Brazil

Planting Resilience in Rural Communities of the Northeast (PCRP)

Annex II – Feasibility Study

GCF Additional Financing

July 2020

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1. INTRODUCTION

This feasibility study was carried out as part of the preparation for the Planting Resilience in Rural Communities of the Brazilian Semiarid (PCRP) project. It's main goal is to promote climate resilient production systems (CRPS) within the poor rural population in the northeastern semiarid region of the country.

The main objectives of this study are:

i) to analyze the current situation of the Brazilian semiarid given the future climate change scenario,
ii) to identify and characterize the most critical problems faced by the rural poor, as well as the barriers and challenges that the situation poses;
iii) describe the main solutions to be implemented by the PCRP;
iv) analyze these solutions and their feasibility in the productive and environmental scope;
v) make a detailed presentation of the PCRP and its various dimensions.

An extensive literature review on the topics mentioned above was undertaken, as well as field information gathering work with various local actors - research entities, rural development support organizations, multiple technicians and farmers working in the field. The PCRP has the endorsement of the National Designated Authority (NDA), the Ministry of Economy, which has issued the no-objection letter and the COFIEX Resolution with the approval of the project. The project design team consulted several public agencies about the theme of resilient production systems in the region, over the following timeline:

- Field mission in Bahia State: 1 to 5 October 2018;
- Field Mission in Pernambuco State: 15 to 17 October 2018;
- Public hearing in Recife, Pernambuco: 18 October 2018;
- Main mission in Brasilia: 19 to 26 October 2018;
- BNDES HQ design mission: 18 to 22 February 2019;
- Indigenous groups consultation: 8 June 2019.

The Public Hearing in Recife was attended by over 100 people representing various stakeholders. The field missions in Bahia and Pernambuco, prepared in collaboration with many partners, have allowed the design team to study and analyze technologies, technical assistance processes, experiences and innovations, specific demand and conditions of the semiarid region, organizational and community-based structures, and institutional arrangements while taking stock of social, environmental, economic and environmental risks.

Meetings with a staff of IFAD-financed projects in Bahia (Pro-semiarid) and Paraiba (PROCASE) were held in July 2018 and a field visit to an agroforestry experience (Fazenda Ouro Fino in Bahia) was organized in August 2018. The consultation at the federal level also included other Ministries: Citizenship; Environment; Science and Technology; Agriculture, Livestock and Food Supply; Home Affairs, and Foreign Relations.

The IFAD also prepared a regional grant project, the Dryland Adaptation Knowledge Initiative (DAKI), which was approved by IFAD in December 2019. The project will start in the first quarter of 2020 and pave the way and prepare for the PCRP.

This document presents the results of all these analyses and consultations. It begins with the discussion of the different elements of the context that characterize the issue of resilience in the face of climate change in the Brazilian Semiarid, including relevant public policies. Then, the socioeconomic and environmental crisis in the Semiarid and the barriers that need to overcome them are presented. In the next section, the initiatives the Project proposes to implement are described and analyzed, and the PCRP activities and modus operandi are explained. The final section presents the main conclusions of this feasibility study.

2. CONTEXT ANALYSIS

2.1 Brazil's Northeast Semiarid

The officially defined Semiarid Region[1] (see Figure 1 below) hosts 27 million people (12% of the country's total population)[2] and covers 1,262 municipalities in ten States. A small part of the official Semiarid Region (18%) of this region are in the State of Minas Gerais and Espirito Santo, while the remaining 82% is in 8 Northeastern States[3]. The Project area will within be the rural semiarid part of these eight northeastern states: Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia; where the most impoverished population lives and where IFAD has been supporting pro-poor rural development for the past 25 years. It is also the area where family farming is concentrated and currently faces the country's most significant challenge regarding poverty eradication.[4]

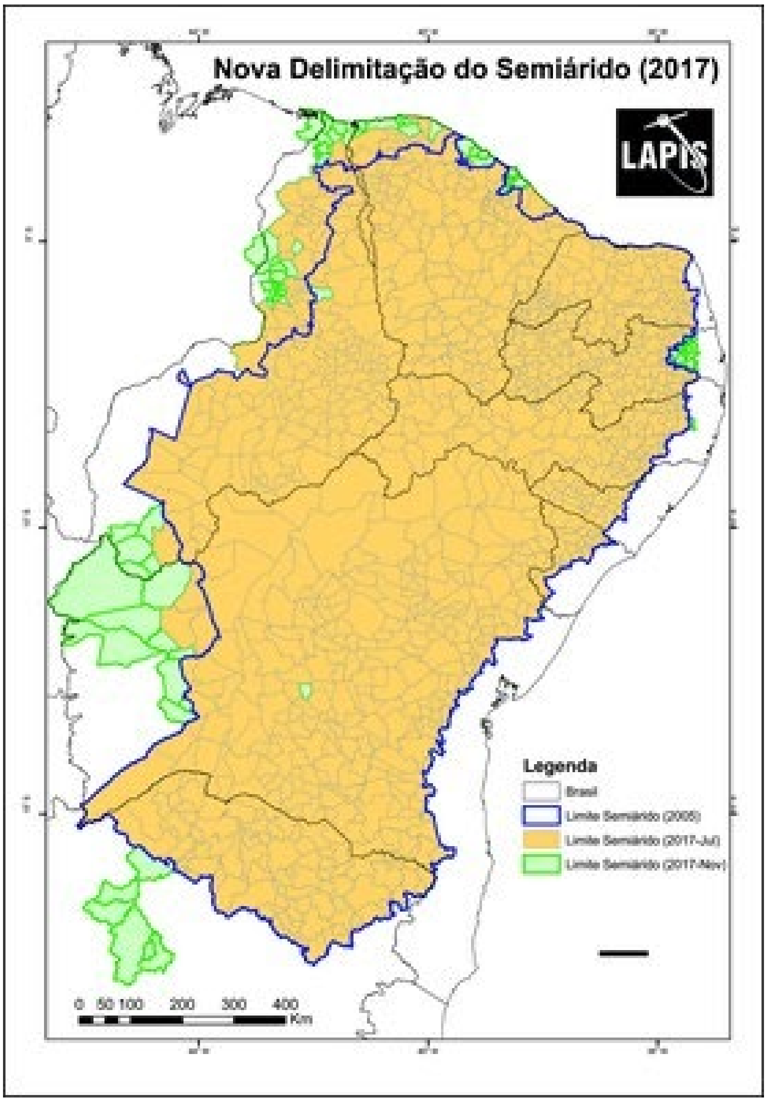

Figure 1 Map of NE Brazil, highlighting the Semiarid region[5]

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[1] The SUDENE (Suoerintendência de Desenvolvimento do Nordeste) Resolution 115 of 23/11/2017 defines the Semiarid region with the following characteristics: i) Average annual rainfall of 800 mm or less; ii) Thornthwaite Aridity Index equal to or less than 0.50; and iii) Daily percentage of water deficit equal to or greater than 60%, considering all days of the year.

[2] Ministry of Integration webpage, available at: http://www.integracao.gov.br/semiarido-brasileiro.

[3] These eight Northeastern States are the following: Bahia, Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, Ceará and Piauí.

[4] IFAD - IPC-IG. Climate change and impacts on family farming in the North and Northeast of Brazil, Working Paper No.141, Brasília, IPC-IG, UNDP, IPEA, IFAD, 2016. (This study was commissioned and paid for by IFAD).

[5] LAPIS (Laboratório de Análise e Processamento de Imagens de Satélites) / UFAL (Universidade Federal de Alagoas), 2017. (https://al1.com.br/noticias/meio-ambiente/14137/Portal_AL1).

2.2 Historical and Current Climate Overview

2.2.1 Historical Climate Data

The semiarid northeast of Brazil (NEB)[6] is it is qualified as a tropical dry climate with average minimum and maximum temperatures between 21.23°C and 30.85 °C, respectively. This region can get much hotter during the dry season, has a short, erratic rainy season from March to May, and annual rainfall averages from 390 to 1,550 mm. The coolest months on average are June and July and the warmest is October. Lowest minimum temperatures can be found in the central area of the State of Bahia, while maximums concentrate primarily in the most northern states.

The northeast region has experienced secular chronic problems related to water scarcity, with periodic droughts. However, it is possible to identify an increase in temperature from 1901 to 2000 of about 0.8 °C in NEB and an important acceleration in warming during the last three decades. An analysis of drought events that occurred in the Semiarid from 1981 to 2016[7] reveals that drought intensity for the last 36 years has been increasing and that recent droughts were more frequent, more severe and affected a larger area with significant impacts for population, as well as economical activities.

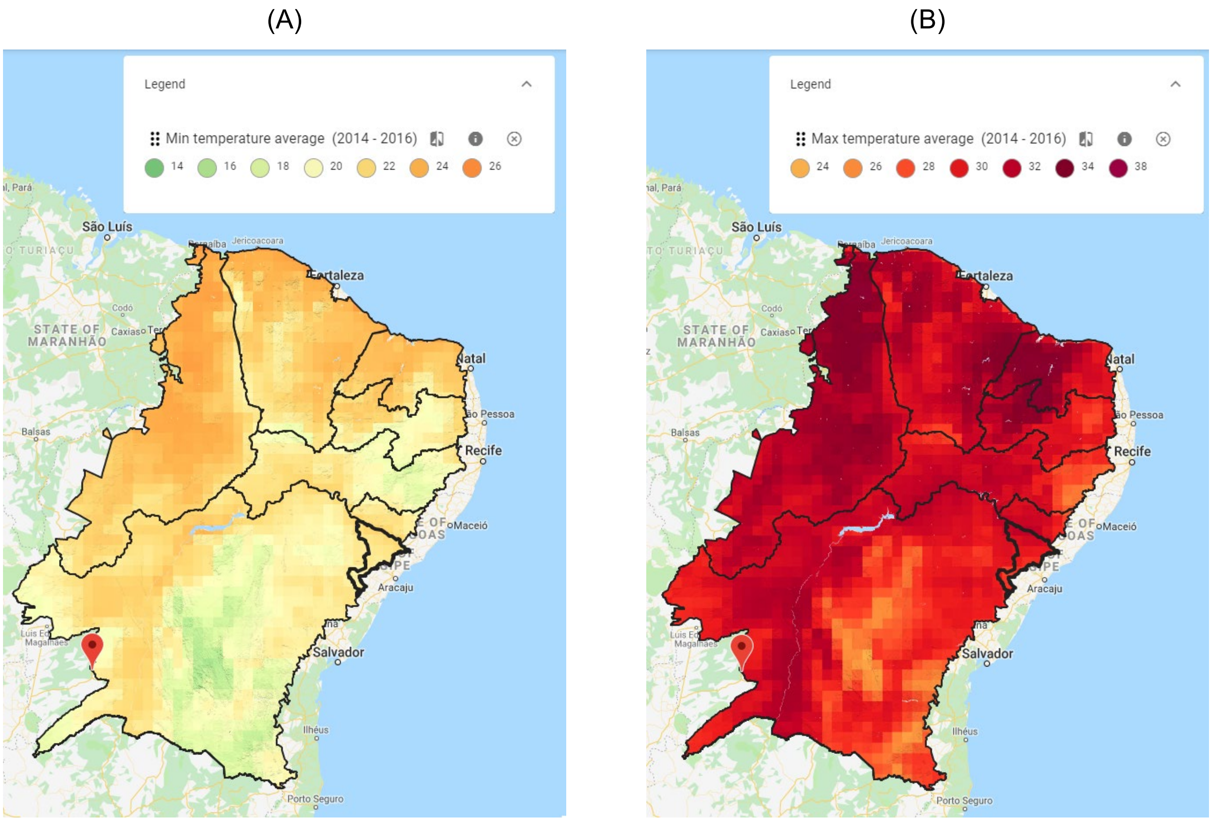


Figure 2 Min (A) and Max (B) average temperature 2014-2016

Appendix IV presents the climate profile for each of the 8 States in the Northeast.

Marengo et al. (2017)[20] presented a historical series (1961-2016) of seasonal precipitation averages for the season February, March, April, and May (FMAM) over Northeast Brazil (Figure 3a) and precipitation anomalies for the same period (Figure 3b). In this study, the low seasonal averages of precipitation for the period 2012-2016 and the strong anomalies of precipitation stand out, showing the severity of the last drought. Still, according to Figure 3b, it is possible to observe that the last drought was the most severe in the last 50 years and that the average precipitation in the region had

[6] The Resolution 115 of 23/11/17 from Sudene defines the Semiarid by the following characteristics: i) Average annual rainfall of 800 mm or less; ii) Thornthwaite Aridity Index equal to or less than 0.50; and iii) Daily percentage of water deficit equal to or greater than 60%, considering all days of the year.
[7] Brito, SSB; et.al. Frequency, duration and severity of drought in the Semiarid Northeast Brazil region, International Journal of Climatology, 2017.

a reduction of up to 60%, which justifies the impacts on the population and economy in the region, in addition to the high costs for the federal government with emergency measures.

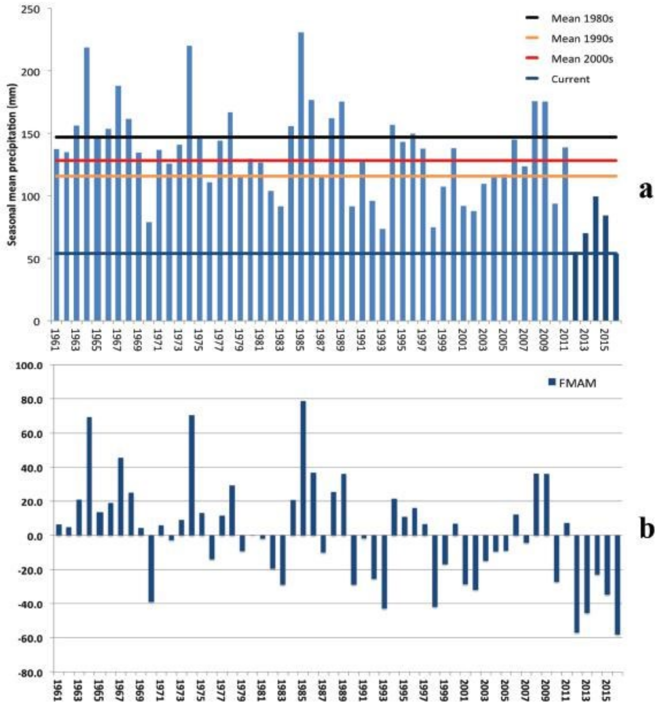


Figure 3. (a) Precipitação média sazonal (FMAM) considerando o período 1961-2016, em mm. (b) Anomalias de precipitação em % relativas à média do período (1980-2000). As linhas horizontais coloridas apresentam a média decadal para a década de 1980, 1990, 2000 Source: Marengo et al. (2017).

Rainfall in NEB is modulated by multiple atmospheric systems.[8] The annual rainfall is less than 500mm in the semiarid inner areas and more than 1500mm in the coastland and in the northwest part of the region, which has resulted in various Köppen climate types (Figure 4). The climate of the whole area alternates between a wet season, for which timing and characteristics vary throughout the region but generally last between 2–5 months, and a dry season for the remainder of the year. Rainfall is characterized by high spatial variability combined with large intraseasonal to interannual variations. Based on the frequency of rainy days over four months, Cunha et al. (2015) divided the area into five sub-regions, which are entirely consistent with the different rainfall regimes (Figure 4).

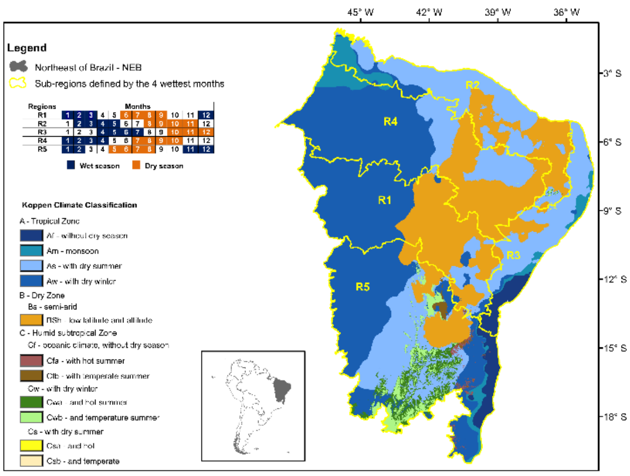


Figure 4. Northeast region of Brazil showing the subregions (yellow polygons) defined by the wettest months (Cunha et al., 2015) and Köppen climate classification Alvares et al. (2013). Source: Martins et al. 2019.

[8] Oliveira, P.T., Santos e Silva, C.M., Lima, K.C.(2017). Climatology and trend analysis of extreme precipitation in subregions of Northeast Brazil. Theor. Appl. Climatol. https://doi.org/10.1007/s00704-016-1865-z.

Due to the complexity in terms of climate variability, it is not adequate to represent the entire region through a spatial averaging. So, many studies have pointed out to local or sub-regional analysis of temperature and precipitation to better represent these variables over the region. Here are presented five different studies related to climate trends in NEB over the past years.

Da Silva et al. (2004)[9] showed time-series (annual period and dry and wet season) of eight climate variables in NEB. They used data records length of 30 years or at most 37 years, except that the rainfall time-series was approximately 80 years. This study emphasizes that the time-series of the climatic variables in NEB presented an increasing trend for almost all stations. Moreover, the relative humidity and rainfall trend is inverse, that is, decreasing over time, in most stations.

Campina Grande station (Figure 5) presented the greatest increasing trend in air temperature in the three periods analyzed (annual period and dry and wet season). The temperature increases corresponding to the total period was 1.71ºC.

[9] Da Silva, V. de P. R. (2004). On climate variability in Northeast of Brazil. **Journal of Arid Environments** 58. 575–596.

