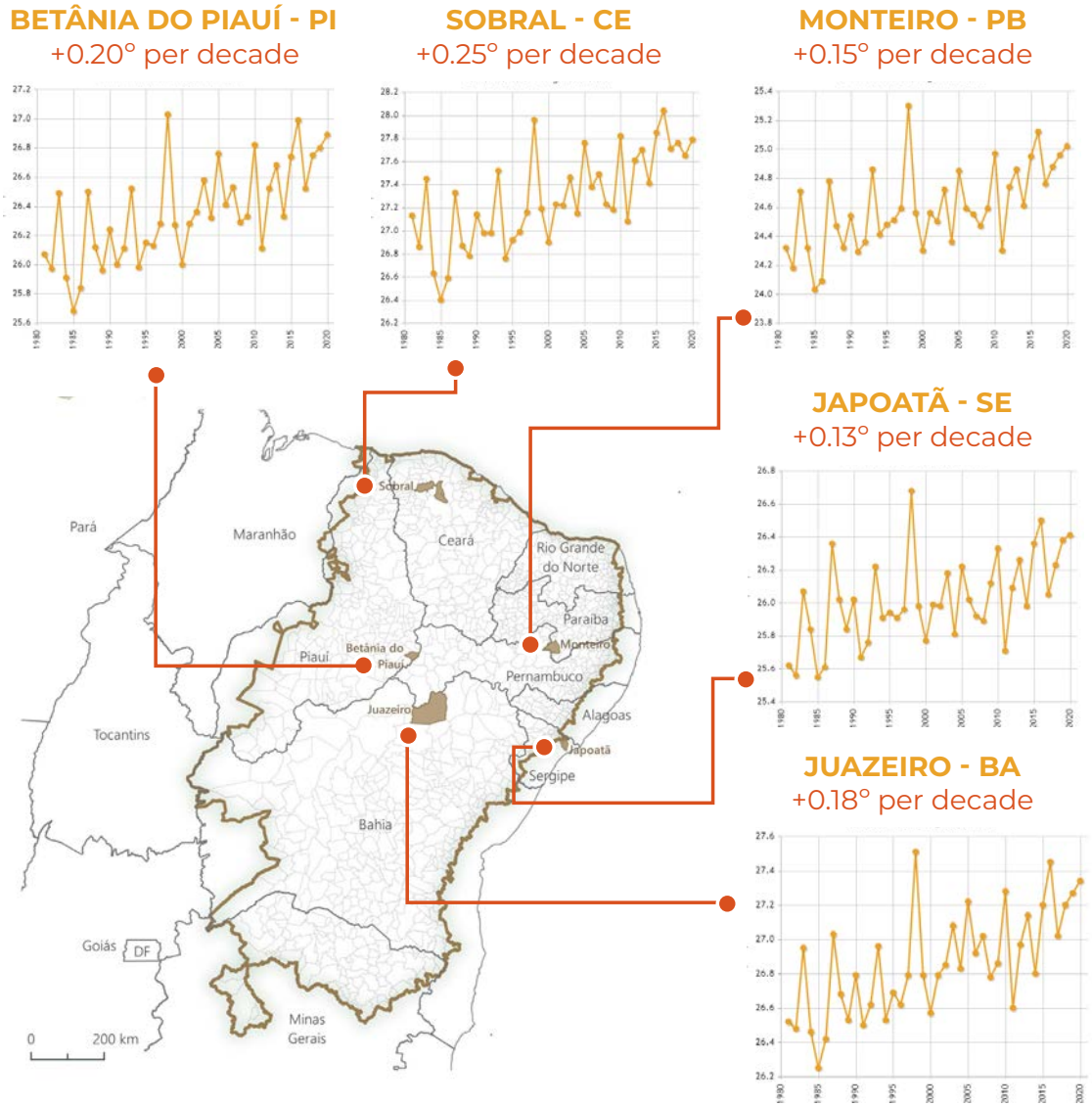
The semiarid region temperature has also risen over time (Figures 8 and 9). The number of very hot days, in which the average temperature exceeded a certain historical maximum limit, increased in such region (average increase of 89% between 1987-1996 and 2007-2016)[5]. Conversely, the number of cold days and nights decreased over the same period. The region has also been more and more exposed to heat waves.

Figure 8. Average annual temperature in the Brazilian semiarid region from 1985 to 2016



Source: Prepared by the author based on data from the Global Meteorological Forcing Dataset for Land Surface Modeling[5]..

Figure 9. Average annual temperature in selected municipalities in the Brazilian semiarid region from 1980 to 2020



Source: Prepared by the author based on data from the Global Meteorological Forcing Dataset for Land Surface Modeling[5]

Temperature rise and heat waves affect the regional water balance, causing not only increased evaporation from water reservoirs, such as lakes and dams, but also increased evapotranspiration (water loss from the soil through evaporation and water loss from plants through transpiration). These factors, added to the decreasing trend of rainfall and the extended duration of the dry season, lead to losses in food production (especially in family farming), compromise regional agricultural development, and, consequently, trigger serious socioeconomic challenges. It is estimated that the drought that occurred between 2011 and 2016, for example, caused losses of about US$6 billion for the agricultural sector in the region, with rainfed family farming being the most affected one[27]. These trends, corroborated by the scientific literature[26], have also been observed by farmers in the region.

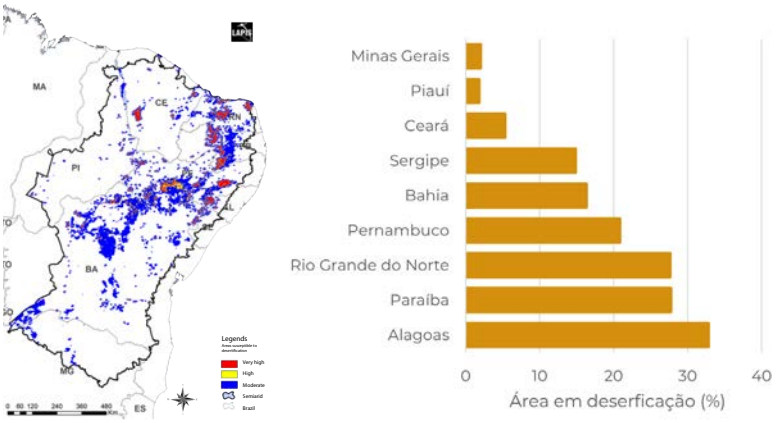
The change in rainfall cycles in the region in recent years has been noticeable, particularly since 2012, when we had a great drought, and the rainfalls have reduced a lot. I understand that it is natural for the region, but the impacts have been much bigger in this period than other moments of past droughts. Sometimes it rains in a region, but in other ones pretty close it doesn't. Sometimes [in this other region] it rains in a larger amount, and in another place [it rains] a smaller amount in the same region, or it doesn't even rain at all. Therefore, the changes in recent years are in terms of amount and distribution in space and time, causing the rainfed agriculture to be even more at high risk of loss. The temperature has increased a lot in the region, and in a very aggressive way, leaving animals and crops in a state of permanent water stress, directly impacting production and coexistence with these regional climate diversities. The rise in temperature has been happening more aggressively, and the sun heat is much more intense, and at this season there is now a dry wind (...), which there wasn't so often before." (Maria Estelina da Rocha, 48 years old, resident of the municipality of Casa Nova, Bahia state).