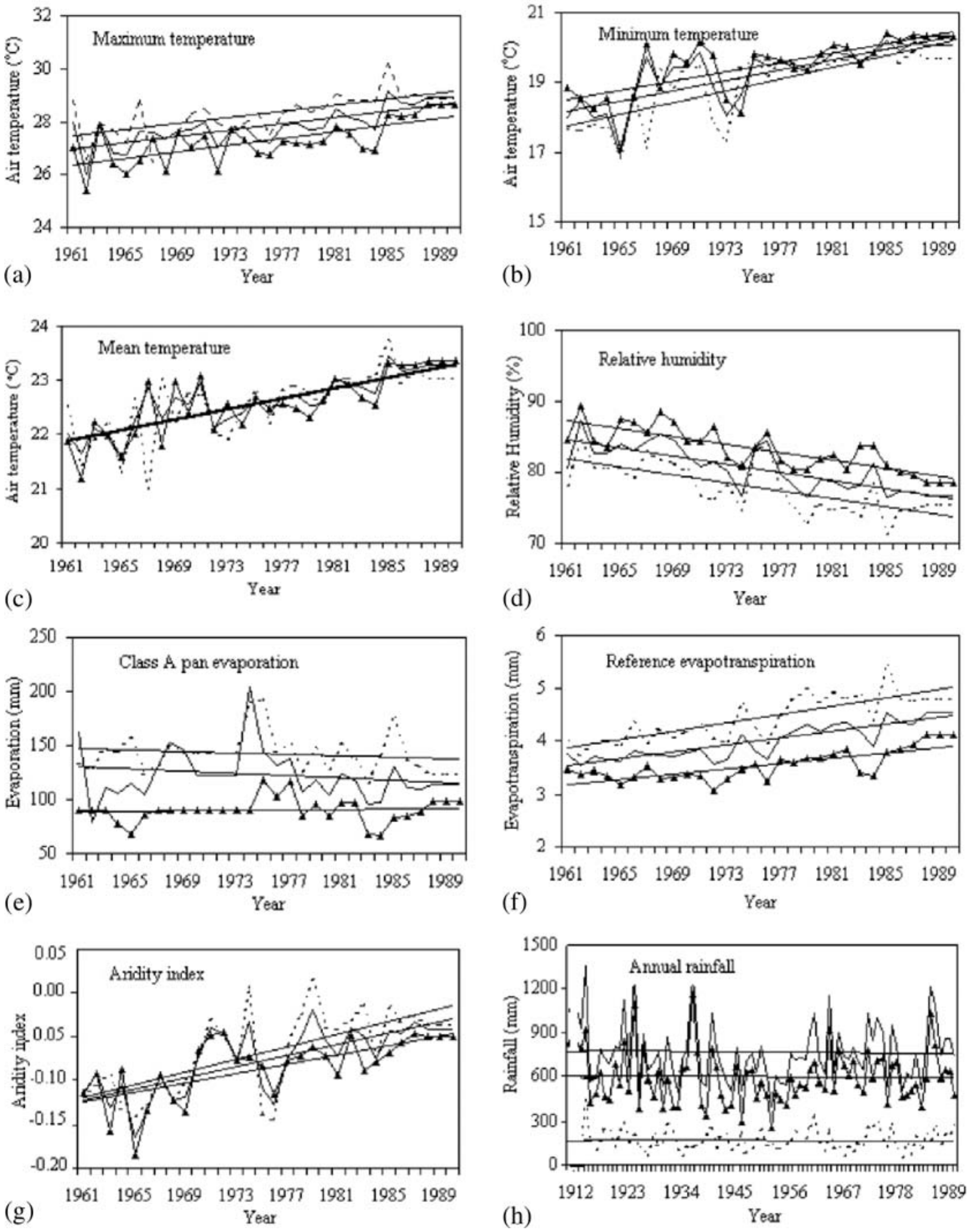


Figure 5. Trends of the climatic variables to Campina Grande station. The continuous line indicates the mean annual trend, the dashed line indicates the mean trend of the dry season and the line with triangles indicates the mean tendency of the wet season. Source: Da Silva et al. (2004).

Unlike the other stations in NEB, analyzed by Da Silva et al. (2004), Petrolina station (Figure 6) revealed an increase of the rainfall and relative humidity and at the same time decrease in the mean temperature, evaporation, evapotranspiration and aridity index.

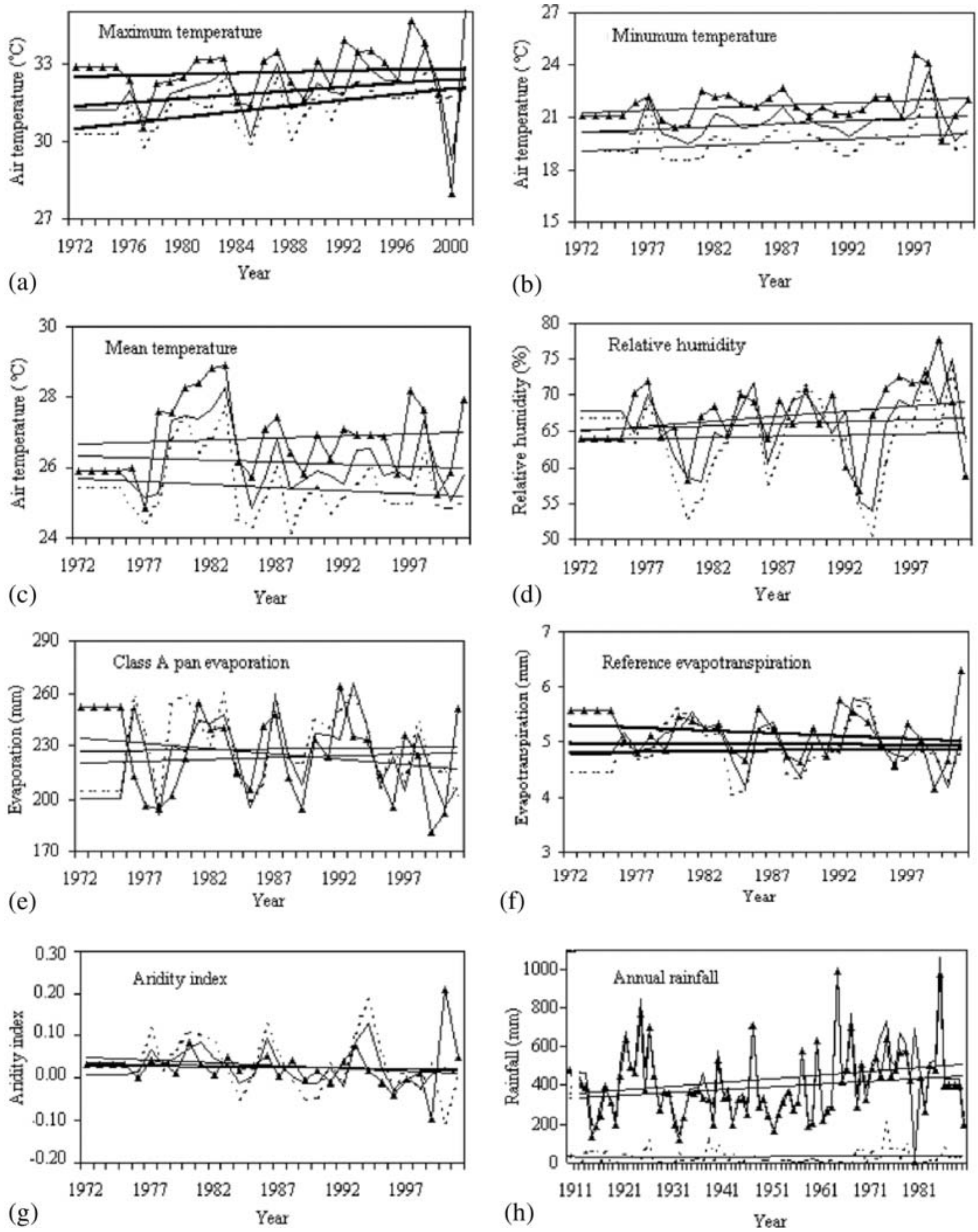


Figure 6. Trends of the climatic variables to Petrolina station. The continuous line indicates the mean annual trend, the dashed line indicates the mean trend of the dry season and the line with triangles indicates the mean tendency of the wet season. Source: Da Silva et al. (2004).

The increase in relative humidity in Petrolina station was accompanied by a reduction in class A pan evapotranspiration, reference evapotranspiration, and aridity index. Figure 6c shows the decrease in the mean air temperature, while Figure 6h shows the increase in the rainfall. The inverse behavior of the climate variables in Petrolina station, compared with the other stations in NEB, is associated with the large expansion of the irrigated perimeter over the middle reaches of San Francisco River Valley, where Petrolina is located.

The São Francisco River basin is one of the most important basins in Brazil, along 2860 km, the river crosses seven Brazilian states: Bahia, Minas Gerais, Pernambuco, Alagoas, Sergipe, Goiás e Distrito Federal, among them, four states are located in NEB.[10]

[10] ANA (2013). Região Hidrográfica do São Francisco. Available at < https://www.ana.gov.br/as-12-regioes-hidrograficas-brasileiras/sao-francisco> Accessed in: 21th July, 2020.

Due to its importance, Bezerra et al (2018)[11] have identified linear trends of climate indices based on precipitation observations, from 1947 to 2012 by using 11 extreme precipitation indices. Analyzing the regionally averaged anomaly series (Figure 7) is noted that the changes in precipitation extremes over São Francisco River Basin during 1947–2012 were low, and only the daily intensity index - SDII and the consecutive dry days - CDD had statistically significant trends, respectively (Figure 7 g, h).

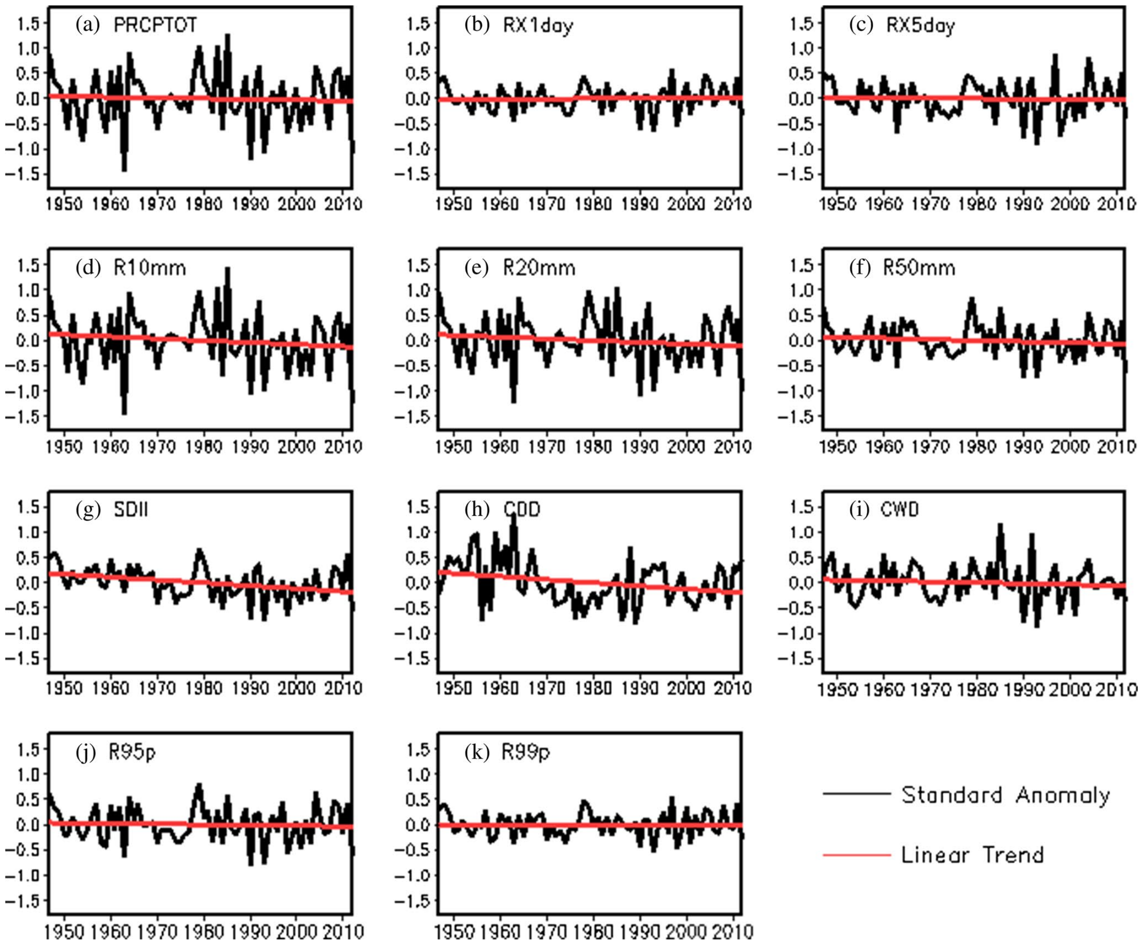


Figure 7. Regional annual anomaly series, 1947–2012, for indices of precipitation extremes. Source: Bezerra et al. (2018).

Still, according to Figure 7 is noted that all precipitation related extremes indices had decreasing trends, except the maximum 1-day precipitation amount - Rx1day (Figure 7b). The Annual total amount of precipitation cumulated in wet days - PRCPTOT had a weak decreasing trend and the regional trend for this index was -7.9 mm/decade (Figure 6a). The Rx1day was the unique index that had an increasing trend, but very weak, while the maximum 5-day precipitation amount - RX5day, had a decreasing trend (-0.73 mm/decade) (Figure 7 b, c). The number of heavy precipitation days indices, with more than 10 mm day^{-1} - R10mm, 20 mm day^{-1} - R20mm, and 50 mm day^{-1} - R50mm had decreasing trends, whose values were - 0.33, - 0.29, and - 0.07 days/decade, respectively (Figure 7 d–f).

Even though the authors presented regionally averaged anomaly, they call attention to the absence of regional coherence of change in climate extreme indices, mainly on Lower-Middle and Lower São Francisco. These opposing trends observed are probably associated with local-scale events, regional circulation induced by the changes in land use.

[11] Bezerra, B.G., Silva, L.L., Santos e Silva, C.M. et al. Changes of precipitation extremes indices in São Francisco River Basin, Brazil from 1947 to 2012. (2019). **Theor Appl Climatol** 135, 565–576. https://doi.org/10.1007/s00704-018-2396-6

Another study elucidates about temperature and precipitation trends in NEB over the past years as shown in Figure 8 and Figure 9.[12] These Figures show the trends of different quantile levels in three municipalities chosen to represent the South, East, and North sectors of NEB. The Standardized Precipitation Evapotranspiration Index (SPEI) is presented as well. It is characterized as the standardized water balance between precipitation and potential evapotranspiration

Figure 8. Trends of SPEI-3/decade multi quantile levels for the NDJ quarter in the cities (a) Barreiras (BA), (b) João Pessoa (PB), and (c) Fortaleza (CE). Source: Da Rocha et al. (2019).

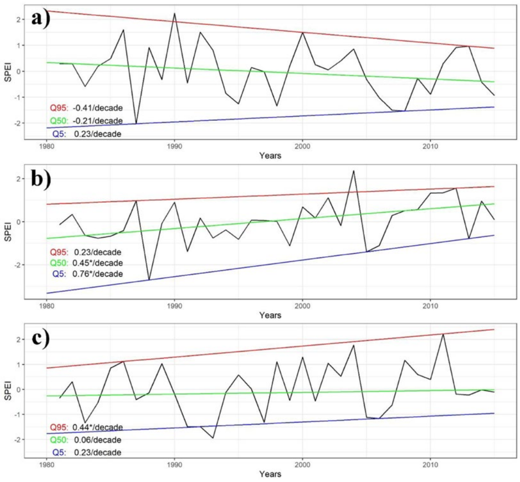
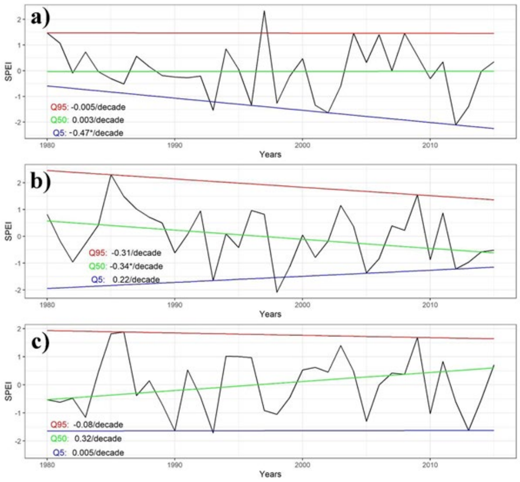


Figure 9. Trends of multi quantile levels of SPEI-3/decade for the FMA quarter in the cities (a) Barreiras (BA), (b) João Pessoa (PB), and (c) Fortaleza (CE). Source: Da Rocha et al. (2019).



The black line is the SPEI, the red line represents the upper quantile 95, the intermediate green line the 50th quantile, and the blue line the lower quantile 05).

In November, December, and January quarter - NDJ, Barreiras presented negative trends in Q50 and Q95, and a positive trend in Q5 (Figure 8a). Considering that there was a negative trend in Q95 and a positive trend in Q5, it can be concluded that there is a clear contraction of drought variability in this municipality, and dry and wet periods should be less intense. João Pessoa and Fortaleza presented positive trends at all levels. In João Pessoa, the Q50 trend of 0.45 SPEI units per decade was statistically significant (Figure 8b), while in Fortaleza, there was statistical significance in the Q95 positive trend of 0.44 SPEI units per decade.

For February, March, and April quarter - FMA, the cities of Barreiras and João Pessoa had significant trends in Q5 (0.47 SPEI units per decade) and Q50 (0.34 SPEI units per decade), respectively. Barreiras exhibited negative trends at levels Q95 and Q05 (Figure 9a), indicating that there was an increase in severe drought events. In João Pessoa, Q95 and Q50 showed negative trends while Q05 showed a positive trend (Figure 9b). The pattern displayed for João Pessoa indicates a decrease in extreme drought and flood events. Fortaleza showed a positive trend only in the median quantile, indicating an increase in drought events, but without an increase in the intensity of extreme events (Figure 9c).

The authors point to changes in rainfall distribution at extreme quantile levels. In NDJ, there is a tendency of decreased rainfall in the upper quantile, indicated by negative values of SPEI, especially in the state of BA. In FMA, this feature persists, with the aggravation of being a feature of the entire NEB

Carvalho et al. (2020)[13] also analyzed trends in the rainfall regime of NEB, including the number of rainy days and temperature for stations located at different continentality and altitude conditions in NEB. Meteorological data of the National Institute of Meteorology - INMET were used. All the 45 stations used have a historical series with a data period of more than 30 years. The trends of Total Annual Rainfall (TAR), Total Annual Number of Rainy Days (TANRD), Mean temperature (Temp), Deviations of Rainfall from the Mean (DRM),

[12] Da Rocha Júnior, R. L., dos Santos Silva, F. D., Lisboa Costa, R., Barros Gomes, H., Herdies, D. L., Rodrigues da Silva, V. de P., Candido Xavier, A. (2019). Analysis of the Space–Temporal Trends of Wet Conditions in the Different Rainy Seasons of Brazilian Northeast by Quantile Regression and Bootstrap Test. **Geosciences**, 9(11), 457. doi:10.3390/geosciences9110457.
[13] Carvalho, A. A. de; Montenegro, A. A. de A.; da Silva, H. P.; Lopes, I; Morais, J. E. F. de; da Silva, T. G. F. (2020). Trends of rainfall and temperature in Northeast Brazil. **R. Bras. Eng. Agríc. Ambiental**, v.24, n.1, p.15-23.

Deviations of Rainy Days from the Mean (DRDM) and the respective Z values of the coastal strip of Northeast Brazil are presented in Figure 10.

The stations showed a trend, both for rainfall and the total annual number of rainy days (TANRD), with an increase of rainfall in Bacabal, MA, and reduction in Itaberaba, BA, Paulo Afonso, BA, and Quixeramobim, CE (Figure 9). The temperature tended to increase in these stations.

The trends for the stations of Quixeramobim, CE, Itaberaba, BA and Paulo Afonso, BA, until the year 2017 are of reduction in rainfall (121, 148 and 140 mm) and in rainy days (3, 21 and 24 days), as well as an increase of temperature (0.9, 0.69 and 0.6 ºC), respectively.

The reductions in TANRD represent a higher concentration of rainfall, consequently resulting in the increase of its intensity and, therefore, in major damage risk to urban and rural environments, possibly increasing flood events and soil degradation.[13] On the other hand, the reduction in the number of rainy days could be related to the shortening of the wet season, impacting the agriculture, water supply, and energy generation.