"It seems that the sun is getting closer to the Earth every day because of the heat we are feeling, besides the evaporation of water from ponds and streams getting faster and faster." (Mateus de Castro Ferreira, 25 years old, resident of the Tremembé indigenous community, municipality of Itapipoca, Ceará state).

The increasingly dry weather and hot sun observed by farmers Maria Estelina and Mateus, as well as by climatology researchers, tend to intensify another problem in the region: desertification. Currently, about 13% of the Brazilian semiarid area is undergoing desertification; the most affected states are Alagoas, Paraíba, and Rio Grande do Norte (Figure 10). This is a phenomenon that takes place in areas where the soils are poor in organic matter, and are sandy and shallow (thus, with a low capacity to store water). Desertification results from land degradation by inappropriate human activities and climatic variations[26][28]. It is an irreversible process that makes the soil unproductive.

> *"Desertification is due to the vulnerability of dry zone ecosystems that cover a third of the planet's surface, overexploitation, and inappropriate land use. Poverty, political instability, deforestation, overgrazing, and poor management practices affect soil productivity negatively. (...) The desert is a natural condition of an arid or semiarid region or landscape, while the desertification process, in addition to the dry natural characteristics, is conditioned by human actions. This way, the area progressively loses its productivity to the point when it can no longer recover" (Humberto Barbosa, professor at the Federal University of Alagoas – UFAL and coordinator of the Satellite Image Analysis and Processing Laboratory – Lapis/UFAL)[29].*

Figure 10. Areas in desertification process in the Brazilian semiarid region



Source: Satellite Image Analysis and Processing Laboratory (Lapis/UFAL)[29]

“People just extract what the planet offers, but they don’t replace it, and right now the planet gives [them] back in the worst way possible.” *(Ana Fabrícia Lira de Araújo, 29 years old, resident of the municipality of Quiterianópolis, Ceará state).*

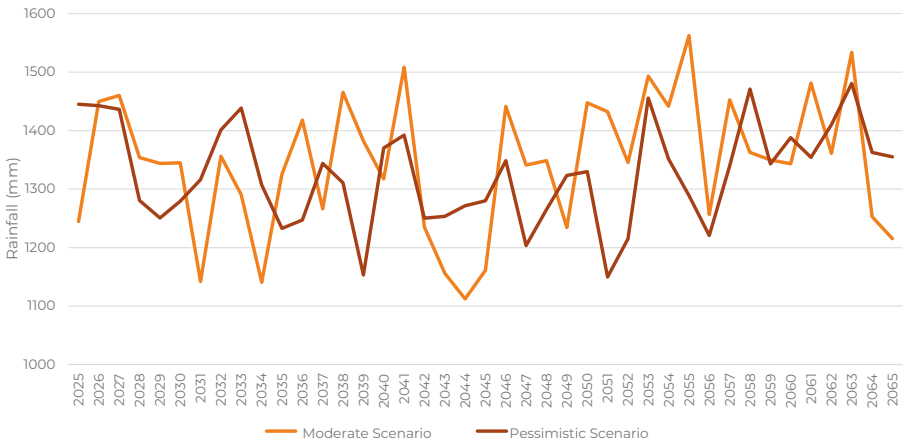
“I think that climate change is caused by the ambition of people who are always increasing deforestation and destroying our mother Earth with fires, causing an imbalance in ecosystems and the extinction of life that ensures a pleasant climate.” *(Adriana Carneiro de Castro, 50 years old, resident of the Tremembé indigenous community, municipality of Itapipoca, Ceará state).*

All the adverse weather conditions that the semiarid region has historically faced tend to worsen in future climate change scenarios. In Brazil, this is the region with the highest level of exposure to the effects of climate change predicted by the scientific community. The future climate change scenarios presented by the IPCC indicate that the semiarid region will experience an increase in the variability of more intense rains and droughts throughout the 21st century. Temperature rises that can reach up to 2°C compared to the current period are also expected.

FUTURE CLIMATE CHANGE SCENARIOS

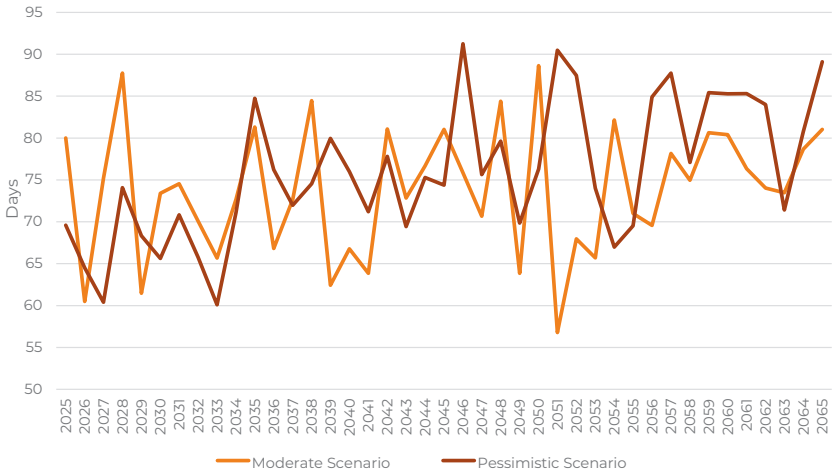
They are representations of different GHG emissions trajectories built on assumptions about population growth, lifestyles, use of fossil fuels (coal and oil, for example), changes in land use, technological and socioeconomic development, and so forth. For each trajectory, scientists estimate temporal changes in temperature, rainfall, and extreme events such as droughts and storms, among other climatic variables. There are many different scenarios, and this booklet presents climate change estimates based on two of them: RCP 4.5 and RCP 8.5. The first one, here called the “moderate scenario”, supposes climate policies that lead to moderate GHG emissions; the second one, called the “pessimistic scenario”, assumes that GHG emissions will triple by the end of the 21st century and that there will be no policies to reduce these emissions[2].

Figure 11. Annual accumulated rainfall in the Brazilian semiarid region in future climate change scenarios from 2025 to 2065



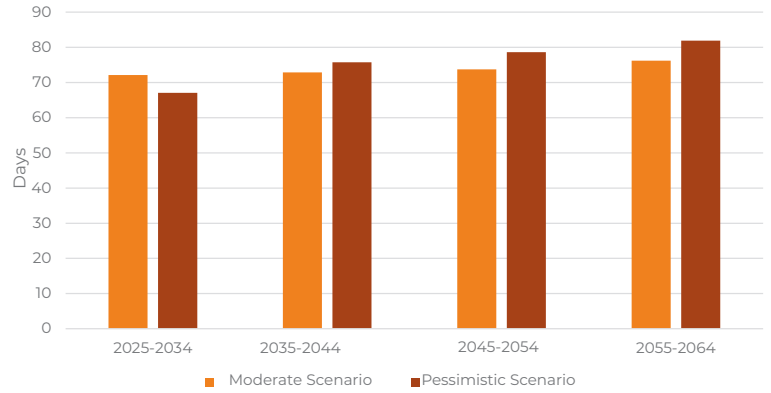
Source: Prepared by the author based on IPCC future climate scenarios[2].

Figure 12. Annual number of consecutive dry days in the Brazilian semiarid region in future climate change scenarios from 2025 to 2065



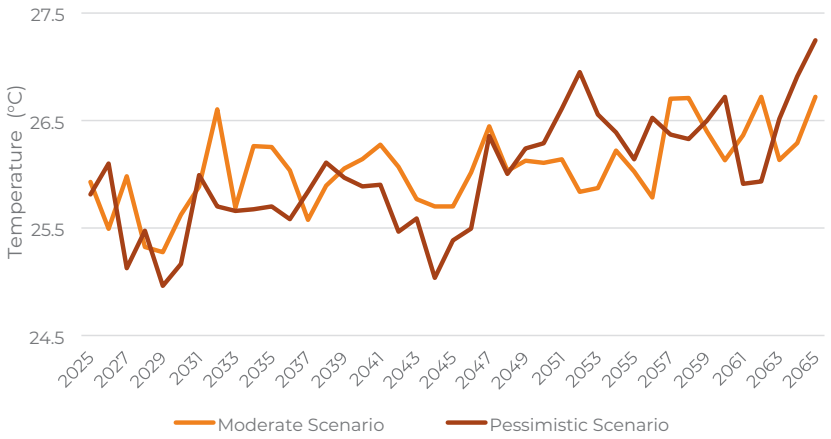
Source: Prepared by the author based on IPCC future climate scenarios[2].

Figure 13. Annual number of consecutive dry days in the Brazilian semiarid region in future climate change scenarios: ten-year averages from 2025 to 2064



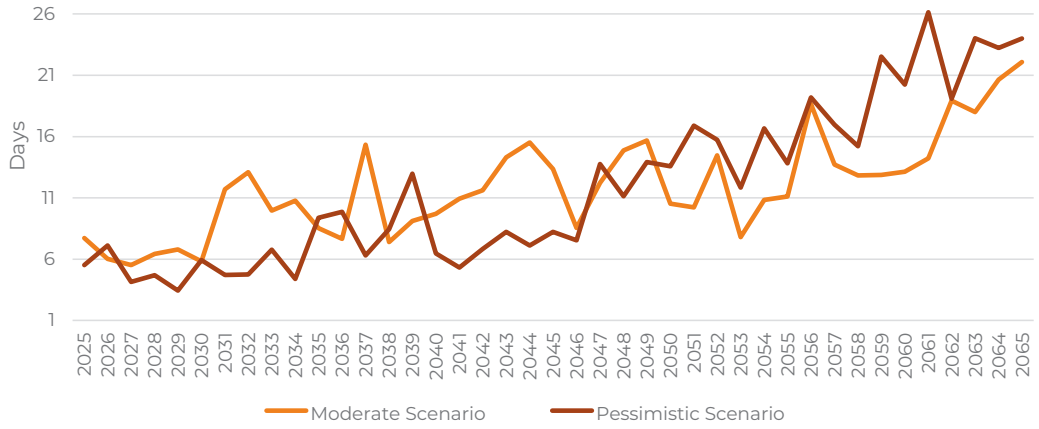
Source: Prepared by the author based on IPCC future climate scenarios[2]

Figure 14. Average annual temperature in the Brazilian semiarid region in future climate change scenarios from 2025 to 2065



Source: Prepared by the author based on IPCC future climate scenarios[2].

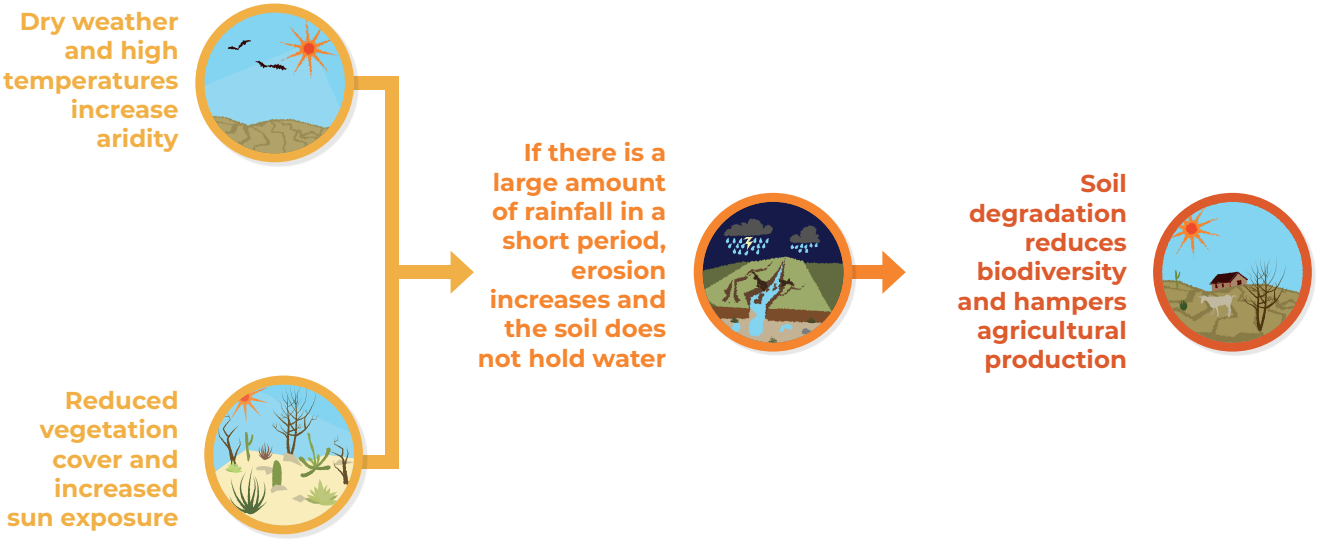
Figure 15. Annual number of hot days (average temperature above the historical maximum) in the Brazilian semiarid region in future climate change scenarios from 2025 to 2065



Source: Prepared by the author based on IPCC future climate scenarios[2].