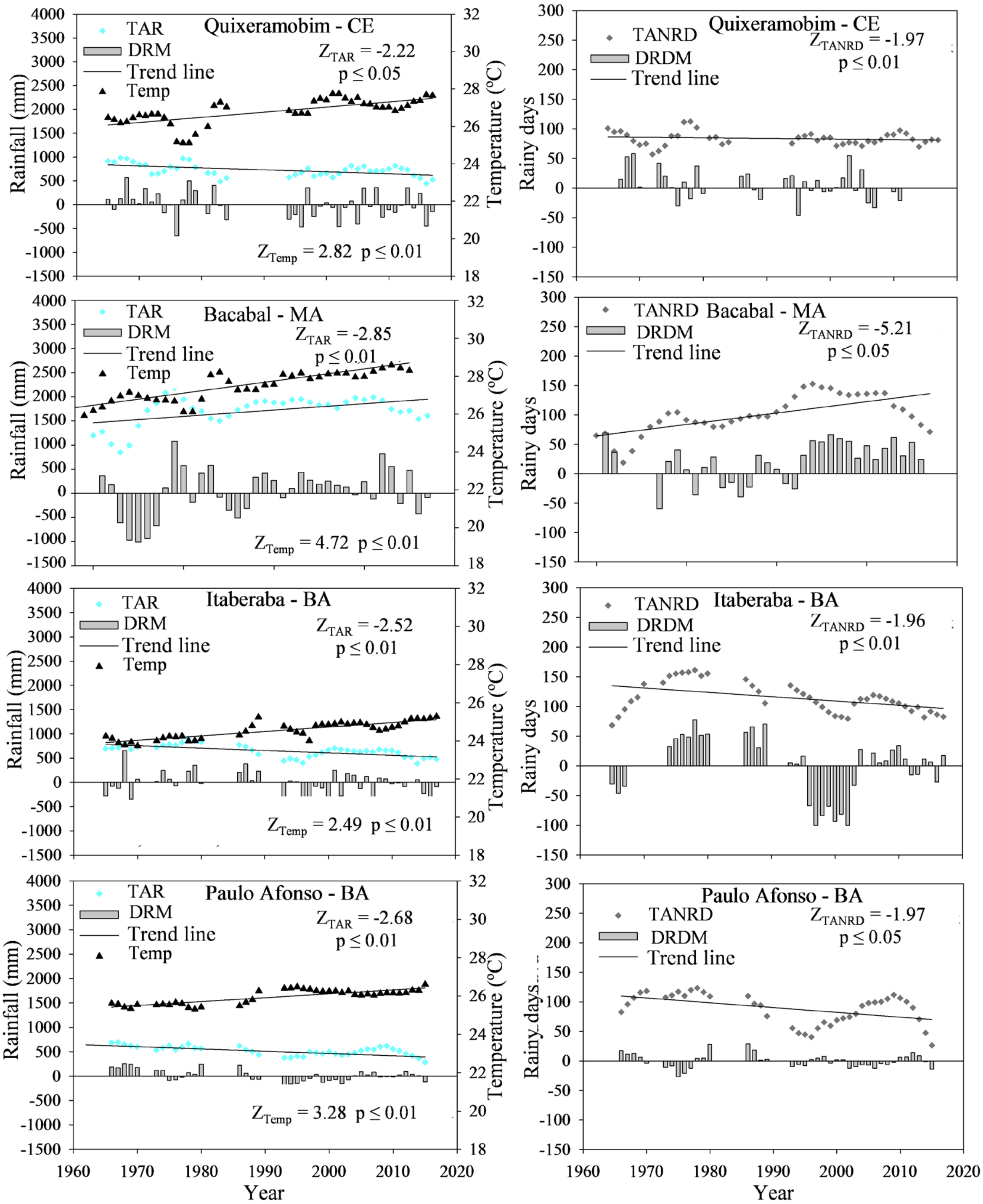


Figure 10. Trend of rainfall (TAR), total annual number of rainy days (TANRD), temperature (Temp), deviations of rainfall from the mean (DRM) and Z values from the coast of Northeast Brazil between 1961 and 2017. Source: Carvalho et al. (2020)

In addition to the previous studies, Lacerda et al. (2015)[14] summarized the trends of annual precipitation and temperature for the state of Pernambuco (Table 1). Simple linear regression to estimate linear trends (i.e., the linear slope) present in the time series was used.

[14] Lacerda, F.F., Nobre, P.; Sobral, M.C.; Lopes, G.M.B.; Chou, S.C. (2015) Long-term Temperature and Rainfall Trends over Northeast Brazil and Cape Verde. **J Earth Sci Clim Change**. 6: 296. doi:10.4172/2157-7617.1000296

Table 1. Trends for the maximum (Txx) and minimum (Txn) of the highest temperature, maximum (Tnx), and minimum (Tnn) of the lowest temperature (°C/decade), rainfall trend (mm/decade) for several locations.

Sites	Period	Temperature Trend (°C/decade)				Precipitation Trend (mm/ decade)
		Txx	Txn	Tnx	Tnn	PRCPTOT
Araripina	1962 -2011	**0.72 (*)**	**1.82**	-0.40	0.05	-25.4
Caruaru	1960 -2011	**0.28**	0.10	-0.37	-0.30	-03.5
Petrolina	1965 -2007	0.19	**0.39**	0.13	0.12	-42.0
Vitoria	1957 -2011	**0.45**	**0.50**	0.43	-0.01	07.5
Recife	1962 -2009	0.19	**0.20**	0.18	0.27	-44.2

Source: Lacerda et al. (2015).

Related to the three stations inside the semiarid region (Arapipina, Caruaru, and Petrolina), the authors emphasize the increased maximum temperatures over all stations and decreased rainfall over all stations. Note that, Araripina presented the highest rates in the maximum temperatures. The steep positive Txn and negative Tnx for the site of Araripina, associated with a significant negative trend of precipitation suggest an intense aridification process.[14] Petrolina presented a strong rainfall reduction with trend values exceeding -40 mm/decade while Caruau also presented an increased trend in the highest temperature.

Looking at all those studies presented, the temperature has an increasing trend in most cases. On the other hand, precipitation does not present the same trend in different localities, maybe due to the complexity of climate patterns in NEB. According to Da Rocha et al. (2019), these studies presented here are useful for managers who will define measures to mitigate problems related to climate variability but do not comprehend all the nuances of the NEB's climate.

According to the World Meteorological Organization – WMO[15], an operational definition of drought helps people to identify the beginning, end, and degree of severity of a drought. This definition is usually made by comparing the current situation to the historical average, often based on 30 years of record, according to WMO (2016). The following definitions of drought are usually considered by Wilhite and Glantz.[16]

- Meteorological: Meteorological drought is usually defined based on the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as specific to a region since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region.
- Agricultural: Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater, or reservoir levels.
- Hydrological: Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater). The frequency and severity of the hydrological drought are often defined on a watershed or river basin scale.
- Socioeconomic: This occurs when physical water shortage starts to affect people, individually and collectively, or, in more abstract terms, most socio-economic definitions of drought are associated with the supply and demand of an economic good.

These terms have become widely accepted and are used as standard ways of identifying droughts for operational purposes based upon regional climatic differences, crop water requirements, duration, and human interactions. In general, meteorological drought onset is first, followed by agricultural, then hydrological. The sequence is similar for recovery[17].

[15] World Meteorological Organization (WMO). Droughts Assessment and Forecasting. 2005.
[16] Wilhite, D. A.; and M. H. Glantz. Understanding the drought phenomenon: The role of definitions. Water International 10:111–20. 1985.
[17] Howard, A.; Biettio, L.; Hayes, M.; Kleschenko, A.; Caiña, K.; Susnik, A. Expert Team 3.1 Report on Drought. World Meteorological Organization; Commission on Agrometeorology. 2018.

According to Howard et al. (2018)[17], historically, droughts have been a part of the evolution of human civilization. However, the potential for droughts to increase in severity, frequency and/or duration as a consequence of climate change, coupled with the increasing demand for food and water resources caused by a growing population, has raised questions as to how humanity will tolerate future droughts. This, in turn, raises questions as to how the global society can best approach the issues of drought preparedness and response.

Drought conditions are expressed in terms of severity, persistence, duration, and frequency. In terms of severity droughts can be classified in Abnormally Dry, Moderate, Severe, Extreme, and Exceptional.[17] Persistence determines the areas of short term (less than 6 months) and areas of long term (greater than 6 months).[17] While the duration is considered equal to the number of months of event and drought frequency is the number of events per period.[7]

The U.S National Drought Monitor classifies the levels of severity related to droughts and their impact on the environment, as follows:

- Abnormally Dry: This is the lightest level, which means the area is either going into drought: short-term dryness slowing planting, growth of crops or pastures, or getting out of the drought, which means some lingering water deficits; and pastures or crops not fully recovered.
- Moderate Drought: This level of drought involves some damage to crops, pastures, streams, reservoirs, or wells low, some water shortages developing or imminent.
- Severe Drought: This level means that crop or pasture losses likely; water shortages common; and water restrictions imposed.
- Extreme Drought: This is the second-highest level of drought, with major crop/pasture losses and widespread water shortages or restrictions.
- Exceptional Drought: This is the most intense level of drought. This level involves exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies.

Note that, although the classification characterizes the doughty levels, different indices have been developed to quantify a drought, each with its own strengths and weaknesses.

Especially for NEB, Brito et al. (2017)[7] analyzed the drought indices for the last 36 years (1981–2016), through the SPI (standardized rainfall index) and VHI (vegetation health index), which are, respectively, a meteorological drought index and an agricultural drought index. It is noteworthy that the SPI index is derived from precipitation data, while the VHI index is based on the vegetation index - NDVI (normalized difference vegetation index) and surface temperatures measured by satellite, therefore consider the vigor of the vegetation and soil moisture. Events were divided into 7-year intervals, organized in hydrologic years from October to September for quinquennial periods 1981–1986, 1986–1991, 1991–1996, 1996–2001, 2001–2006, 2006–2011, 2011–2016 (partial). Figures 11, 12, and 13 show the duration severity and frequency according to meteorological index – SPI, while Figures 14, 15, and 16 show the duration severity and frequency according to vegetation index – VHI. **Both indices reveal that drought intensity for the last 36 years has been increasing and that recent droughts were more frequent, more severe, and affected a more substantial area with significant impacts for population, as well as economic activities**

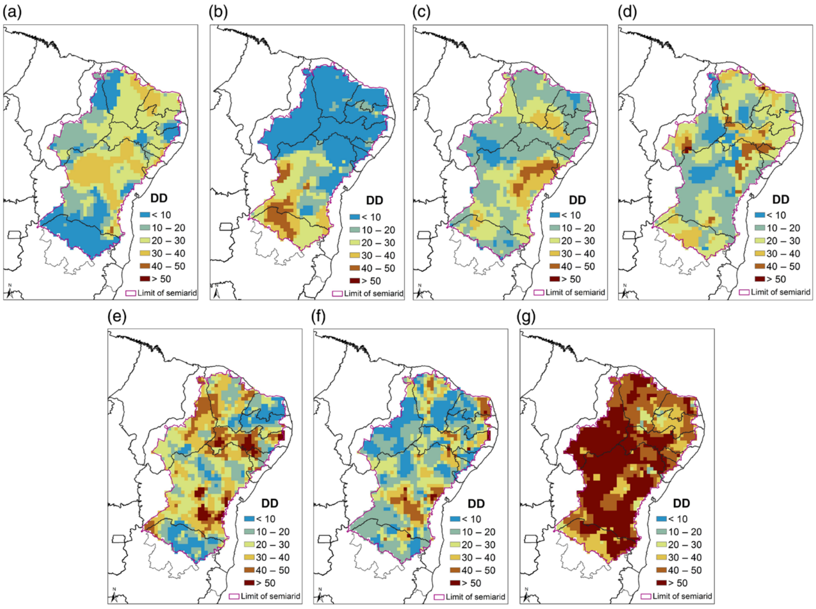


Figure 11. Drought duration maps for (a) 1981–1986, (b) 1986–1991, (c) 1991–1996, (d) 1996–2001, (e) 2001–2006, (f) 2006–2011 and (g) 2011–2016 quinquennia, according to SPI data. Source: Brito et al. (2017).

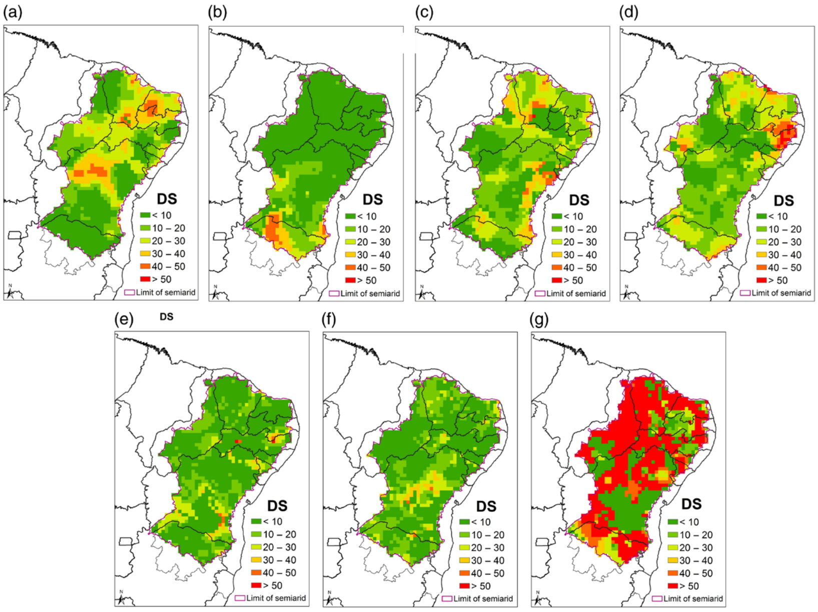


Figure 12. Drought severity maps for (a) 1981–1986, (b) 1986–1991, (c) 1991–1996, (d) 1996–2001, (e) 2001–2006, (f) 2006–2011 and (g) 2011–2016 quinquennia, according to SPI data. Source: Brito et al. (2017).

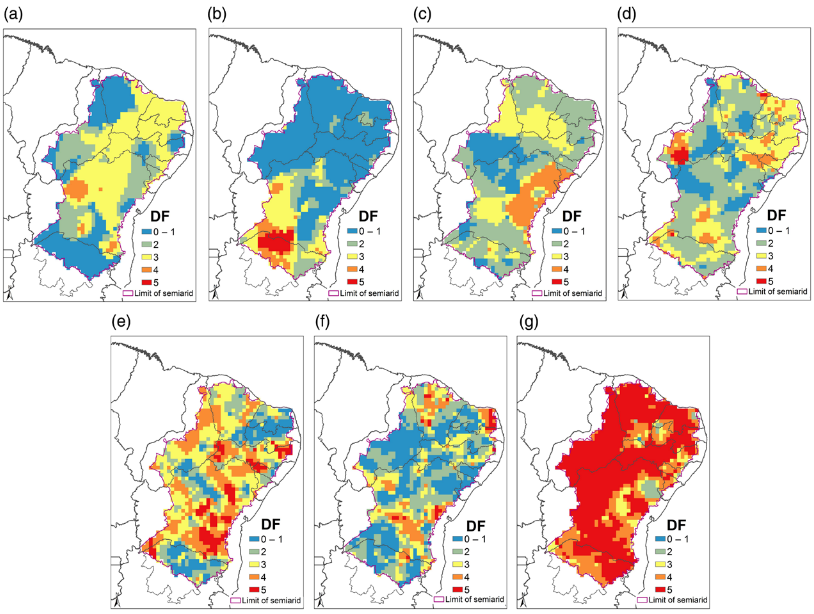


Figure 13. Drought frequency maps for (a) 1981–1986, (b) 1986–1991, (c) 1991–1996, (d) 1996–2001, (e) 2001–2006, (f) 2006–2011 and (g) 2011–2016 quinquennia, according to SPI data. Source: Brito et al. (2017).

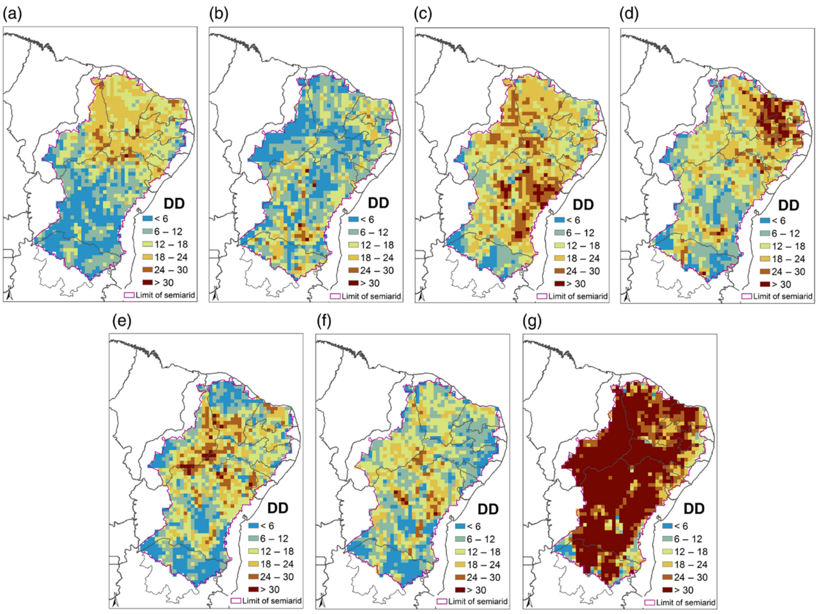


Figure 14. Drought duration maps for (a) 1981–1986, (b) 1986–1991, (c) 1991–1996, (d) 1996–2001, (e) 2001–2006, (f) 2006–2011 and (g) 2011–2016 quinquennia, according to VHI data. Source: Brito et al. (2017).

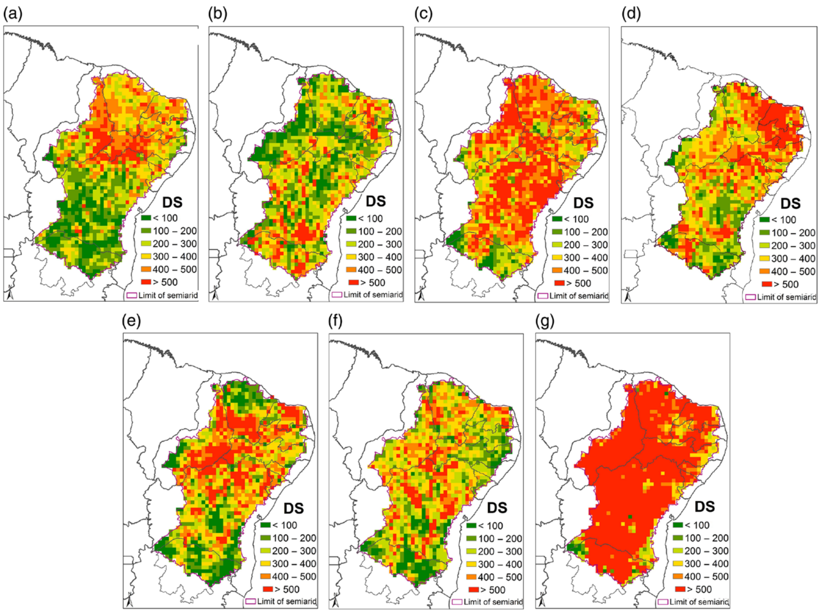


Figure 15. Drought severity maps for (a) 1981–1986, (b) 1986–1991, (c) 1991–1996, (d) 1996–2001, (e) 2001–2006, (f) 2006–2011 and (g) 2011–2016 quinquennia, according to VHI data. Source: Brito et al. (2017).

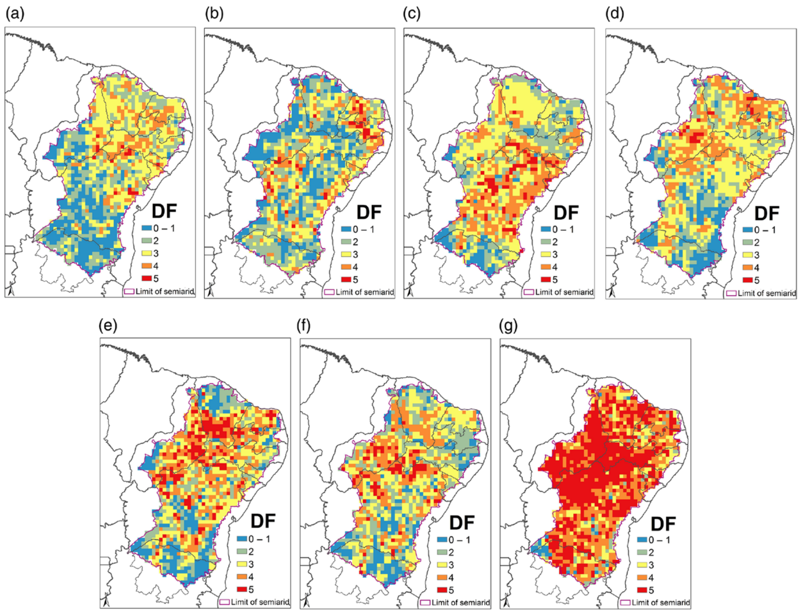
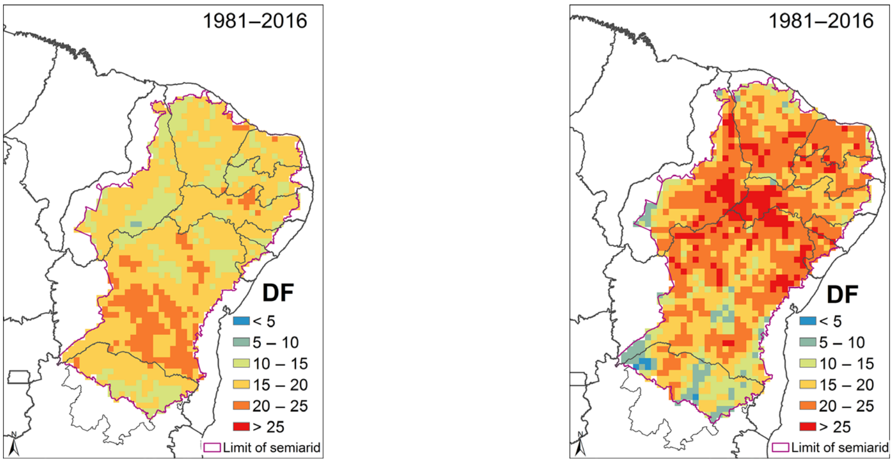


Figure 16. Drought frequency maps for (a) 1981–1986, (b) 1986–1991, (c) 1991–1996, (d) 1996–2001, (e) 2001–2006, (f) 2006–2011 and (g) 2011–2016 quinquennia, according to VHI data. Source: Brito et al. (2017).

In general, the most affected States by recurrent meteorological drought during 36 years were Bahia, Pernambuco, and Ceará (Figure 17a). It is noteworthy that droughts affected all states in the NEB for almost half of the period (from 15 to 20 years, Figure 17b). The most impacted areas, considering the vegetation index, are located in the central study area, including eastern Piauí, northern Bahia, and the western Pernambuco States. Drought conditions remained at a considerable period (more than 25 years).

Important to note that droughts are not independent of factors such as temperature, wind speed, humidity, runoff, groundwater, soil moisture, and snow, or human factors such as land and water management.[17]



(a) (b)

Figure 17. Drought frequency map for the entire period (number of events in period) from October 1981 to May 2016, according to SPI data (A) and Drought frequency maps for the entire period (number of events in period) from October 1981 to May 2016 according to VHI data (B). Source: Brito et al. (2017).

Due to differences in the source of data (SPI and VHI), the maps of duration, severity, and frequency of drought may show different characteristics. For instance, for the five years 2001–2006, SPI indicates drought events longer than 50 months, while VHI maps present a maximum length of 30 months. Table 2 summarizes some differences and show the region (states) most hit by the drought events for each variable and quinquennium.

Table 2. States most affected by drought events for each quinquennium.

Quinquennia	SPI	VHI
1981–1986	BA, CE, RN	BA, PE, PI, RN
1986–1991	BA, MG	BA, MG, PB, RN
1991–1996	CE, PB, PE	BA, CE, PE, PI
1996–2001	AL, BA, PB, PE	CE, PB, PE, PI, RN
2001–2006	BA, PE	BA, CE, PB, PE, PI, RN
2006–2011	BA, CE, MG, PE, RN	BA, PE, PI
2011–2016	All states	All states

Source: Brito et al. (2017).

The drought that affected this region during 2011-2016 is considered the worst in the past 100 years and has exacerbated many social problems through the indebtedness of farmers, migration, disease, and malnutrition.[18, 19] The estimated economic losses of this drought event are in the order of US$ 6 billion in the agricultural sector alone.[20] Regarding the impact on water supply, the water reserves of the equivalent reservoirs (storage capacity above 10 hm^3) in the Northeast have presented successive reductions since 2012, which resulted in a minimum stored volume of approximately 13.8% in March 2017. Also, the drought that started in 2012 continues to highlight the vulnerability of the Northeast region. Arid conditions (which did not exist previously) have been detected during the last years, mainly in the central semiarid region, covering almost 2% of the NEB.[21]

[18] Gutiérrez APA, Engle NL, De Nys E, Molejon C, Martins ES (2014) Drought preparedness in Brazil. Weather Clim Extremes 3:95– 106. doi:10.1016/j.wace.2013.12.001
[19] Marengo, Jose A., et al. "Climatic characteristics of the 2010-2016 drought in the semiarid Northeast Brazil region." Anais da Academia Brasileira de Ciências 90.2 (2018): 1973-1985.
[20] Marengo, Jose A., Roger Rodrigues Torres, and Lincoln Muniz Alves. "Drought in Northeast Brazil—past, present, and future." Theoretical and Applied Climatology 129.3-4 (2017): 1189-1200.
[21] Marengo, J. A., Cunha, A. P. M. A., Nobre, C. A., Ribeiro Neto, G. G., Magalhaes, A. R., Torres, R. R., Álvala, R. C. S. (2020). Assessing drought in the drylands of northeast Brazil under regional warming exceeding 4 °C. Natural Hazards. doi:10.1007/s11069-020-04097-3

It should be noticed that these indexes incorporate climate variables, for example, precipitation and temperature, and, therefore, represent the region's climate patterns that have been changing to the point of promoting greater frequency, intensity, and duration of droughts.

In terms of value of agricultural losses, the study commissioned by IFAD (see appendix VII) by Prof. Young found the evolution of these losses over time in spatial terms, considering the average loss in agricultural production considering five-year averages. Figures 15 and 16 below indicate that municipalities in the semi-arid Caatinga suffered much more losses than the rest of Brazilian Northeast and Minas Gerais and confirm that bean and corn (the main crops of family agriculture) suffered more than the other crops.

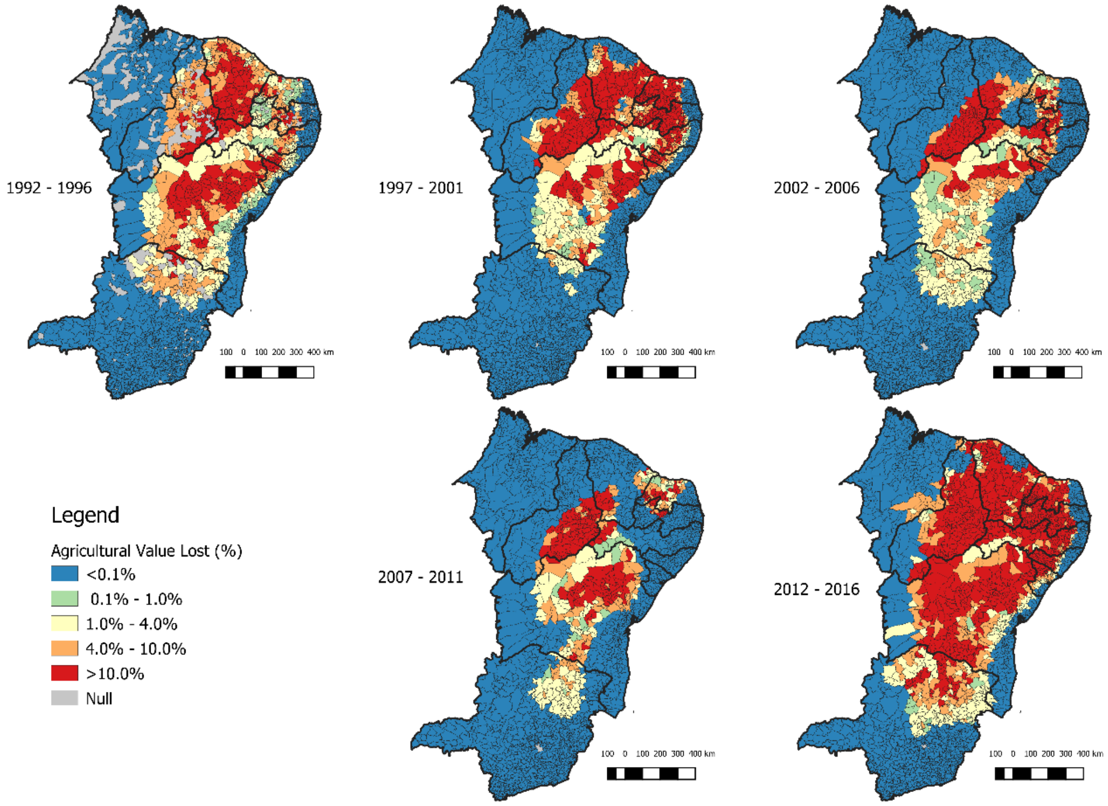


Figure 18. Value of agricultural production lost to all crops. Source: Young, C.E et al, 2018 (see full study in Appendix VII)

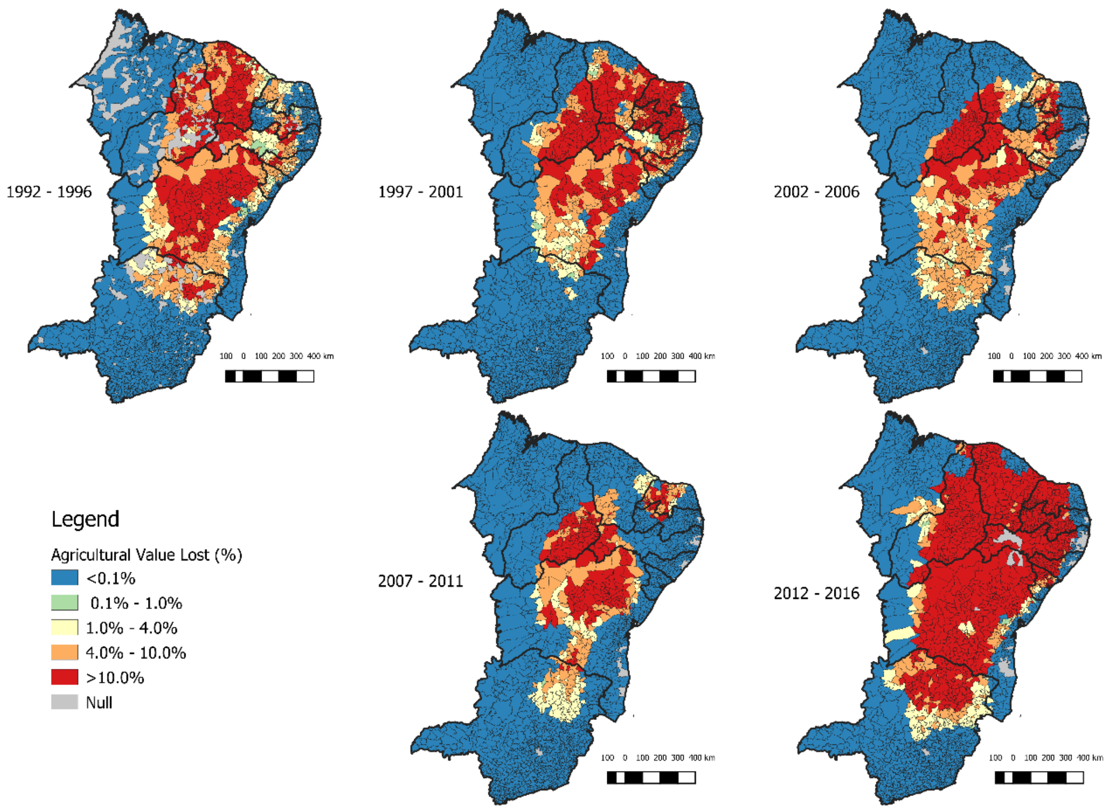


Figure 19. Value of lost agricultural production for beans and corn. Source: Young, C.E et al, 2018 (see full study in Appendix VII)

The meteorological and rain gauges used for the studies cited come from different sources such as INMET (National Meteorology Institute), CEMADEN (*National Center for Monitoring and Early Warning of Natural Disasters*, CPTE / INPE (National Institute for Space Research) and the State Meteorology Centers. Data from these stations were interpolated to obtain spatial coverage. Please see Figure 15 below for the location of meteorological stations.

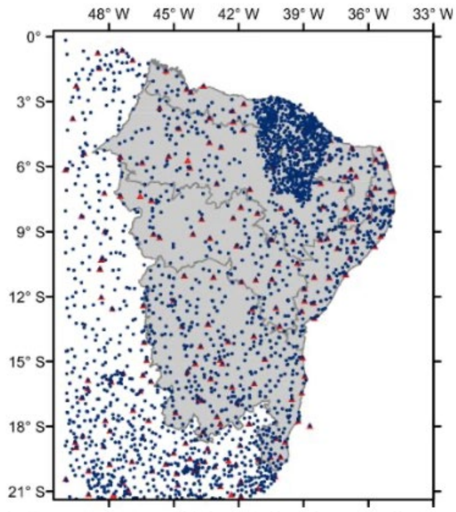


Figure 20. Meteorological stations (blue) and fluviometric stations (red). Source: adapted from Martins et. al. 2019.

2.2.2 Greenhouse Gas Emissions in NEB

Concerning the issue of mitigation, Brazil has the world's sixth-largest greenhouse gas (GHG) emissions and has released 2.3 billion tons of carbon dioxide equivalent (CO2e) in 2016, compared with 2.1 billion in 2015. In 2016 emissions were 8.9% higher than in 2005, distancing the country from its Paris goal of reducing 37% of its carbon emission by 2025 compared to 2005 levels.[22] GHG emissions in Brazil are mainly due to forest and grassland conversion, followed by agriculture and fossil fuel combustion. Land-use change and agriculture accounted for 73% of all the carbon emitted in 2016.[23]

Total emissions in the nine states of the Northeast accounted for a quarter of Brazil's total emissions (591.4 $MtCO_2e$) in 2016. Land use, land-use change and forestry (LULUCF), with 381.8 $MtCO_2e$ (65%), was the primary cause of emissions, followed by agriculture with 106.9 MtCO2e (18%) and energy with 102.7 MtCO2e (17%). Land-use change, specifically the deforestation of the *Caatinga* biome, represented almost 5% of the carbon emissions (28.2 $MtCO_2e$). With 93.7 $MtCO_2e$ emitted, enteric fermentation represented 88% of the agricultural emissions and 16% of the emissions in the Northeast.

Finally, with 102.7 $MtCO_2e$ emitted the energy sector emissions in the Northeast are caused mainly by fuel production, energy generation, road transport and the industrial sub-sector. Renewable biomass from waste material such as coconut husk, cashew nut shells as well as wood from sustainably managed forest plantations and agroforestry systems could be vital to helping the Northeastern states move towards more renewable sources of energy and halt deforestation of the Caatinga.

2.3 Climate change scenarios

2.3.1. Precipitation, Temperature and Aridity Scenarios

Climate models producing better simulations of the present climate should be more credible in projecting future climate change. [24] Furthermore, a multimodel ensemble usually yields better performance than any single model.[25] Thus, it is plausible to affirm that a group of climate models with small uncertainty should be more reliable in projecting future climate change.

For that purpose, the Coupled Model Intercomparison Project Phase 5 (CMIP5) [26] provides estimates of future climate change around the world based on data from more than 40 global climate models (GCMs), with a grid size ranging from 100 to 200 km. Since this spatial resolution is inadequate for studies that focus on small-scale climate change impacts, there is a reliance on the use of regional atmospheric models that allow for horizontal resolutions at the level of tens of kilometers that enable explicit simulations of mesoscale processes with a better representation of local climatic characteristics. [27]

For this reason, the downscaled climate scenarios of the regional climate model Eta, nested in three CMIP5 GCMs models: CanESM2, HadGEM2-ES, and MIROC5[28] are recommended for climate impact assessments over Brazil. Further information about the robustness of those models can be consulted in Almagro et al. (2020) and Chou et al. (2014; 2018).[29] In the case of Brazil, the dynamic downscaling from Eta regional climate

[22] Carbon Brief, 2018. Retrieved at: https://www.carbonbrief.org/state-of-the-climate-how-world-warmed-2018.
[23] The Greenhouse Gas Emissions and Removals Estimates (SEEG), 2018. Retrieved at: http://seeg.eco.br.
[24] Shukla J, DelSole T, Fennessy M, Kinter J, Paolino D. 2006. Climate model fidelity and projections of climate change. Geophysical Research Letters 33: L07702. DOI: 10.1029/2005GL025579.
[25] Gleckler PJ, Taylor KE, Doutriaux C. 2008. Performance metrics for climate models. Journal of Geophysical Research 113: D06104. DOI: 10.1029/2007JD008972
[26] Taylor KE. 2001. Summarizing multiple aspects of model performance in a single diagram. Journal of Geophysical Research 106: 7183–7192.
[27] Tavares, P.S., Giarolla, A., Chou, S.C., Silva, A.J.P., Lyra, A.A., 2018. Climate change impact on the potential yield of Arabica coffee in southeast Brazil. Reg. Environ. Change 18, 873–883. https://doi.org/10.1007/s10113-017-1236-z.
[28] Arora, V.K., et al., 2011. Carbon emission limits required to satisfy future representative concentration pathways of greenhouse gases. Geophys. Res. Lett. 38, L05805. https://doi.org/10.1029/2010GL046270.
Collins, W.J., Bellouin, N., Doutriaux-Boucher, M., Gedney, N., Halloran, P., Hinton, T., Hughes, J.P., Jones, C.D., Joshi, T., Liddicoat, S., Martin, G., O'Connor, F., Rae, J., Senior, C., Sitch, S., Totterdell, I., Wiltshire, A., Woodward, S., 2011. Development and evaluation of an earth-system Model-HadGEM2. Geosci. Model. Dev. 4, 1051–1075. https://doi.org/10.5194/gmd-4-1051-2011.
Watanabe, M., Suzuki, T., O'ishi, R., Komuro, Y., Watanabe, S., Emori, S., Takemura, T., Chikira, M., Ogura, T., Sekiguchi, M., Takata, K., Yamazaki, D., Yokohata, T., Nozawa, T., Hasumi, H., Tatebe, H., Kimoto, M., 2010. Improved climate simulation by MIROC5: mean states, variability, and climate sensitivity. J. Clim. 23, 6312–6335. https://doi.org/10.1175/2010JCLI3679.1.
[29] Chou, S.C., Lyra, A., Mourão, C., Dereczynski, C., Pilotto, I., Gomes, J., Bustamante, J., Tavares, P., Silva, A., Rodrigues, D., Campos, D., Chagas, D., Sueiro, G., Siqueira, G., Marengo, J., 2014. Assessment of climate change over South America under RCP 4.5 and 8.5 downscaling scenarios. Am. J. Clim. Change 03, 512–527. https://doi.org/10.4236/ajcc.2014.35043.
Chou, S.C., Lyra, A., Chagas, D., Dereczynski, C., Gomes, J., Tavares, P., 2018. Downscaling projections of climate change over South America and Central America under RCP4.5 and RCP8.5 emission scenarios. Geophys. Res. Abstr. 20 EGU2018-8866

model provides more accurate climate simulations compared to general climate models, particularly in terms of the intensity and frequency of extreme precipitation events.[29, 30]

The CO_2 emission scenarios include RCP's 4.5 and 8.5, considered, respectively, as an optimistic and pessimistic scenario and encompass the period 2006-2100. Even so, the simulations for the scenario RCP4.5 and period 2007-2040 satisfy the considerations of the Paris Agreement. Projections point to the warming of the entire continent. For the Northeast region, accordingly, the simulations (HadGEM2-ES and MIROC5 for two RCP scenarios—8.5 and 4.5) predicted a temperature increase from 0.5 – 2.0ºC in the period 2011- 2040 compared to a baseline period of 1961-1990.**Error! Bookmark not defined.** It is expected that the interior – which is already becoming drier – would be more affected than the coastal areas.[31] Figure 16 presented downscaled data specific to NEB, showing the baseline and projected changes for the main climate variables.