The aridity increase predicted in future climate change scenarios may cause the Caatinga areas to advance over the Cerrado and mainly the Atlantic Forest in the Brazilian semiarid region. The Caatinga area can increase by about 16% in the moderate climate scenario and up to 24% in the pessimistic scenario[28]. These changes in the vegetation cover of the region tend to intensify the desertification process already underway, and so, compromise biodiversity and further reduce the production capacity of family farming (Figure 16).

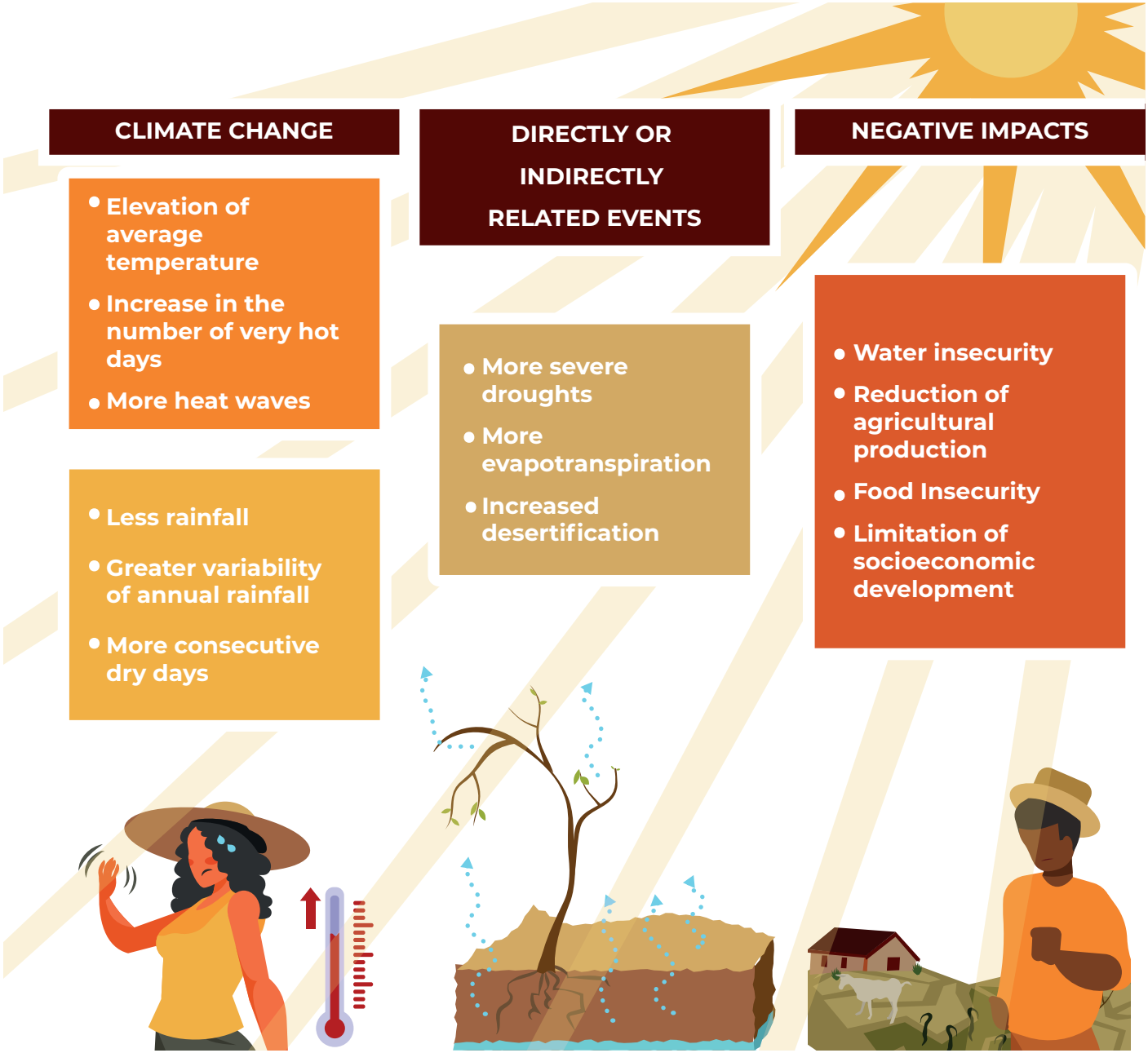
Figure 16. Climate change and desertification



Source: prepared by the author based on the results of Oliveira et al. (2021)[28] and on information from the Satellite Image Analysis and Processing Laboratory (Lapis/UFAL)[29].

Given the expectations about climate change in the Brazilian semiarid region described throughout this chapter and summarized in Figure 17, it is essential that farmers have access to more knowledge about this topic, its challenges, and opportunities. Furthermore, it is vital to raise their awareness of associated risks and actions to reduce socioeconomic losses and vulnerability, including production techniques that ensure greater resilience in climate change scenarios. The actions of coexistence with the semiarid region, which will be discussed in the next chapter, play a valuable role in this process.

Figure 17. Main IPCC findings on climate change in the Brazilian semiarid region



Source: prepared by the author based on the IPCC findings (2021)[1]..

CHAPTER 3

COEXISTENCE WITH THE SEMIARID REGION, ADAPTATION TO CLIMATE CHANGE, AND SUSTAINABLE DEVELOPMENT

Catingueira fulora, vai chover
Andorinha voou, vai ter verão
Gavião se cantar, é estiada
Vai haver boa safra no sertão
(Oricuri, o segredo do sertanejo – João do Vale)

The umbuzeiro, a typical species of the Caatinga, is usually remembered as a symbol of the sertanejo people's resilience. The name of this beautiful tree comes from the word "ymbu", which means "tree that gives [something] to drink" in the Tupi-Guarani language[30]. Due to its great water-storage capacity, not even long droughts prevent the umbuzeiro from fruiting and providing food to people and animals. Euclides da Cunha, in his book "Os Sertões", refers to the umbuzeiro as the "sacred tree of the sertão" that represents "the most striking example of adaptation of the sertanejo flora"[31]. Just as the umbuzeiro is adapted to the conditions of its natural habitat, the sertanejo people have developed actions of coexistence with the semiarid region over time as an attempt to improve their quality of life.