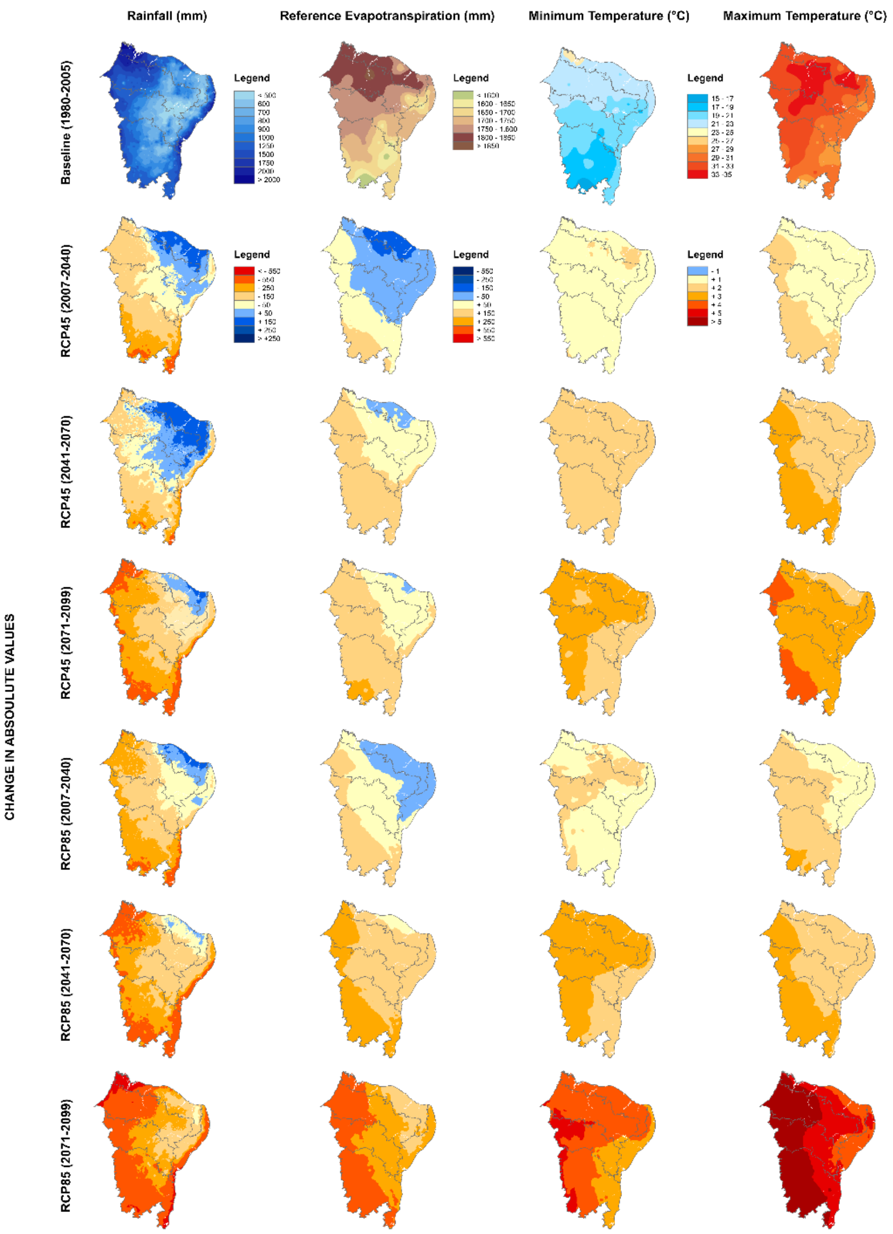


Figure 21. Bias corrected Rainfall, Reference Evapotranspiration (ETo), Minimum Temperature (Tmin) and Maximum Temperature (Tmax) for baseline 1980 - 2005 and projected absolute changes for time slices 2007. Source: Martins et al. 2019

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[30] Almagro, A.; Oliveira, P.T.S.; Rosolem, R.; Hagemann, S.; Nobre, C.A. (2020) Performance evaluation of Eta/HadGEM2-ES and Eta/MIROC5 precipitation simulations over Brazil, Atmospheric Research. Doi: https://doi.org/10.1016/j.atmosres.2020.105053

[31] International Policy Centre for Inclusive Growth (IPC-IG) Working Paper No.141; UNDP, 2016. " Climate change and impacts on family farming in the North and Northeast of Brazil"

Despite the rise of precipitation in the summer, the projected annual cycle shows a dominating annual reduction of rainfall in the region. Furthermore, an increase in the length of consecutive dry days and wide climate variability are common features in these and other simulations for the Northeast of Brazil[32]. Dry summer months are expected to perceive a moderate increase between 2 and 6 ºC in Northearestn Brazil[33]. Impacts are expected to grow exponentially within a range temperature increase of approximately 4.5 ºC for the period 2041 and 2070, in line with IPCC projections.

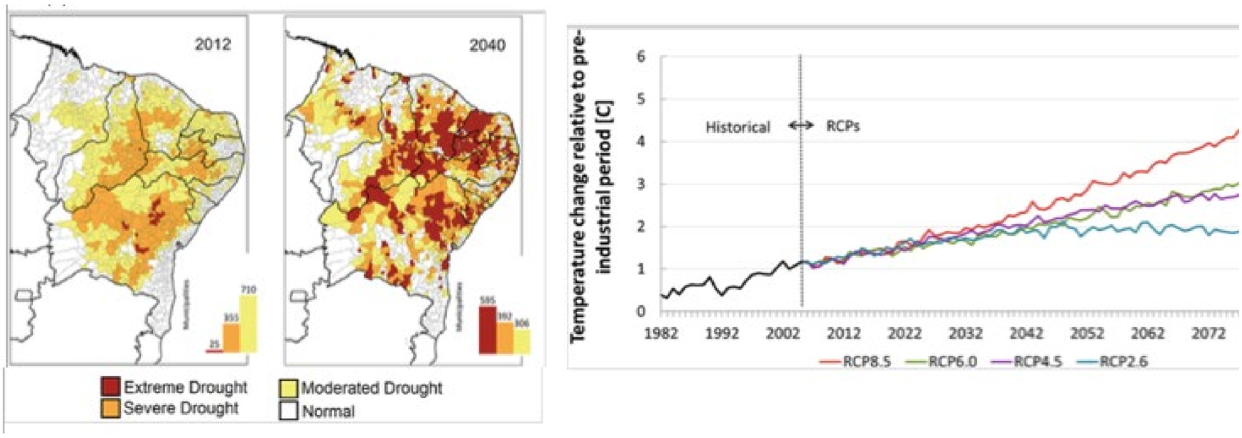

Figure 22 Municipalities affected by the drought, according to (A) observed Vegetation Health Index (VHI) for 2012, (B) future projections for 2040, (C) CMIP5 annual temperature changes. Source: Margengo (2017). [34]

For the RCP 2.6 (Fig. 17) the temperature change stabilizes at 2 °C above the average around 2040. On the other hand, the RCP4.5 and 6 Scenarios predict increases in excess of 3 °C.by the middle 2070s.

While Marengo et al. (2017) used simulations from general circulation models from CMIP5 (Taylor et al. 2012), Martins et al. (2019) used six sets of downscaled simulations of the Eta Regional Climate Model (RCM) forced by three global CMIP5 climate models for two representative concentration pathways (RCP) for carbon emissions: CanESM2, HadGEM2-ES, and MIROC5 (Arora et al., 2011; Collins et al., 2011; Watanabe et al., 2010).

[32] LACERDA, F. F.; et.al. Long-term Temperature and Rainfall Trends over Northeast Brazil and Cape Verde. **Journal of Earth Science & Climatic Change**, v. 6, n. 8, p. 296, 2015.
[33] INPE. 2015. "Cenários de Mudanças Climáticas: Regionalização." Unpublished. São José dos Campos: Instituto Nacional de Pesquisas Espaciais.
[34] MARENGO, J. A., et al. "Increase Risk of Drought in the Semiarid Lands of Northeast Brazil Due to Regional Warming above 4 C." Climate change risks in Brazil. Springer, Cham, 2019. 181-200.

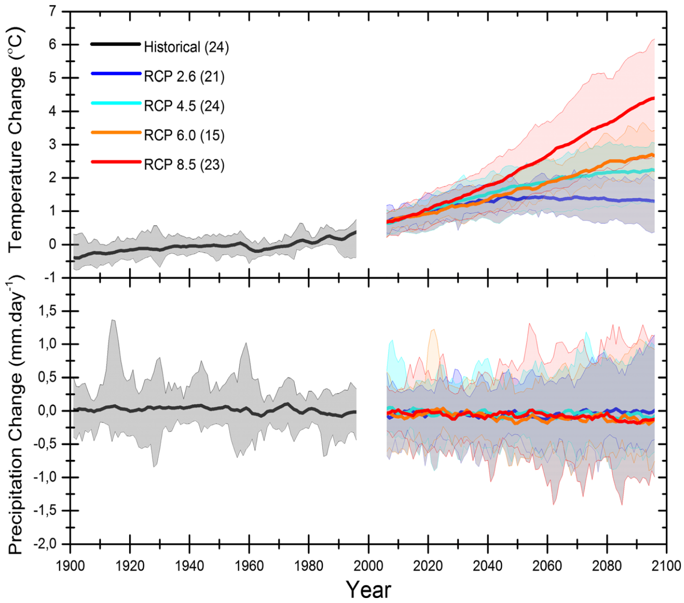

Figure 23. Time series of rainfall (mm day^{-1}) and temperature anomalies (°C) for Northeast Brazil for the four RCPs and the historical runs from the CMIP5 models. The number of models used is shown in brackets. Anomalies are relative to 1961–1990. Shaded areas represent the dispersion among CMIP5 models. All the time series have been smoothed using a 5-year moving average. Source: Marengo et al. (2017)

The degree of aridity can be measured by the relationship between precipitation and evapotranspiration. For the Northeast region of Brazil, Vieira et al (2020) warn of an expansion of semiarid climate areas, particularly in the Northwest of the study region and an increase in aridity in the South-Central region, particularly in those drought-prone inner areas (Figure 19) and that the CO_2 emission scenario, RCP8.5 contributes significantly to increase the degree of aridity and potential water use conflicts. Besides, the study points out that land management was the main driver of desertification susceptibility, suggesting that mitigation and adaptation strategies for the region should incorporate sustainable land-use policies.

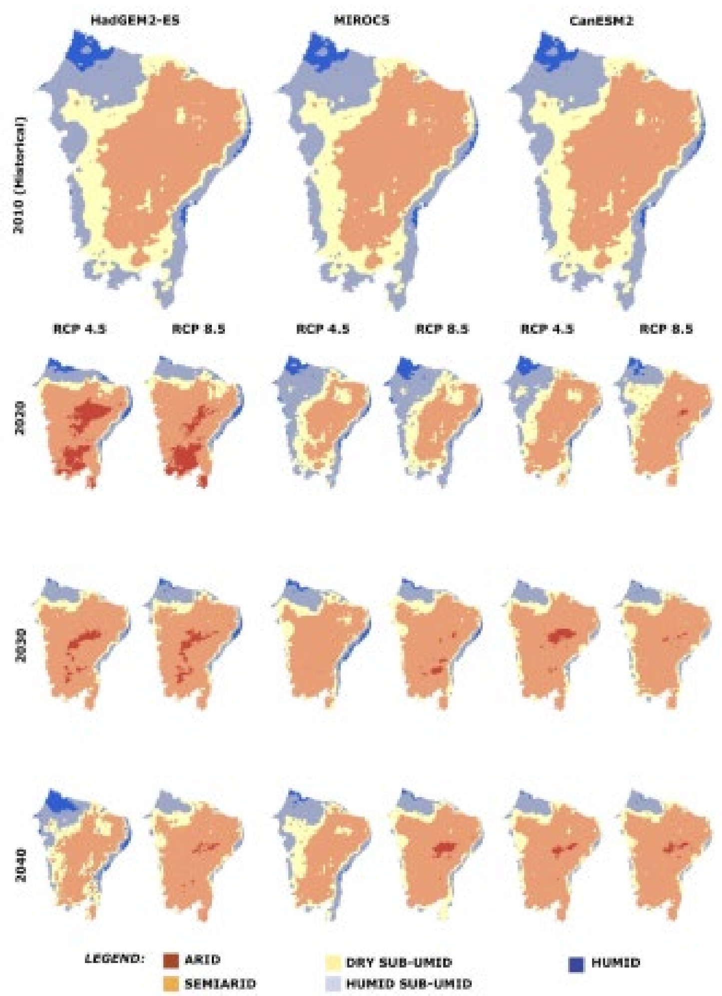

Figure 24. Spatial distribution of the aridity index for the time-slices (from top to down rows) 2010, 2020, 2030 and 2040, estimated using dynamically downscaled scenarios of the HadGemES2 (left column), MIROC5 (middle column), CanESM2 (right column) models, and for the RCP4.5 and RCP8.5 emission scenarios. Source: Vieira et al. (2020).

From both studies (Figure 16 and Figure 19), it is possible to show that while there was an agreement between all the simulations that the temperature will increase, the projected changes in precipitation differed among the models, both in terms of the magnitude and in the signal of changes. However, it is worth highlighting that the Central and Southern regions of the Northeast are the most affected in terms of reduced precipitation and increased evapotranspiration since the beginning of the century (Figure 19).

A specific in-loco study in the Northeast confirmed the findings of the South American downscaling scenarios discussed above. Both station data analysis and numerical simulations (for the periods of 1960-2000 and 2010-2050) revealed trends of increasing maximum temperature and diminishing precipitation. The water-balance calculations showed reduced soil moisture availability and total rainfall. The atmospheric model simulations were consistent with the station data regarding the present warming; the climate change scenarios for 2010-2050 indicated a faster increase of daily maximum temperature over the Northeast compared to that simulated for the recent past.[35]

The water availability in the present and the future is closely linked to climate conditions. In this regard, climate change modifies the water cycle leading to the occurrence of extreme hydrological events, such as maximum river discharge and droughts. According to Nobre et al. (2011), although there is a level of uncertainty regarding the NEB, there are great convergences in the scenarios showing an increase in average temperature

[35] RIBEIRO NETO, A; ROLIM DA PAZ, A; RAIMUNDO DA SILVA, E. Impactos e vulnerabilidade do setor de recursos hídricos no Brasil às mudanças climáticas. In: BRASIL. MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO (Eds) **Modelagem Climática e Vulnerabilidades Setoriais à Mudança do Clima no Brasil**. Brasília, Ministério da Ciência, Tecnologia e Inovação, (p. 189 – 240), 2016.

and the frequency of heatwaves and warm nights (Marengo, 2007), thus impacting, in a consistent manner, increasing water loss through evaporative processes and contributing to decreasing water availability. Also, the impacts should be analyzed regionally, since changes in land use may influence the water storage.

When modelling surface and groundwater supplies per water basin, the results for the Northeast region are alarming, **estimating a sudden reduction in flows by 2100** in the river basins that supply the region: *São Francisco, Atlântico Norte e Nordeste* and *Atlântico Leste*. Such a scenario is of concern, given that the Northeast's interior is already becoming drier and experiencing a seven-year continuous cycle of prolonged severe droughts from 2011-2017.[36]

2.3.2. Climate Change and the Main Crops in NEB

Follador (2016) found that the seven main crops of Brazil are expected to be negatively impacted by climate change, with the exception of sugar cane, which shows an increase in viable area, suggesting that sugar cane may be better able to cope with the increase in temperature than the other crops. The percentage losses predicted for each region in 2030, in relation to the 2009 base year, for scenarios B2 (optimistic) and A2 (pessimistic), can be seen in Figure 22.[37]

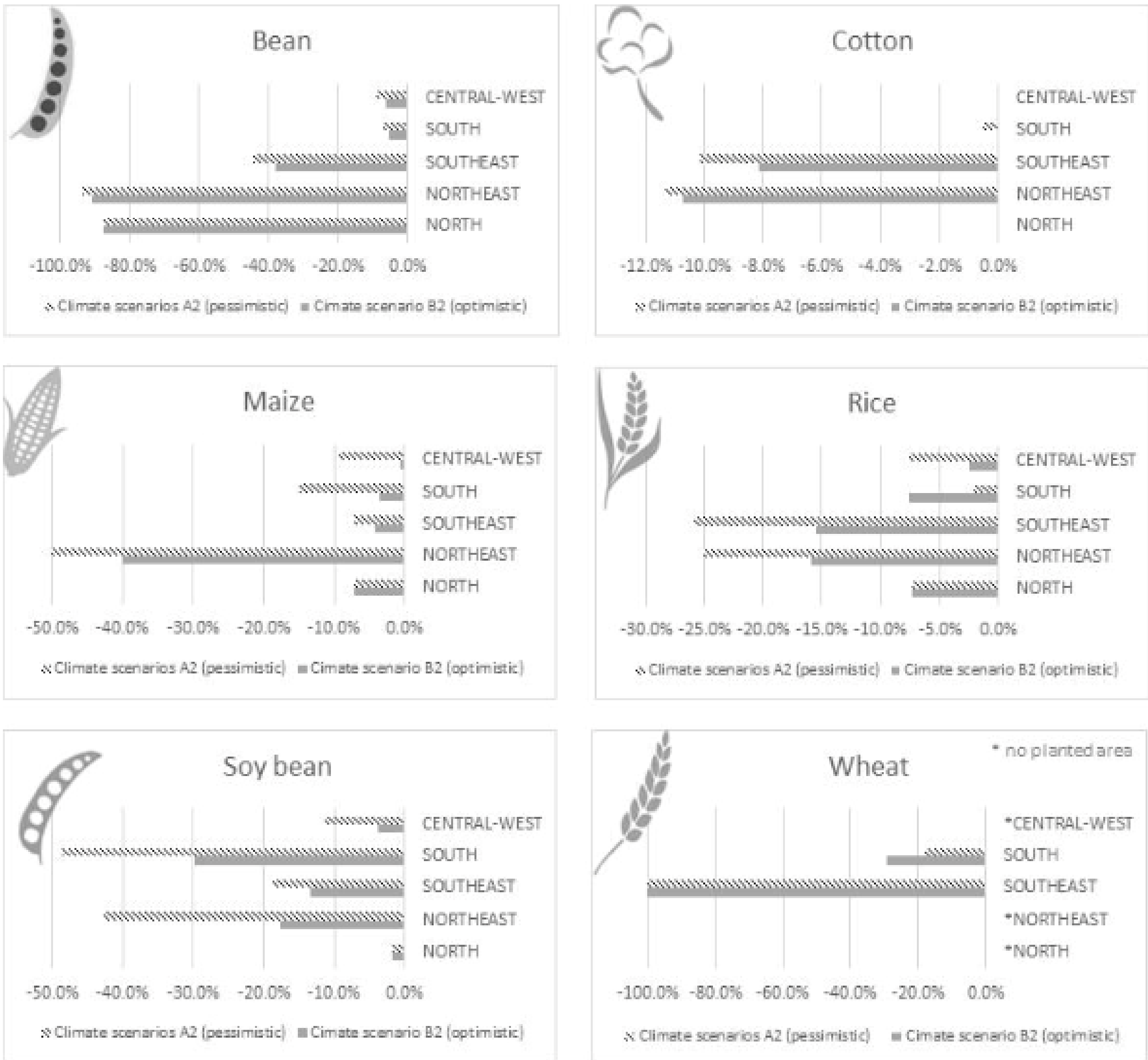

Figure 25. Effects of Climate Change in Crops. Source: Follador, 2016.