According to the “Serimiarid Declaration”, published in 1999 by the Brazilian Semiarid Articulation (ASA), coexistence with the semiarid region aims at “the conservation, sustainable use, and environmental restoration of the natural resources of the semiarid region”, as well as “the breaking up of a monopolistic access to land, water, and other means of production”[32]. This way, it is not just a matter of seeking to reduce negative impacts resulting from adverse natural conditions in the region, but also one of developing actions based on local reality, including the various people involved in the production process and conservation of natural resources by associating “cultural values and social justice”[32].

The actions of coexistence with the semiarid region are aligned with the ideal of sustainable local development, and, according to the ASA, also with “norms, values, and practices of Agroecology, Popular and Solidarity Economy, Contextualized Education, Popular Communication, and both Food and Nutrition Security.” Based on social technologies, they all seek social transformation with solutions developed for and with the communities built on the decentralization and democratization of access to productive resources, mainly water. Therefore, when considering the local specificities and adopting the resources and knowledge of the communities, important elements such as productive diversification, increased productivity, food security, less dependence on external inputs, conservation of biological diversity, lower environmental impact, and, above all, better quality of life for the families, are assured.[33]

SOCIAL TECHNOLOGIES

According to the Institute of Social Technology (ITS BRASIL)[34], Social Technologies (STs) consist of a set of transforming techniques and methodologies developed and/or applied by interacting with the population and owned by it. They represent effective solutions for social inclusion and the improvement of living conditions. The STs have well-defined features, such as low implementation cost, easy construction and replication, non-discriminatory participation, and social gain for the population. These technologies are widely used in the Brazilian semiarid region and are generally implemented by beneficiary families under the supervision of technical assistance and rural extension teams. In addition to creating work and income in the territories, the implementation of such technologies involves an education element that guarantees the development of skills and capacities for their maintenance so that they do not depend on paid services in the future. The STs create better conditions for farmers to strengthen their production systems, leading to food and nutrition security. The implementation of different STs for coexistence with the semiarid region by different IFAD projects in Brazil has improved the living conditions of vulnerable small farming families in situations of poverty and of extreme poverty, particularly those in the priority groups (women, young people, indigenous peoples, and quilombolas).

SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

The term sustainability comes from the Latin word “sustinere”, which means “to support”, “to maintain”, “to conserve”. Robert Constanza, one of the most important researchers on the subject, states that “sustainability defines the relationship between human economic systems and the ecological systems in which human life can live on indefinitely; individuals can develop; and human cultures can flourish. Furthermore, the effects of human activities remain controlled in the sense that they do not destroy the diversity, complexity, and life-support role of the ecological system”[35]. It is a multidimensional concept that involves the improvement of economic conditions associated with social and environmental protection.

Sustainable Development, as defined by the report “Our Common Future” (published by the United Nations – UN in 1987), is one that “meets the needs of the present without compromising the ability of future generations to meet their own needs”[36]. In other words, “sustainable development requires

that societies meet human needs both by increasing productive potential and by ensuring equitable opportunities for all (...) and must not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings"[36].

Currently, the achievement of sustainable development is summarized in an action plan known as "Sustainable Development Goals – SDGs". This "development agenda" was presented by the UN during the United Nations Summit on Sustainable Development, held in New York City (the United States) in 2015. According to the UN, the SDGs seek to sensitize the global community – governments, policymakers, civil society organizations, local leaders, and the people at large – to take action "to end poverty, protect the environment and climate and ensure that people everywhere can enjoy peace and prosperity."[37] Although the proposed goals are of a global nature, the necessary actions must go through policies at regional and local levels, involving the whole of society.

A key aspect of the coexistence with the semiarid region is access to water. In a region where it naturally rains less, and where droughts – which are already frequent – can worsen with climate change, ensuring that the population has water security is vital. It is not, however, a matter of creating reactive and emergency strategies to "fight the drought"[38]. Projects of this nature, which were widespread throughout the 20th century, were based on "ready-made solutions" disconnected from local knowledge. The community and its natural resources played a secondary role, given the underlying market logics and capitalist accumulation[38].

In the coexistence strategies, the natural conditions of the region are not seen as "to blame" for the social and economic problems. In this way, they aim at the "reconciliation of man with nature", since they are based on the idea that it is possible to "sustainably take advantage of their potential to satisfy human needs", through productivity)[38]. The semiarid region peoples are encouraged to reflect on the diversity and complexity of the region, seeking together solutions that come "from within" and guarantee work and a dignified life, respecting not only nature but also their local traditions and knowledge[39].

Research carried out by the professor Luis Cláudio Monteiro de Mattos at the Federal Rural University of Pernambuco (UFRPE) showed that the dissemination of strategies for coexistence with the semiarid region minimized the impacts of the drought that occurred from 2011 to 2016[39]. The rainfall time series for the Semiarid region analyzed in Chapter 2 demonstrate that the years from 2012 to 2016 were drier than the decades 1980s, 1990s, and 2000s.

> *"Although this drought has already been considered the most intense ever seen, its social impacts are significantly less intense now than they have been in the past. There are no records of social calamities and riots. Part of these different social impacts is related to a new way of mitigating the drought. This new response was gradually drawn up through three decades of political and social transformations in the region. (...) The trend of decentralization of water supply, formation of stocks, and adoption of low-cost technologies (...) consolidated the concept of coexistence with the semiarid region, making it more efficient to face prolonged droughts" (Luis Cláudio Monteiro de Mattos, professor at the Federal Rural University of Pernambuco – UFRPE, and author of the research "A time between droughts: overcoming social calamities caused by drought through actions in defense of coexistence with the semiarid region – Denis colocar certinho")*[39].