[36] RIBEIRO NETO, A; ROLIM DA PAZ, A; RAIMUNDO DA SILVA, E. Impactos e vulnerabilidade do setor de recursos hídricos no Brasil às mudanças climáticas. , In: BRASIL. MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO (Eds) **Modelagem Climática e Vulnerabilidades Setoriais à Mudança do Clima no Brasil**. Brasília, Ministério da Ciência, Tecnologia e Inovação, 2016. p. 189 – 240.
[37] Follador, Marco. (2016). Potential impacts of climate change on Brazilian agriculture and economy. 10.13140/RG.2.2.17781.99040. Technical Report, July 2016, CEPAL (ECLAC) Economic Commission for Latin America and the Caribbean - UN

The Northeast is clearly the region most affected, with beans showing a percentage loss of over 80%. Following this is maize with losses of up to 50%, and soy with over 40% losses. Finally, rice and cotton with 15 to 25% losses.

The percentage losses for almost all of the crops are higher in the pessimistic scenario, with bean crops having similar values in both scenarios. A breakdown can be observed in Table 2 of each crop per state. The most affected states are Pernambuco, Ceará and Alagoas.

Table 2: Decrease (%) in land use for each product, aggregated by macroregion. Climate change scenarios A2 (pessimistic

		B2/2030 % Bean	A2/2030 % Bean	B2/2030 % Cotton	A2/2030 % Cotton	B2/2030 % Maize	A2/2030 % Maize	B2/2030 % Rice	A2/2030 % Rice	B2/2030 % Soy bean	A2/2030 % Soy bean
NORTHEAST	ALAGOAS	-99,9	-100,0	-66,3	-66,3	-62,5	-62,5	-100,0	-100,0	-100,0	-100,0
	BAHIA	-94,7	-95,0	-9,7	-9,9	-61,0	-65,5	-25,7	-29,3	-9,0	-35,3
	CEARÁ	-79,1	-88,7	0,0	-15,8	-18,5	-39,5	-100,0	-100,0	-100,0	-100,0
	MARANHÃO	-42,7	-49,6	0,0	0,0	-3,9	-3,9	-3,1	-9,3	-0,3	-26,2
	PARAÍBA	-100,0	2,0	-23,9	-45,7	-49,6	-79,9	-99,6	-99,7	-	-
	PERNAMBUCO	-100,0	-100,0	-94,4	-96,6	-74,0	-81,0	-100,0	-100,0	-	-
	PIAUÍ	-98,2	-98,3	-14,8	-15,8	-39,7	-48,2	-18,9	-42,8	-72,3	-92,4
	RIO GRANDE DO NORTE	-99,8	-100,0	-25,2	-29,1	-46,5	-73,0	-100,0	-100,0	-	-
	SERGIPE	-100,0	-100,0	-	-	-10,5	-10,5	-100,0	-100,0	-	-

Intense thermal stress accompanied by moisture-stress can intensify the vegetative drought. These points can be verified from the VHI projections under various RCP scenarios over grasslands in semiarid for the present and future. Drought risk is defined by the intensity of the VHI and the percentage of the area of the municipality affected by drought. To define extreme drought, the VHI index varies from 0 to 10 and at least 75% of the area of a municipality is affected by drought. For severe drought, the VHI varies between 10 and 20, and the area affected by drought should be at last 50% of the municipality. In 2012, which was the most affected year of the last drought event in Northeast Brazil[20], the number of municipalities in extreme drought was 25, severe drought 355 and moderate drought 710. Marengo et al. (2018) show projections for 2040, of 595 municipalities under the risk of extreme drought, 392 to under risk of severe drought and 306 under moderate drought risk.[34]

As discussed above, agricultural and meteorological drought were evaluated by Brito et al. (2017) in NEB.[Error! Bookmark not defined.] These authors analyzed the droughts since 1981, through the SPI (standardized rainfall index) and VHI (vegetation health index), which are, respectively, a meteorological drought index and an agricultural drought index. As shown in Figures 25a and 25b, it is possible to observe a linear increasing trend since 1981 for both indexes and that the last 5-years period drought was the most intense in terms of severity and duration, covering a large area in all NEB states.

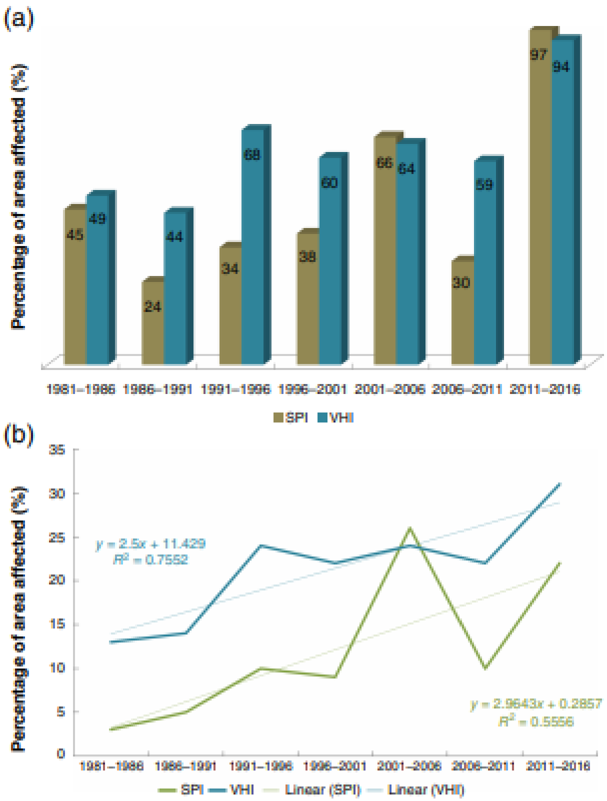

Figure 26. Percentage of area affected by drought (a) with drought frequency above 3 years and (b) above 4 years, considering each quinquennial period of SPI (green) and of VHI (blue). Source: Brito et al. (2017)

To focus on the effects on family/subsistence farming, Young e. al. (2018) used the Agricultural Census to identify the main crops and family farms. and chose beans and corn for as proxies for family agriculture because beans and corns are produced mainly by family farming in the states selected in this study. Cassava was not considered in the analysis because, even though most of production comes from family agriculture it represents a minor share of the subsistence agriculture (see Appendix VII for more details). The figures below show the 2019 crop calendar for bean and corn.[38]

[38] CONAB. Calendário de Plantio e Colheita de Grãos no Brasil 2019. Available at: <http://www.conab.gov.br>

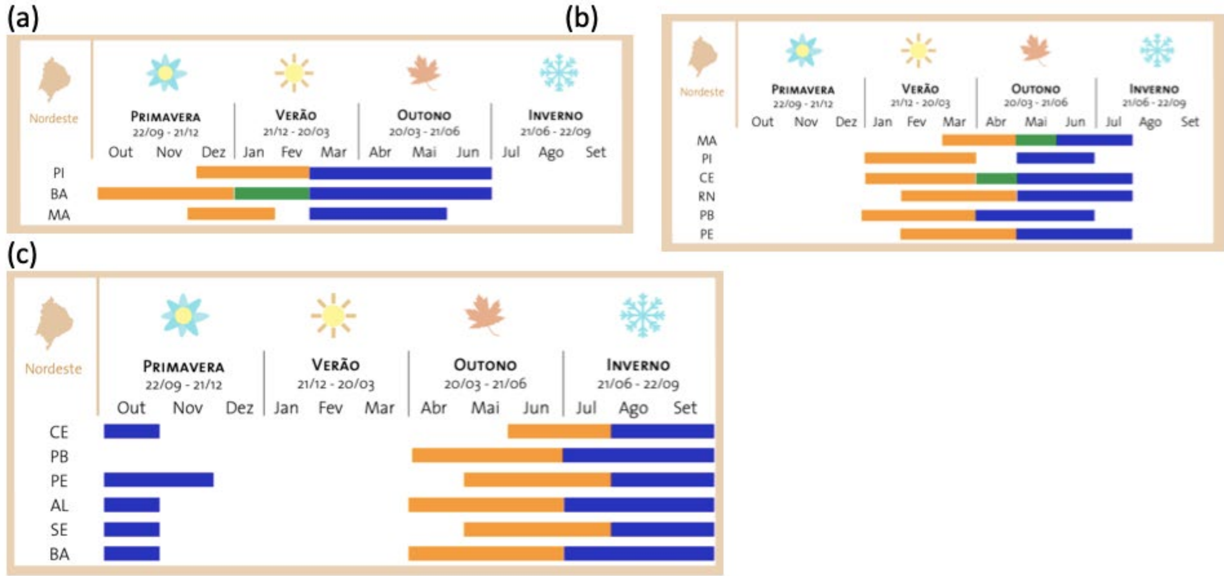

Figure 27. Crop Calendar for Beans. (a) First harverst (b) second harvest (c) third harvest. Legend orange: planting, blue: harvest, green: planting and harvest. States of the NEB - PI: Piauí, BA: Bahía, MA: Maranhão, CE: Ceará, PB: Paraíba, PE: Pernambuco, SE: Sergipe, AL: Alagoas, RN: Rio Grande no Norte. Source: CONAB, 2019

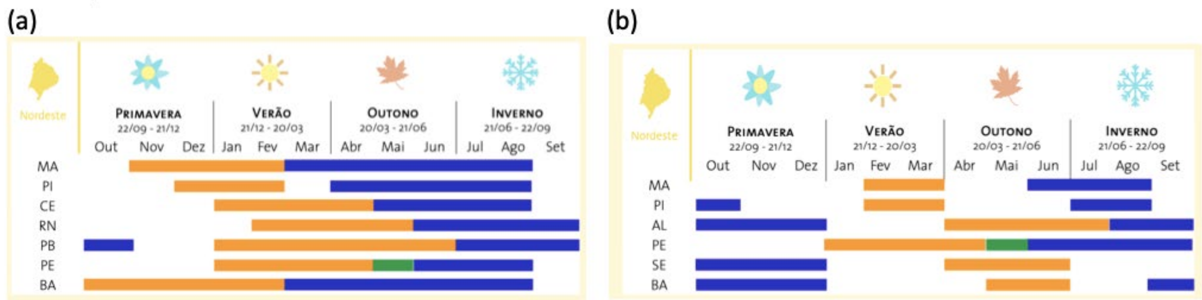

Figure 28. Crop Calendar for Maize. (a) First harverst (b) second harvest Legend orange: planting, blue: harvest, green: planting and harvest. States of the NEB - PI: Piauí, BA: Bahía, MA: Maranhão, CE: Ceará, PB: Paraíba, PE: Pernambuco, SE: Sergipe, AL: Alagoas, RN: Rio Grande no Norte. Source: CONAB, 2019

The water demand for crops is closely related to climate conditions and can be estimated by the crop evapotranspiration. Martins et al. (2019) suggested that for maize in NEB, the water needs will increase compared to the baseline period, regardless of the scenario, region, and evaluated period. This analysis was made considering the areas suitable for expansion of irrigation in NEB, but also the evaporative demand of the atmosphere and the intrinsic crop features (Figure 26). [39]

[39] Martins, M. A.; Tomasella, J.; Dias, C. G. Maize yield under a changing climate in the Brazilian Northeast: impacts and adaptation. 2019. Agricultural Water Management. https://doi.org/10.1016/j.agwat.2019.02.011

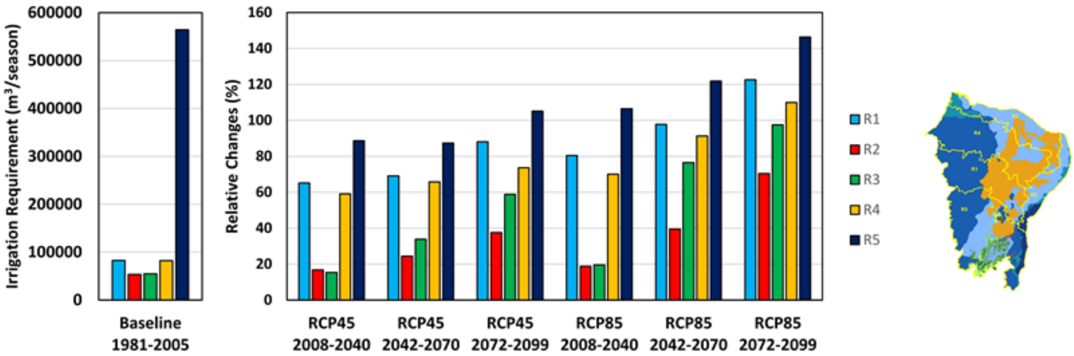

Figure 29. Irrigation requirements estimated using 2015 rainfed planted and irrigated areas for the baseline scenario for the five subregions of the study area (left panel); changes of each future scenario relative to the baseline (right panel). Source: Martins et al. (2019)

In this assessment, it is worth noting the significant increase in water demand for the Southern region of the NEB (R5). This region also showed a significant reduction in precipitation and an increase in evapotranspiration and minimum and maximum temperatures (Figure 26).

The increase in water demand associated with areas suitable for expansion of irrigation can be seen as a viable measure of adaptation for maize aiming to reduce crop losses in the future. However, the authors argued that the use of large-scale irrigation has strong implications for water availability.

Rodrigues da Silva et al. (2010)[40] evaluated the effects of climate change on cowpea bean crop grown in northeastern Brazil based on three scenarios that assume air temperature increases of 1.5 (a), 3.0 (b) and 5.0◦C (c), compared to the normal climatic conditions and no changes in precipitation. The authors found that in the first growing season, the areas with high and medium climate risks increased while the areas with low climate risk decreased, making cultivation of cowpea bean in the region less favorable. However, during the second and third growing seasons, only the agricultural area with high climate risk increased in the climate scenarios while the agricultural area with medium and low climate risks decreased except for scenario A at the third growing season, when compared to the current weather conditions. For the three growing seasons, the agricultural area with high climate risk under scenario C is greater than the sum of the areas with low and medium climate risks under the same scenario.

Table 3 summarizes the change in agricultural area of cow- pea bean grown in northeastern Brazil under the normal climatic conditions and scenarios A, B and C. At normal climatic conditions, only 44.7% of the agricultural area has high climate risk, versus 61.6% and 78.1% for the first and third growing seasons, respectively. Therefore, most of northern NEB is agriculturally suitable for cowpea bean cultivation from February to April, probably due to soil conditions and certain regularity conditions of seasonal ITCZ patterns. The increased rates in areas with high climate risk (difference between scenario C and normal climatic conditions) were 109,218, 246,484 and 163,353 km^2 for the first, second and third growing seasons, respectively. The second growing season presented the largest increases in areas with high climate risk under all scenarios.

[40] Rodrigues da Silva, V.P. et al. Impact of global warming on cowpea bean cultivation in northeastern Brazil. **Agricultural water management**, v. 97, n. 11, p. 1760-1768, 2010.

Agricultural area (km^2) of cowpea bean grown in northeastern region of Brazil with low, medium and high climate risks under the normal climatic conditions (NCC) and scenarios A (warming of 1.5 °C), B (warming of 3.0 °C) and C (warming of 5.0 °C) for three growing seasons.

Climate risk	NCC	Scenario A	Scenario B	Scenario C
First growing season (November, 15)				
High	961,230.2	998,357.2	1,035,540.6	1,070,448.2
Medium	314,830.7	370,416.3	400,540.1	431,540.2
Low	282,848.6	190,136.1	122,828.8	56,921.2
Second growing season (February, 15)				
High	697,132.0	797,270.2	869,933.5	943,615.9
Medium	372,580.1	371,792.1	360,516.4	338,822.9
Low	489,197.4	389,847.2	328,459.6	276,470.8
Third growing season (May, 15)				
High	1,216,768.0	1,255,148.1	1,306,883.3	1,380,120.7
Medium	146,077.8	153,516.3	138,504.6	108,699.7
Low	196,063.8	150,245.2	113,521.7	70,089.1

Table 3. Source: Rodrigues da Silva et al. (2010)

The temporal variability in percent of total agricultural area planted with cowpea bean in the study region under the normal climatic conditions and warming scenarios as well as its average and standard deviation are presented in Figure 27. The overall agricultural area appears to be similarly affected by the warming scenarios when changing the planting date. Although rainfall changes are not analyzed here, it is possible to say that agriculture in NEB is very vulnerable to climate variables because it is highly dependent on rainfall and air temperature. As expected, the percentage of total agricultural area under low climate risk basically showed an inverse pattern throughout the scenarios compared to the total agricultural area under high climate risk. Possible reasons for the percentage of total agricultural area to be lower for high climate risk and higher for low climate risk in November and February include the fact that the majority of the region has its main rainy period during these months. Therefore, the regularity of the seasonal ITCZ cycle would have a positive effect on the percentage of total agricultural area of cowpea bean in northeastern Brazil for all warming scenarios and normal climatic conditions. Inversely, higher temperatures would have a negative effect on total agricultural area and, consequently, on both yield and net crop revenues. [40]

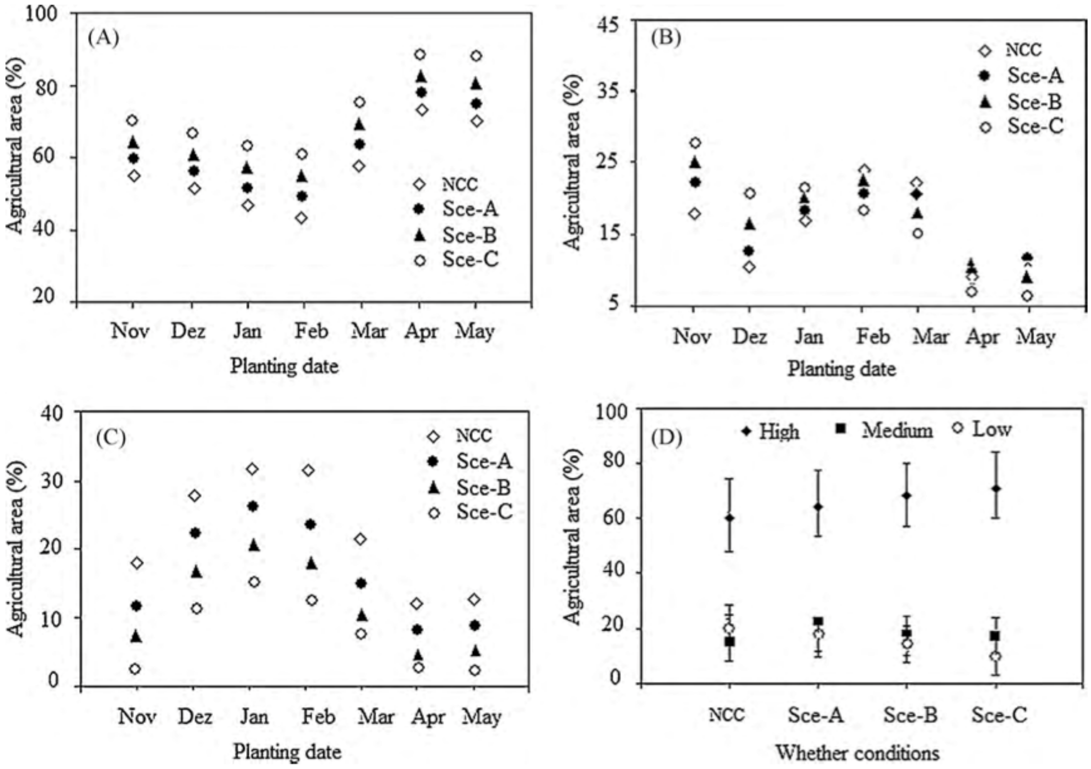

Figure 30. Percentages of total agricultural area in northeastern Brazil classified as high climate risk (A), medium climate risk (B) and low climate risk (C) under normal climatic conditions and scenarios A, B and C. Average and standard deviation (D) of the percentages of total agricultural area classified as high, medium and low climate risk under normal climatic conditions (NCC), scenario A (Sce-A), scenario B (Sce-B) and scenario C (Sce-C). Source: Rodrigues da Silva et al. 2010.

Rodrigues da Silva et al. (2010) found considerable differences between the three warming scenarios and normal climatic conditions in terms of projected effects of changes in temperature on the area suitable for cowpea bean cultivation. Under the warming scenarios, the length of the growing period and yield should be drastically affected as a consequence of the decrease in agriculturally suitable area. The impacts of climate change are highly variable in both space and time due to the variability in air temperature, rainfall, soil and vegetation throughout the region. The second growing season (from February to April) appears to be less affected by the warming scenarios than the first and third growing seasons, probably due to the soil conditions and regularity of seasonal ITCZ patterns in most of northern NEB. These results are important because the effects of projected climate change on the agricultural sector must be considered as part of future climate risk management. The landscape of rural areas in northeastern Brazil is shaped with crops, including maize and beans, among others, that are well adapted to a semiarid climate. However, under a warming scenario the climate risk of these crops will increase, resulting in a drastic crop yield reduction as well as a reduction in agriculturally suitable areas.[40]

Young et.al (2018) projected to the 2017-2030 period, *ceteris paribus*, this would represent an accumulated loss between R$ 1.4 to 2.7 billion (current values), about half of this concentrated in the two crops mostly identified with family agriculture, bean and corn (Table 4) in the Northeast. If the period is extended to 2017-2050, the accumulated losses increase to R$ 3.3 to R$ 6.6 billion (current values).

Table 4. Accumulated loss in agricultural production value due to climate change, 2017-2030 and 2017-2050 periods. Source: Young et. al (2018) (see Appendix VII for full study).

	2017-2030		2017-2050	
Crop	Total Agricultural Value Lost due to Climate Change - 10% (thousand R$)	Total Agricultural Value Lost due to Climate Change - 20% (thousand R$)	Total Agricultural Value Lost due to Climate Change - 10% (thousand R$)	Total Agricultural Value Lost due to Climate Change - 20% (thousand R$)
Bean	290.685	581.371	705.950	1.411.900
Corn	308.867	617.734	750.106	1.500.212
Total	1.353.269	2.706.538	3.286.510	6.573.020

Note these are underestimates of the total costs of climate change, since they do not consider livestock and other agriculture activities. Also, there is an implicit assumption that costs are proportional to the reduction in average rainfall. However, there are possible discontinuities in this relationship, and losses are very likely to be more than proportional to the reduction in rainfall.

2.4 Baseline Scenario: Sources of vulnerability and climate impacts

Low-income family farmers, the target group of this project, face very harsh and challenging conditions for developing productive and sustainable livelihoods. According to a study by the Ministry of Environment, (*Ministério do Meio Ambiente – MMA*), the Ministry of National Integration (*Ministério da Integração Nacional – MIN*) and WWF – Brasil[41], the Northeastern Semiarid region is the most vulnerable region to climate change in the country, as suggested by the map below.

[41] BRASIL-MMA; BRASIL-MIN; WWF-BRASIL. **Índice de vulnerabilidade aos desastres naturais relacionados às secas no contexto da mudança do clima** Brasília: Ministério do Meio Ambiente, Ministério da Integração Nacional e WWF - Brasil, 125 p., 2017. Available at: https://d3nehc6yl9qzo4.cloudfront.net/downloads/estudo_secas_completo_com_isbn.pdf.

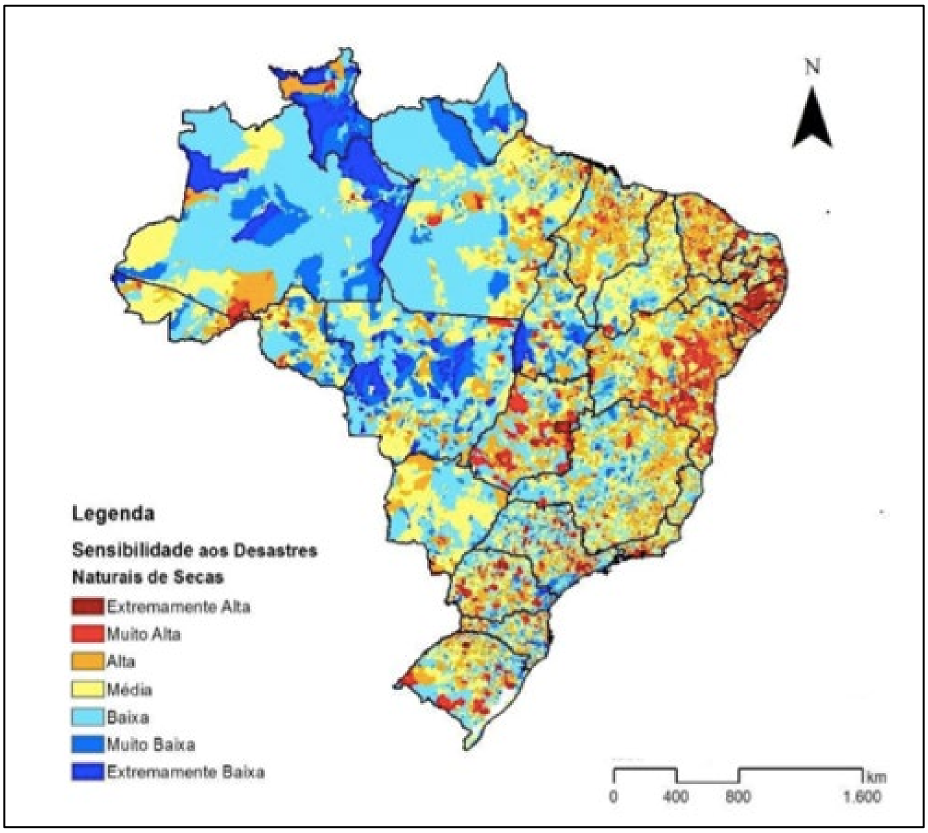

Figure 23 Sensitivity to Droughts [42;43]

Superimposing climate change upon pre-existing social-economic vulnerabilities places intense pressure on freshwater availability and quality in the region translating into losses of arable land, desertification, increased food insecurity and reduced local economic activities that lower farmers' income and result in rural exodus. The climate change vulnerabilities of Brazil's semiarid region are a consequence of sensitivity and adaptive capacity factors that reinforce one another and exacerbate the impacts of climate change. The main ones are: a) high poverty incidence, b) water scarcity and poor quality; c) inadequate productive practices, and d) deforestation of the *Caatinga* Biome depleting the ecosystem services.

2.4.1 Poverty in the region

Brazil is placed in a high human development category (0.761 in 2019), raking 79th in the world. However, it ranks second in income inequality, with one third of the wealth in the hands of the richest 1%. Over half (59.1%) of Brazilians living in extreme poverty are in the Northeast region. Historically, the area has been the single largest pocket of rural poverty in Latin America; and, despite improvements over the past 25 years, it still is Brazil's most impoverished region, hosting 3 million of those living in extreme poverty, of which 46% belong to households in rural areas.[44]

The municipal human development index (m-HDI) of the semiarid rural municipalities in the Brazilian Northeast region ranges from 0.443 to 0.710, with an average of 0.587[45]. Although the indexes have improved over the past 25 years, semiarid NE Brazil is still plagued by several social malaises, especially in rural areas where the percentage of the population living in poverty[46] is around 50% in the nine States. Worst yet, in some

[42] From top to bottom: Extremely High; Very High: High: Medium; Low; Very Low; Extremely Low.
[43] BRASIL-MMA; BRASIL-MIN; WWF-BRASIL. **Índice de vulnerabilidade aos desastres naturais relacionados às secas no contexto da mudança do clima** Brasília: Ministério do Meio Ambiente, Ministério da Integração Nacional e WWF - Brasil, 125 p., 2017. Available at: https://d3nehc6yl9qzo4.cloudfront.net/downloads/estudo_secas_completo_com_isbn.pdf.
[44] PNUD; IPEA; PINHEIRO, F. J. **Atlas do Desenvolvimento Humano no Brasil - 2010**. Brasília: PNUD, 2013. Available at: http://www.atlasbrasil.org.br/2013/.
[45] PNUD; IPEA; PINHEIRO, F. J. **Atlas do Desenvolvimento Humano no Brasil - 2010**. Brasília: PNUD, 2013. Available at: http://www.atlasbrasil.org.br/2013/.
[46] The criteria to define poverty and extreme poverty in Brazil are the following: Extremely poor: with a monthly per capita household income of less than 1/8 of the minimum wage, or less than R$63, according to the 2010 Demographic Census. Poor: with a monthly per capita household income of 1/8–1/4 the minimum wage, or R$63–R$127.These figures refer to the value of the minimum wage of R$510 in effect in 2010, when the last national Demographic Census was conducted: Demographic Census /IBGE.

states, the extreme poverty rates are about 40%. Infant mortality in the rural northeastern states varies between 23 and 33 deaths per thousand births, reaching almost double the national average of 16.7 in 2010. The illiteracy rate is also striking in the region (ranging from 42% to 32%) when compared to a national average of 9.63%.

The semiarid or *Sertão* (its common name in Brazil) is characterized by a significant imbalance in land ownership, and most of the impoverished are smallholding family farmers[47]. These family farms account for over 90%[48] of farms in the semiarid drylands of NE Brazil. According to data from the 2006 agricultural census, approximately 2 million family farms employed over 6.5 million people in the Northeast, covering a total of 28 million ha, which accounted for 52% of the value of production and 87% of the total labor in the sector.[49]

These family farms are less than twenty hectares in size.[50] Despite some variants, they generally blend annual rain-fed agriculture harvesting food crops – mainly maize, beans and cassava – for home consumption and sale, with livestock-raising.[51] Whenever possible, families also have backyard vegetable gardens, a few fruit trees and poultry. In rare cases, there is a small irrigated area.

Food crop plots occupy a part of these smallholdings. Forage growing areas are also present, those include cultivated pastures and forage production plots, with, for example, fodder cactus (known as *palma forrageira*[52]*)* cultivation. Generally, the properties also have an area of native vegetation (*Caatinga*), commonly used as grazing land. The *Caatinga* is used as a source of fodder and is also the source of other 'extractive' products, such as fruit, firewood, nuts, etc. Also, most family establishments suffer from what can be called 'water insecurity', characterized by an insufficient capacity to collect and store water reserves.

A deep economic recession that began in 2015 in Brazil aggravated these factors. The real GDP per capita fell approximately ten percentage points between 2014 and 2016[53] and unemployment rose to 13.7% in 2017.[54] ·From 2014 to 2017 poverty increased by 33%, climbing from 8.38% to 11.18% of the Brazilian population.[55] This contingent represents 23.3 million poor people in the country, of which the most impacted regions were the North and Northeast. In addition to the recession, in the same period, the Brazilian government introduced significant spending cuts that had a substantial impact on agricultural subsidies and public policies targeting family farming. The government reduced the Safra Plan and the budget for the Program for Strengthening Family Farming (PRONAF), the National School Feeding Program (PNAE), the Food Acquisition Program (PAA), the National Policy for Technical Assistance and Rural Extension (PNATER), the housing policy *Minha Casa Minha Vida* in rural areas, among others (these programs are explained in detail later in section 3.2.1).

Concerning the climate vulnerability of family farming systems in the region, Burney et al. affirm that the *coping* capacity of farming families before climate stress often depends upon the availability of assets (for

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[47] BURNEY, J. et al. Climate change adaptation strategies for smallholder farmers in the Brazilian Sertão. **Climatic Change,** v. 126, n. 1 – 2, pp. 45 - 59, 2014.

[48] A study on the São Francisco Sertão Territory, in Bahia State, shows that 90.7% of all agricultural production units are family farms. (Articulação-Nacional-de-Agroecologia, **Desenvolvimento rural sustentável e agroecologia no Sertão do São Francisco baiano: contribuição das redes territoriais e do Projeto Ecoforte**. Documento não publicado, 2018).
In the Chapada do Vale do Itaim Territory of the Sertão in Piauí State, this percentage reaches 92.7%. (SIDERSKY, P. **Sobre a cadeia produtiva da caprinovinocultura no Sertão do Piauí: um estudo centrado no Território da Chapada do Vale do Itaim [região de Paulistana]**. Salvador: SEMEAR-FIDA-IICA, 2017. 106 p.). Available at: http://www.fida.org.br/assets/downloads/Estudo%20de%20caso%20sobre%20caprinoovinocultura%20-%20regi%C3%A3o%20de%20Paulistana,%20Piau%C3%AD.pdf .

[49] GUANZIROLI, C. E.; DI SABBATO, A. ; VIDAL, M. DE F. **Agricultura familiar no Nordeste: uma análise comparativa entre dois censos agropecuários**. Fortaleza: Banco do Nordeste do Brasil, 172 p., 2011.

[50] Using data from the 2006 Census of Agriculture 2006 conducted by the Brazilian Institute for Geography and Statistics (IBGE), a study of the São Francisco do Sertão Territory in Bahia State showed that 62% of the farms and ranches in this Territory cover between 0 and 20 hectares.

[51] Particularly in the states of Piauí, Ceará and Rio Grande do Norte, there are areas where cashew tree groves are often found on family farms, in addition to shifting food-crop plots and livestock. There is also a territory in Bahia State where almost all family farms have areas set aside for perennial sisal plantations.

[52] Imported from Mexico, several species of fodder cactuses were introduced into the semiarid region. The most common are: *Nopalea cochenillifera* Salm-Dyck and *Opuntia ficus-indica* Mill.

[53] ROSSI, J. L. **Development Challenges in Brazil -** IDB Policy Brief 282. Brasília: Inter-American Development Bank, 2018.

[54] IBGE (2017). Pesquisa Nacional por Amostra de Domicílios Contínua (PNAD). Available at: https://www.ibge.gov.br/estatisticas/sociais/habitacao/17270-pnad-continua.html?=&t=o-que-e.

[55] NERI, M. **Qual foi o Impacto da Crise sobre a Pobreza e a Distribuição de Renda?** Rio de Janeiro: Fundação Getúlio Vargas, 2018. Available at: https://www.cps.fgv.br/cps/bd/docs/NOTA-CURTA-Pobreza-Desigualdade-a-Crise-Recente_FGV_Social_Neri.pdf.

example, assets that may be depleted in a given year to overcome a climate shock). It follows, therefore, that poverty can hinder coping capacity, making these families more vulnerable to climate stress[56].

Family farmers are the most affected by climate change. There is a significant correlation between average precipitation and agricultural production, but the effect is statistically significantly higher for crops produced by family farmers than average production. The average crop area lost due to droughts in the 1990-2016 period was 221,973 hectares per year.[57] This is particularly relevant considering that current productivity in the semiarid is already low; hence, any further losses would threaten food security in the region, with consequent repercussions on both local and national food security. Besides, the expected climate changes may exacerbate other environmental problems that already affect family farming in the semiarid: animal breeding, wild plant gathering, soil degradation, and pests, dissemination of diseases and weeds and desertification.

The drought of 2011–2017, which is considered the worst in the past 100 years, has exacerbated many social problems through the indebtedness of farmers, migration, disease, and malnutrition.[58] The estimated economic losses are in the order of $US 6 billion in the agricultural sector alone.[59] States reported an annual crop production reduction ranging from 30-75% when compared to the average in the years previous to the drought (2009/2010). In addition to the farmers' income, the prolonged climatic event affected local food markets. Whereas before the drought 80% of beans, 55% of manioc and 52% of maize sold in the Northeast came from local farmers, during the drought their participation fell to 47%, 46% e 16%, respectively.[60] Animal husbandry also suffered setbacks, losing in 2012 1.3 million bovines, 700,000 sheep, 780,000 goats[61], and 75% of the beehives.[62]

Projections estimate possible losses of up to 79.6% in agro-productive areas and subsequent increase in food insecurity and health issues due to climate change and maladaptive practices.[63] Staple food crops, such as beans, corn and cassava, can suffer productivity losses up to 5% by 2030 in the Northeast due to climate change. Some scenarios even project that manioc can disappear from the region[64]. Projections indicate that while most crops, including coffee, sugarcane, oranges and cotton, will be affected, maize and wheat will be the most severely impacted.[65] From 2017 to 2030, a 10% precipitation reduction scenario could cause an average annual loss of R$ 96.7 million in family farmer's agriculture production value. If the rainfall reduction is 20%, these losses increase to a yearly loss of R$ 193.3 million in family farmer's agriculture production value[66].

Main issues affecting agricultural productivity will arrive from increasing temperatures, changes in amount and distribution of rainfall, and increased droughts intensity and occurrence. Maladaptation practices derived from agricultural intensification (e.g. with subsequent deforestation and soil erosion) will further affect NEB and its agricultural sector. This negative consequence is particularly relevant considering that the current productivity in the semiarid is already low; hence any further losses would mean a more significant threat to food security in the region, with consequent repercussions on both local and national food security. Besides, the expected climate changes may exacerbate other environmental problems that already affect family farming in the semiarid, like soil degradation, pests, dissemination of diseases and weeds and desertification.