"STOCK CULTURE"

Coexistence with the semiarid region presupposes the adoption of a "stock culture", that is, storing water, food, and seeds to meet the family's daily needs[40]. Built on agroecological principles, the idea refers to "reinforcing stocks to resist droughts and rehabilitate production systems after their end (resilience)"[39]. A pioneering project is the "Um Milhão de Cisternas Program (P1MC)", whose objective is to "improve the lives of families living in the semiarid region of Brazil, ensuring access to quality water". The P1MC was developed by ASA in 2001 and later became a public policy of the government, with resources included in the budget of the government. According to ASA, the program consists of the construction of cisterns next to the homes of the beneficiary families. Each cistern can store up to 16,000 liters of rainwater that is used to quench thirst and prepare food. It guarantees "decentralization and democratization of water", from which each family starts to manage the resource. Along with P1MC, other programs based on social technologies have been developed to ensure water security and contribute to the sustainable development of the region, such as "Uma Terra e Duas Águas Program (P1+2)" (larger cisterns of up to 52 thousand liters for using water in agricultural production) and "Cisternas nas Escolas"[40]. The greywater reuse systems, that is, the reuse of the water used in domestic activities (bathing and washing utensils and clothes, for example) after adequate filtration, should also be highlighted

Living with the semiarid region improves the resilience of family farming, keeping its productive capacity and social organization and, consequently, increasing its capacity to adapt to climate change. According to the IPCC, adaptation corresponds to investing in activities that make it possible to reduce potential and future negative impacts or those that already occur due to climate change and associated extreme events, such as the worsening of droughts in the Brazilian semiarid region. The beneficial results of adaptation have a local scope, which boosts the economy of the regions and maximizes positive effects on the local quality of life[2].

In the semiarid region of the Northeast, local populations have adapted to drought and the forces of nature. Traditional communities - such as indigenous, quilombolas and fundo e fecho de pasto communities* have particularly developed a variety of successful adaptation technologies and techniques that provide solutions to the specific climate risks they face. The accumulated wealth of traditional knowledge in adapting to them has to be used, valued, and replicated.

.

Fundo e fecho de pasto are traditional communities where “each family has their own portion of land that contains their home, some subsistence crops, and the housing for the goats and sheep that form the basis of most people’s livelihoods”. Visit https://www.ifad.org/en/web/latest/-/brazil-grass-funds?p_l_back_url=%2Fen%2Fweb%2Flatest%2Fstories for more information.

STRATEGIES FOR ADAPTATION TO CLIMATE CHANGE IN AGRICULTURE

- Adjustment of the timing of agricultural practices

- Investment in agroecological farming techniques

- Storage of creole seeds to maintain regional genetic wealth

- Rational use of water resources, including water reuse

- Rational use of water resources, including water reuse

- Organization and strengthening of farmers' associations and cooperatives for purchasing inputs and marketing products

- Increase in productive diversification, with emphasis on agroforestry systems

- Use of seed and animal varieties that are more resistant to local conditions

- Greater use of soil management and conservation practices

- Rainwater collection and storage for irrigation

- Use of alternative energy sources through biodigesters and eco-friendly stoves.

- Processing and adding value to local products; for instance, through distinctive seals of quality and origin.

Click or scan the QR code and learn about some of the good practices of coexistence with the semiarid region and adaptation to climate change that have been implemented by the International Fund for Agricultural Development (IFAD) projects in Brazil:

Productive backyards

Biodigesters

Coexistence with the Semiarid Region

Creole seeds

Caatinga Management

Resilience in family farming

Agroforestry systems

Animal Farming

Marketing of family farming products

Eco-friendly stoves

Water Management

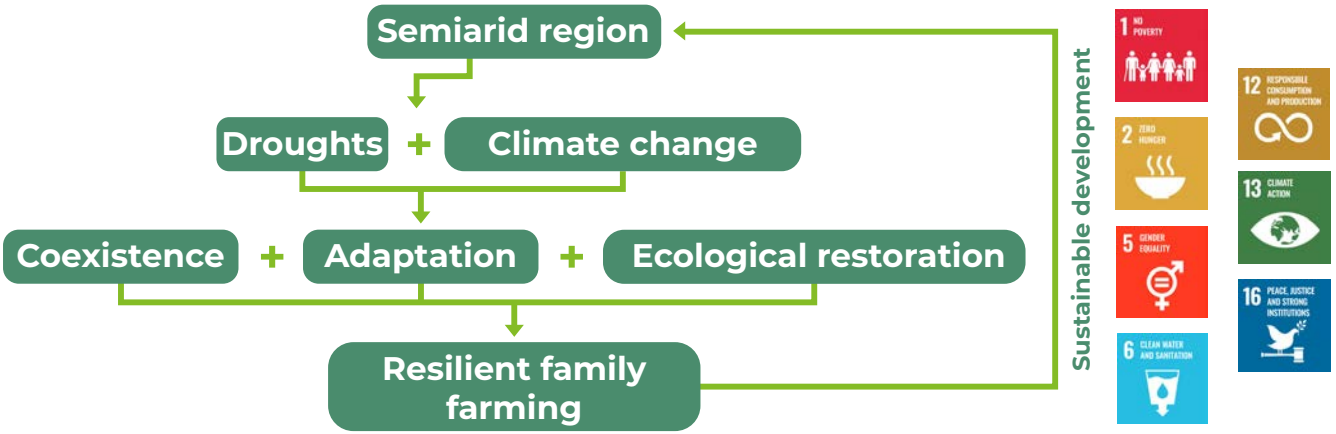
Coping with climate change

> We reinvent ourselves! As one of the alternatives, we plant exotic species adapted to the semiarid region to process them as silage and hay; we use native plants such as catingueira, maniçoba and malva, which are a source of protein, in an attempt to reduce costs without affecting the nutrition of goats. We use sustainable practices to preserve natural resources, like good Caatinga management practices, and to conserve the soil and the little water we have left. (...) This has motivated us in many ways, awakening the hope of how much it is possible to live in the semiarid region, despite all the obstacles caused by the drought." (Heleno Silva Pereira, 58 years old, resident of the municipality of Barra de Santa Rosa, Paraíba state).

> "Drilling wells and building an underground dam helped to keep the forage crops that serve as food for our animals. The implementation of the SAF (Agroforestry System) was very beneficial to us, making even a small area very productive, contributing both to our food and to our animals, leading us to harvest (...) watermelons, pumpkins, jerimuns, vegetables, fruits... in addition to teaching us to take better care of our natural resources through sustainable management practices in the Caatinga, (...) maintaining life on the land through vegetal cover and intercropping" (Arlindo Ferreira de Macedo, 55 years old, resident of municipality of Sossego, Paraíba state).

Strategies to adapt to climate change and actions to coexist with the semiarid region have clear synergy with the SDGs, especially those highlighted in Figure 18. At the same time that they reduce the vulnerability of agriculture and of the local population, they minimize the impacts to the environment as well as promote the improvement of social conditions with greater food production and reduction of poverty and inequality. As family farming becomes more resilient, its adaptive capacity also increases in a positive feedback process.

Figure 18. Synergy between coexistence with the semiarid region, adaptation to climate change, and the Sustainable Development Goals



The will to remain in the semiarid region, their native land, drives farmers to invest in coexistence and adaptation actions. This is because agriculture is perceived beyond income generation, that is, "as something intrinsically linked to their culture and way of life"[41]. Therefore, knowledge about coexistence actions and climate change is a very important factor to enhance the resilience and adaptive capacity of family farming.

In order to improve coexistence with the Semiarid, it is crucial to take care of its main biome, the Caatinga. And one of the ways to reverse the process of environmental degradation the Caatinga has undergone over time is through Recaatinga. It is about reforesting the Caatinga with native species or those adapted to the natural conditions of the region, trying to make it go back to its original state. Recaatinga results from the interaction between traditional popular knowledge and technical-scientific approaches. Through this technique, the process of desertification in the Brazilian semiarid region can be controlled, and at the same time, it can contribute to mitigating climate change and to valuing the regional genetic heritage. The ecological restoration of the Caatinga guarantees the necessary balance between conservation/recovery of natural environments and the productive processes that generate income for the local population[42].

The IFAD has contributed to the financing and development of various actions and programs for coexistence with the semiarid region and adaptation to climate change. Some the goals of its actions are: (i) “creating and sharing knowledge to aid in improving the capacity of rural populations and local institutions (government and civil society) to take advantage of the potential of the semiarid region, to adapt to climate change, and to implement public rural development programs and policies”; and (ii) “recording and spreading knowledge and good practices of family farmers in living with the semiarid region, seeking to cause public policies to be created in order to reduce rural poverty”[43]. The IFAD has also been investing in identifying and fighting against knowledge barriers that limit the adoption of climate-smart agriculture practices.

Nowadays I have a place to sell my products at a fixed point of sale location, which is the Quiosque Agroecológico. When we used to run out of institutional marketing from the PAA (Food Acquisition Program) and PNAE (National School Feeding Program), our products would spoil as we had no way to sell them. Nowadays I have water stored in the second-water cistern for my crops, and the water from the greywater reuse that is for the fruit trees in my backyard. I also have worms which produce humus that serves as fertilizer for my plants. I am very grateful!” (Maria José Prudêncio Rodrigues, 67 years old, resident of the municipality of Sobral, Ceará state).

“It was a gratifying experience to have lived more than six years with farmers. The experience contributed to both my professional and personal growth. Nowadays I understand how it is possible to build a better future by applying local and daily practices. The important thing is that everyone really puts them into practice so that there is an accumulated positive result.” (Thiago César Farias da Silva, 38 years old, biologist and technician in projects supported by IFAD).

All in all, it can be said that IFAD’s actions help to improve living conditions in the semiarid region, and at the same time, to care for the environment and make family farming more resistant to the effects of climate change. Its programs and projects have as guiding elements: the conservation of biodiversity; sustainable production, as well as production based on the principles of associativism and cooperativism; the inclusion of traditional peoples and communities; the participation of women and young people; food sovereignty; the aggregation of value and commercialization of products; and the easier access to public policies[43].

REFERENCES

[1] Intergovernmental Panel on Climate Change – IPCC. **Summary for Policymakers**. In: Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, B. Zhou (Eds.). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In Press. 2021.

[2] Intergovernmental Panel on Climate Change – IPCC. **Climate Change 2014: Synthesis Report**. In: Core Writing Team, R.K. Pachauri, L.A. Meyer (Eds.). Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 2014.

[3] World Meteorological Organization – WMO. **Climate**. 2022. Disponível em: https://public.wmo.int/en/our-mandate/climate. Acesso em 10 jan. 2022.

[4] Decicino, R. **Efeito estufa - Mecanismo atmosférico mantém o planeta aquecido.** 2020. Disponível em: https://educacao.uol.com.br/disciplinas/geografia/efeito-estufa-mecanismo-atmosferico-mantem-o-planeta-aquecido.htm. Acesso em 06 jan. 2022.

[5] Sheffield, J; Goteti, Gopi; Wood, Eric F. Development of a 50-year high-resolution global dataset of meteorological forcings for land surface modeling. **Journal of climate**, 19 (13), p. 3088-3111, 2006.

[6] Tol, R. The Economic Impacts of Climate Change. **Review of Environmental Economics and Policy**, 12 (1), p. 4-25, 2018.

[7] Lesk, C.; Coffel, E.; Winter, J. et al. Stronger temperature–moisture couplings exacerbate the impact of climate warming on global crop yields. **Nature Food**, 2, p. 683-691, 2021.

[8] Njoro, J. **Re-imagining food systems through the climate–nutrition nexus**. 2021. Disponível em https://www.ifad.org/en/web/latest/-/climate-nutrition-nexus. Acesso em 10 abr. 2022.

[9] Mbow, C.; Rosenzweig, C.; Barioni, L. G.; et al. **Food Security**. In: Shukla, P. R.; Skea, J.; Calvo, E.; et al. (Eds.). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. 2019. In press.

[10] Springmann, M. Mason-D'Croz, D.; Robinson, S.; et al. Global and regional health effects of future food production under climate change: a modelling study. **The Lancet**, 387 (10031), p. 1937-1946, 2016

[11] Intergovernmental Panel on Climate Change – IPCC. **Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change**. In: Pörtner, H. O.; Roberts, D. C.; Tignor, M.; Poloczanska, E. S.; Mintenbeck, K.; Alegría, A.; Craig, M.; Langsdorf, S.; Löschke, S.; Möller, V.; Okem, A.; Rama, B. (Eds.). Cambridge University Press. In Press. 2022.

[12] International Fund for Agricultural Development – IFAD. **Measuring climate resilience: environmental and climate chan**ge. 2015. Disponível em: https://www.ifad.org/documents/38714170/40193941/htdn_climate_resilience.pdf/fd0b42b0-3fc1-41e2-bd45-c66506fa5004. Acesso em 10 abr. 2022.

[13] Intergovernmental Panel on Climate Change – IPCC. **WGII AR5 Glossary**. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the IPCC 5th Assessment. Geneva, Switzerland: IPCC.

[14] Barrett, C. B.; Constas, M. A. Toward a theory of resilience for international development applications. **PNAS,** 111 (40), p. 14625-14630, 2014.

[15] Souza, B.; Haddad, E. Climate change in Brazil: dealing with uncertainty in agricultural productivity models and the implications for economy-wide impacts. **Spatial Economic Analysis**, 17 (1), p. 83-100, 2022.

[16] Ferreira Filho, J.; Moraes, G. Climate change, agriculture and economic effects on different regions of Brazil. **Environment and Development Economics**, 20 (1), p. 37-56, 2015.

[17] Nazareth, M.S.; Gurgel, A.C.; Da Cunha, D.A. Economic effects of projected decrease in Brazilian agricultural productivity under climate change. **GeoJournal**, v. 87, p. 957-970, 2022.

[18] Rosa Neto, C.; Silva, F. A. C.; Araújo, L. V. **Qual é a participação da agricultura familiar na produção de alimentos no Brasil e em Rondônia?** 2020. Disponível em https://bit.ly/3L6FrfQ. Acesso em 10 abr. 2022.

[19] Machado, L.W.; La Roveri, E. L. The Traditional Technological Approach and Social Technologies in the Brazilian Semiarid Region. Sustainability, 10 (1), p. 25, 2018.

[20] Superintendência do Desenvolvimento do Nordeste – SUDENE. **Resolução N° 150, de 13 de dezembro de 2021**. Disponível em: https://www.gov.br/sudene/pt-br/centrais-de-conteudo/resolucao1502021.pdf. Acesso em 22 mar. 2022.

[21] Instituto Brasileiro de Geografia e Estatística – IBGE. **Semiárido Brasileiro**. 2019. Disponível em: https://www.ibge.gov.br/geociencias/organizacao-do-territorio/estrutura-territorial/15974-semiarido-brasileiro.html?=&t=o-que-e. Acesso em 09 jan. 2022.

[22] Ministério da Ciência, Tecnologia e Inovações – MCTI. **Semiárido Brasileiro**. 2022. Disponível em: https://www.gov.br/mcti/pt-br/rede-mcti/insa/semiarido-brasileiro. Acesso em 09 jan. 2022.

[23] Sinimbu, F. **Riquezas da mata branca**. 2016. Disponível em: https://www.embrapa.br/busca-de-noticias/-/noticia/18708656/riquezas-da-mata-branca. Acesso em 09 jan. 2022.

[24] Instituto Brasileiro de Geografia e Estatística – IBGE. **Censo Agropecuário 2017 – Resultados definitivos**. Rio de Janeiro: IBGE, 2019. Disponível em: https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2017. Acesso em 06 abr. 2022.

[25] Articulação Semiárido Brasileiro – ASA. **É no Semiárido que a vida pulsa!** 2022. Disponível em: https://www.asabrasil.org.br/semiarido. Acesso em 06 abr. 2022.

[26] Costa, R.L.; Baptista, G.M.M.; Gomes, H.B. et al. Analysis of climate extremes indices over Northeast Brazil from 1961 to 2014. **Weather and Climate Extremes**, 28, p. 100254, 2020.

[27] YOUNG, C. E. F.; Costa, L. A. N.; Fares, L. R. **Drought in the Brazilian Semi-Arid**. 2019. Fundo Internacional para o Desenvolvimento Agrícola.

[28] Oliveira, G.C.; Arruda, D.M. Fernandes Filho, E. I. et al. Soil predictors are crucial for modelling vegetation distribution and its responses to climate change. **Science of the Total Environment**, 780, p. 146680, 2021.

[29] Universidade Federal de Alagoas, Assessoria de Comunicação (ASCOM/UFAL). **LAPIS utiliza metodologia inédita para monitorar processo de desertificação no Brasil**. 2019. Disponível em https://ufal.br/ufal/noticias/2019/7/lapis-utiliza-metodologia-inedita-para-monitorar-processo-de-desertificacao-no-brasil. Acesso em 03 fev. 2022.

[30] Instituto Sociedade, População e Natureza, Cerratinga – ISPN. **Umbu**. 2022. Disponível em: https://www.cerratinga.org.br/especies/umbu/. Acesso em 03 fev. 2022.

[31] Cunha, E. **Os sertões**. Rio de Janeiro: Ediouro, 2003.

[32] Articulação Semiárido Brasileiro – ASA. **Declaração do Semiárido**. 1999. Disponível em: https://www.asabrasil.org.br/images/UserFiles/File/DECLARACAO_DO_SEMI-ARIDO.pdf. Acesso em 05 abr. 2021.

[33] Articulação Semiárido Brasileiro – ASA. **História: conheça mais sobre nossa rede**. 2022. Disponível em: https://www.asabrasil.org.br/sobre-nos/historia. Acesso em 05 abr. 2021.

[34] Instituto de Tecnologia Social – ITS BRASIL. **Caderno de Debate – Tecnologia Social no Brasil**. São Paulo: ITS, 2004.

[35] CONSTANZA, R. **A Economia Ecológica: Uma agenda de pesquisa**. In. MAY, P. H.; MOTTA, R. S. da. Valorando a Natureza. Rio de Janeiro: Campus, 1994

[36] Comissão Mundial Sobre Meio Ambiente e Desenvolvimento. **Nosso Futuro Comum**. 2 ed. Rio de Janeiro: Editora da Fundação Getúlio Vargas, 1991.

[37] Nações Unidas – ONU, Brasil. **Objetivos de Desenvolvimento Sustentável no Brasil**. Disponível em: https://brasil.un.org/pt-br/sdgs. Acesso em 22 fev. 2022.

[38] SILVA, R. M. A. Entre dois paradigmas: combate à seca e convivência com o Semiárido. Sociedade e Estado, 18 (1-2), p. 361-385, 2003.

[39] Mattos, L. C. M. **Um tempo entre secas: superação de calamidades sociais provocadas pela seca através das ações em defesa da convivência com o semiárido**. 2017. 273 f. Tese (Doutorado em Ciências Sociais em Desenvolvimento, Agricultura e Sociedade) – Instituto de Ciências Humanas e Sociais, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro.

[40] Articulação Semiárido Brasileiro – ASA. **P1MC – Programa Um Milhão de Cisternas**. 2022. Disponível em: https://www.asabrasil.org.br/acoes/p1mc. Acesso em 22 fev. 2022.

[41] Carlos, S.M.; Da Cunha, D.A.; Pires, M.V.; Couto-Santos, F.R. Understanding farmers' perceptions and adaptation to climate change: the case of Rio das Contas basin, Brazil. **GeoJournal**, 85, p. 805-821, 2020.

[42] Instituto Regional da Pequena Agropecuária Apropriada – IRPAA. **Experiências de Recaatingamento no Semiárido Brasileiro**. 2019. Disponível em: https://irpaa.org/publicacoes/32/cartilhas/experiencias-de-recaatingamento-no-semiarido-brasileiro. Acesso em 17 abr. 2022.

[43] Fundo Internacional para o Desenvolvimento Agrícola – FIDA. **O FIDA no Brasil: estratégias para promover o desenvolvimento rural no Nordeste**. Salvador: FIDA, 2017.

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