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[56] BURNEY, J. et al. Climate change adaptation strategies for smallholder farmers in the Brazilian Sertão. **Climatic Change,** v. 126, n. 1 – 2, pp. 45 - 59, 2014.
[57] YOUNG, C.E. et Al.. Drought in the Brazilian Semi-Arid. Study commissioned by IFAD (please see Annex 23).
[58] GUTIÉRREZ, A. P. et al. Drought preparedness in Brazil. **Weather and Climate Extremes,** v. 3, p. 95 - 106, 2014. Retrieved at: https://www.researchgate.net/publication/262922408_Drought_preparedness_in_Brazil.
[59] MARENGO, J. A.; RODRIGUES TORRES, R.; ALVES, L. M. Drought in Northeast Brazil — past, present and future. **Theoretical and Applied Climatology,** v. 124, n. 3-4, p. 1189 - 1200, 2016.
[60] BRASIL-MAPA. **Informativo sobre a Estiagem no Nordeste - nº 113 - 31/10/2017**. Brasília: Ministério da Agricultura, Pecuária e Abastecimento, 2017. Available at: http://www.agricultura.gov.br/assuntos/politica-agricola/combate-a-seca-1/arquivos-combate-a-seca/113.pdf.
[61] MADEIRO, C. 2013. Seca fez Nordeste perder 4 milhões de animais em 2012, diz IBGE... – Available at: https://economia.uol.com.br/agronegocio/noticias/redacao/2013/10/15/seca-fez-nordeste-perder-4-milhoes-de-animais-em-2012-diz-ibge.htm?cmpid=copiaecola.
[62] VIDAL, M. D. F. Efeitos da seca de 2012 sobre a apicultura nordestina. **Informe Rural,** v. 7, n. 2. Available at: https://www.bnb.gov.br/documents/88765/89729/%20ire_ano7_n2.pdf/7a9e8843-0f57-4ed8-b737-0a6096c915cd, 2013.
[63] BARBIERI, A.; CONFALONIERI, U. E. C. (2010). Migrações e saúde: cenários para o nordeste brasileiro, 2000-2050. Viabilização do semiárido do Nordeste um enfoque Multidisciplinar, 45-65.
[64] MACHADO FILHO, H. et al. **Climate change and impacts on family farming in the North and Northeast of Brazil. Working Paper 141**. Brasília: IPC-IG/UNDP; IFAD - Semear; IPEA, 61 p., 2016. (This study was commissioned and paid for by IFAD).
[65] USAID, 2018. Climate Risk Profile. Fact Sheet. Available at: https://www.climatelinks.org/sites/default/files/asset/document/2018-April-30_USAID_CadmusCISF_Climate-Risk-Profile-Brazil.pdf
[66] YOUNG, C.E. et al. Drought in the Brazilian Semiarid. Study commissioned by IFAD (please see Annex 23).

2.4.2 Water is scarce and of poor quality

Brazil holds 12% of the world freshwater; however, the distribution of this resource is disproportionate across its territory and the population's demand. The Northeast represents the most critical situation, with only 3.3% of the country's water volume. Water is a scarce natural resource in the semiarid region. Water scarcity is intrinsically related, on the one hand, to the low rainfall and the high evaporation rates and, on the other hand, to its geological structure - a crystalline shield that does not allow for sufficient accumulation of water in the subsoil.

Within Semiarid NEB (figure 28), water bodies represent less than 1% of total land cover; while the highest percentage of the territory is shrubs at approximately 36%; another 19% are dry forests, 17% is grasslands. Bahia and Piauí are the states with the highest concentration of areas suffering from annual fires, as well as the areas with most access to forest resources.[67]

(A) (B)

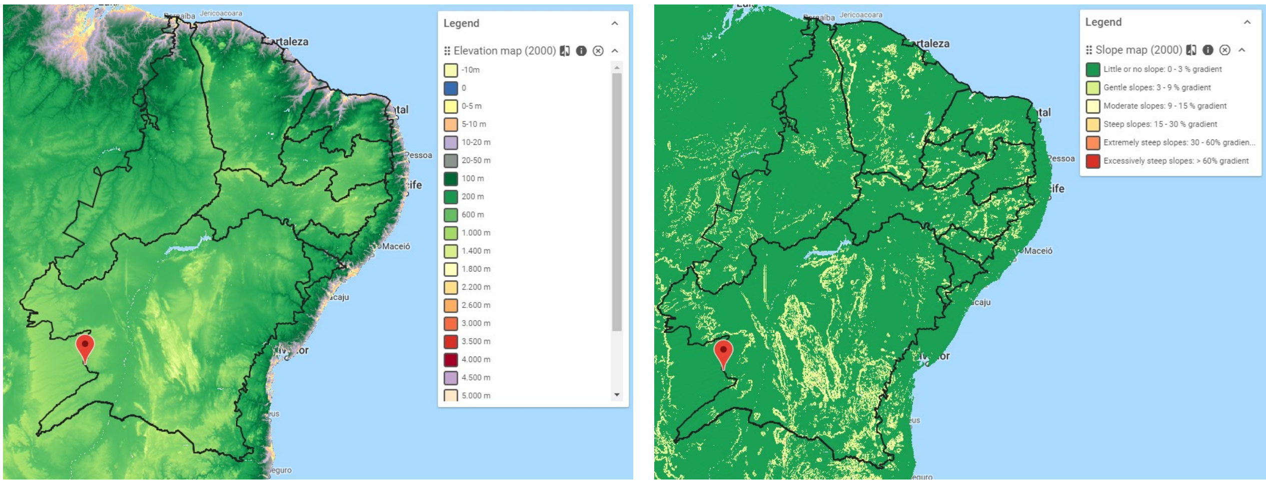
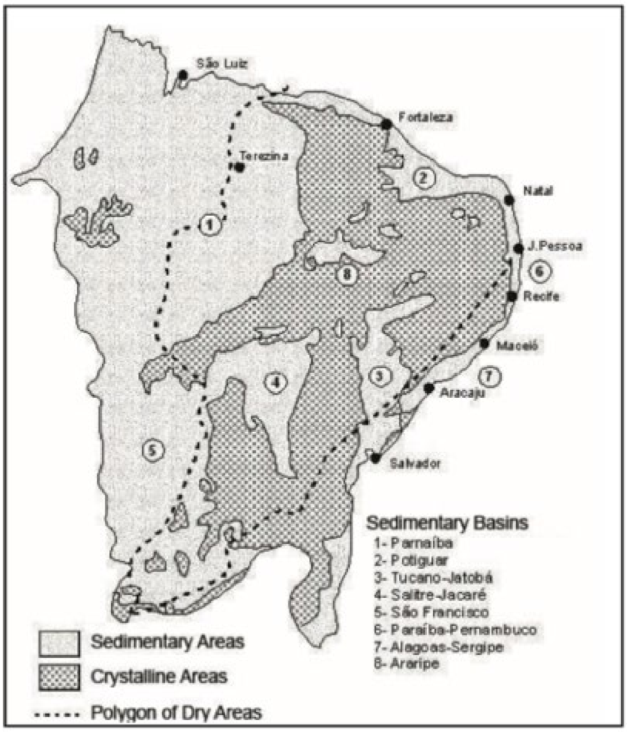


Figure 31 (A) Elevation Map of NEB[68], and (B) Slope

The Semiarid northeastern territory is constituted of more than 80% crystalline rock (as can be seen in Figure 29), which has poor surface drainage. Consequently, the region has a dense network of temporary rivers, the major exception being the São Francisco River, which is perennial. The groundwater of the crystalline formation has predominantly elevated salt levels and low flow wells (in the order of 1 m^3/h). The exception occurs in sedimentary formations, where the water is generally of better quality and where it is possible to exploit flows of the order of tens to hundreds of m^3/h, continuously.[69]

[67] MCD64A1.006 MODIS Burned Area Monthly Global 500m
[68] SRTM Digital Elevation Data Version 4
[69] CIRILO, J. A. Public water resources policy for the semiarid region. **Estudos Avançados,** v. 22, n. 63, p. 61 - 82, 2008.



Source: Demetrio et al. (2007)

Figure 32 Distribution of sedimentary and crystalline rocks occurring in the area within the Semiarid[70]

There are inequalities in access to supply services of quality water and sewage. Only about 31% of the rural municipalities in the Northeast are connected to the water distribution network.[71] In addition to lack of access to water, there are serious concerns regarding the quality of the water that can be accessed. The National Sanitation Information System (SNIS) shows, for the year of 2015, that about 27% of all the population in the Northeast still has no access to treated water.[72] This number is undoubtedly much higher amongst rural households in the Semiarid region. The main water access policy aims at increasing household water storage capacity through the use of cisterns, which are primarily fed by rainwater capture or water trucks (please see the section 3.2.1 for more details on government policies and programs).

Alternative forms of water supply, predominant in rural areas, face one or more of the following challenges: not meeting the quality standards defined in the legislation, lacking internal channeling in residence, receiving intermittent supplies and having insufficient amounts. There are public health implications arising from the consumption of unsafe water supplied by inadequate solutions.[73]

A study carried out by the National Water Agency (ANA) shows climate change will aggravate the situation intensifying aridity conditions in the semiarid region.[74] The depletion of water reservoirs due to the marked evaporation present in the region is expected to accentuate with climate change. Studies have shown that 40% of the water in a small reservoir is lost to the atmosphere by evaporation, which in the region often exceeds 2000 mm/year, in some cases reaching 3000 mm/year[75,76]. The intense evaporation causes salinization of the stored water.[77] The recent severe drought has reduced the water stored in reservoirs in the Northeast by

[70] DEMETRIO, J. G. A.; FEITOSA, E. C.; SARAIVA, A. L. Aquíferos fissurais. In: CIRILO, J. A.;CABRAL, J. J., *et al* (Ed.). **O uso sustentável dos recursos hídricos em regiões semiáridas**. Recife, PE: Editora da UFPE, 2007. p.105 - 132.
[71] IBGE, 2010.
[72] INSTITUTO-TRATA-BRASIL. **Acesso à agua nas regiões Norte e Nordeste do Brasil: desafios e perspectivas**. São Paulo: Instituto Trata Brasil, 186 p., 2018. Available at: http://tratabrasil.org.br/images/estudos/acesso-agua/tratabrasil_relatorio_v3_A.pdf.
[73] Instituto Trata Brasil (2018), as above.
[74] ANA; CGEE, Mudanças Climáticas e Recursos Hídricos (2016), as above.
[75] MOURA, M. S. B. D. et al. Clima e água de chuva no Semi-Árido. In: BRITO, L. T. D. L.;MOURA, M. S. B. D., *et al* (Ed.). **Potencialidades da água de chuva no Semi-Árido brasileiro**. Petrolina, PE: Embrapa Semi-Árido, 2007. p. 37 - 59.
[76] MOLLE, F. **Perdas por evaporação e infiltração em pequenos açudes**. Recife: SUDENE/DPG/PRN/GT.HME, 1989. 175 p.
[77] For instance, the installation of flushing devices at the bottom of reservoirs can extract salinized water deposits at the end of the dry periods, which creates adequate conditions for the accumulation of fresh water during the next rainy season. The same operating scheme could transform a salinized well water into fresh water by pumping the residual salinized water at the end of the dry season.

approximately 43% in volume from May 2012 to May 2017[78]. As can be seen in figure 30, the projected water balance (considering precipitation and evaporation) is expected to be negative in the next few decades[79]. This reality will have a direct consequence on groundwater availability, which is projected to suffer a reduction in recharge rates of up to 70% by 2050.[80]

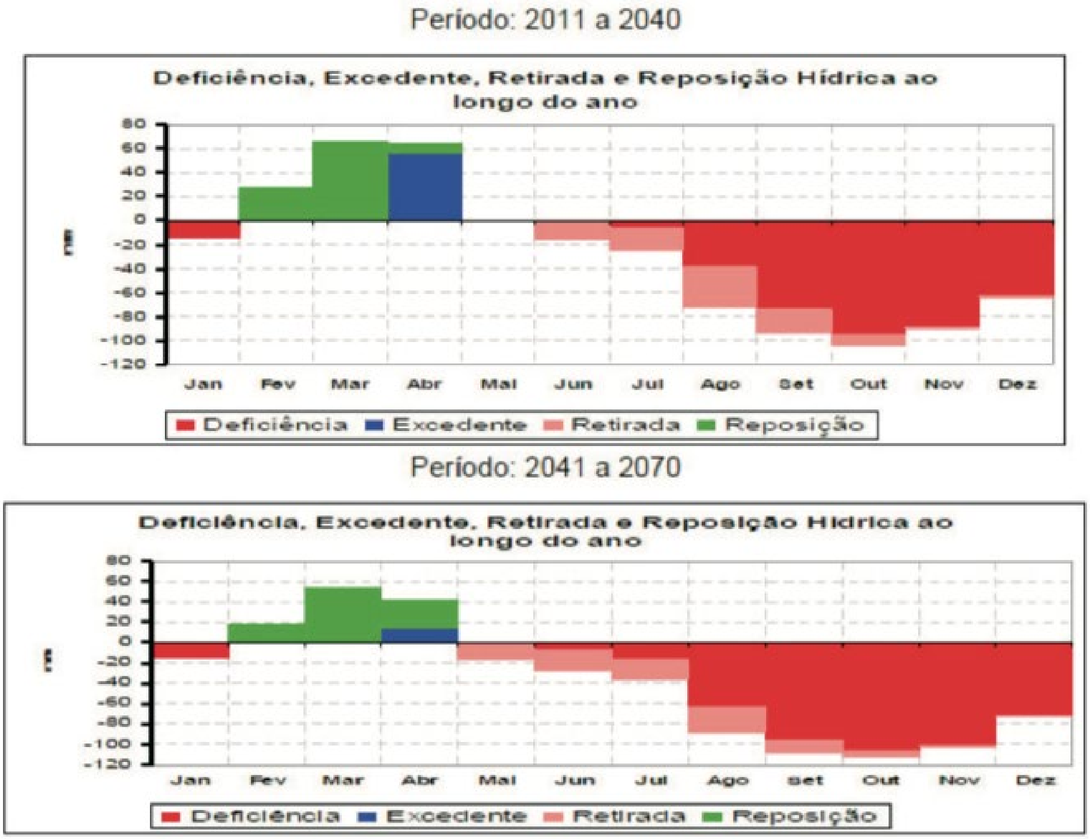


Figure 33 Projected Water Balance for the Northeast (red: deficient, blue: exceeding, pink: withdrawal, green: recharge)[81]

[78] GONDIM, J. et al. A seca atual no Semiárido nordestino – Impactos sobre os recursos hídricos. **Parcerias Estratégicas,** v. 22, n. 44, p. 277 - 300, 2017.

[79] NOBRE, P. et al. Impactos de mudanças climáticas globais na hidrologia do semiárido do Nordeste brasileiro para o final do século XXI. In: MEDEIROS, S. D. S.; GHEYI, H. R., *et al* (Ed.). **Recursos hídricos em regiões áridas e semiáridas**. Campina Grande, PB: INSA, 2011. p. 423 - 439.

[80] ANA; CGEE, Mudanças Climáticas e Recursos Hídricos, 2016.

[81] NOBRE, P. et al. Impactos de mudanças climáticas globais na hidrologia do semiárido do Nordeste brasileiro para o final do século XXI. In: MEDEIROS, S. D. S.; GHEYI, H. R., *et al* (Ed.). **Recursos hídricos em regiões áridas e semiáridas**. Campina Grande, PB: INSA, p. 423 – 439, 2011.

2.4.3 Inadequate agricultural practices

Agricultural systems of the Semiarid region evolved with the intensification of productive units, which is related to the increase of the density of the land occupation, the growth of the herds and the spread of private appropriation of once open grazing lands. This process calls for innovation, as many of the usual agricultural practices become increasingly inadequate.

Ill-suited soil preparation techniques accentuate degradation processes in a soil that is already shallow, vulnerable to erosion, and with a thin layer of organic matter, which further restricts water retention capacity. Fire is still used to prepare for planting, further accelerating land degradation and desertification processes as well as emitting carbon to the atmosphere. This practice is part of the swidden agriculture (also known as slash-and-burn agriculture) that farmers have traditionally used in tropical regions for centuries.[82] Itinerant agriculture prepares plots in the traditional slash and burn, with cleared areas used for two or three years and then abandoned, with cultivation moving on to other areas opened for planting new crops. Today, constraints on space are forcibly extending the length of time these areas must be used for farming purposes, thus rendering the system to become dysfunctional in Semiarid Northeastern Brazil.[83]

Historically, periodic droughts, soil limitations, and other environmental constraints did not allow the establishment of intensive agriculture. The region has been more suitable for animal grazing instead. Raising ruminants has been the main activity in the Semiarid ever since colonial times. Rearing goats, sheep and cattle are still the main productive activities for the majority of the region's farms.[84] Currently, about 19% of the overall national cattle herd, 50% of the sheep herd, and 90% of the goatherds in Brazil raise in the Northeast. Traditionally, the natural *Caatinga* vegetation of the semiarid region furnishes the staple food consumed by goats and sheep.

As forage supplies from the *Caatinga* shrink steadily during the dry season, farmers are raising livestock using waste biomass from their food-crop plots as additional food sources for their herds. Recently, farmers are planting fodder crops to boost overall livestock production. Noteworthy amongst the fodder crops is the *palma forrageira* cactus[85], a small set of cactus species brought from Mexico that flourishes in the region. In areas with more water availability grasses and sugarcane were planted for forage. In the '90s, rural technical assistance and cheap credit were the incentives used to disseminate a new practice: planting trample-resistant herbs (very often buffel grass[86]). Nevertheless, the combination of on-going use with heavy grazing pressure under limited rainfall conditions has resulted in many of these areas becoming severely degraded, despite these species being reasonably drought-resistant.[87] Fodder processing and conservation, such as silage and, to a lesser extent, haymaking, are other new practices that are gradually spreading in the region.

It is also worth recalling that the availability of drinking water for livestock[88] is a crucial element for these herds. Water sources are scarce, as discussed previously, and farmers invest in installing drinking ponds, waterholes, boring wells, digging pits and constructing weirs and cisterns[89]. However, this problem – which becomes crucial during dry seasons – is far from being solved and is being aggravated by climate change.

Despite the recent innovations in fodder plantations and storage mentioned above, the grazing system is still predominantly extensive, with overgrazing as the dominant factor. Extensive animal husbandry limits the return of nutrients to the soil, as herds are left loose to pasture and plots receive manure irregularly and in low

[82] ASHTON, M. S.; KELTY, M. J. **The Practice of Silviculture: Applied Forest Ecology**. Hoboken, NJ: John Wiley & Sons, 776 p., 2018.
[83] In this system, the natural forest vegetation is cut and burned, and a crop such as maize or beans is grown for two or three cycles, and then the area is left fallow. Forest vegetation is allowed to develop, and soil nutrient stocks build up. Food is grown on alternate plots until the fallow site has been restored to a condition suitable for clearing and cropping again. Fallow periods vary depending on available land, but family units are getting smaller and smaller and thus fallow periods must be shortened to the point where they no longer serve their purpose, soil rapidly degrades, and agricultural yields decline.
[84] Studies show that families add together a variety of sources in order to constitute total family incomes. But even for families leaning heavily on agricultural output, this never outstrips the weight of livestock production, in terms of gross value produced. (HOLANDA JR., E. V. et al. Tipologia e estrutura da renda de caprino-ovinocultores de base familiar no Sertão Baiano do São Francisco. VI Encontro da Sociedde Brasileira de Sistemas de Produção, 2004. Aracaju, SE. Sociedade Brasileira de Sistemas de Produção, 20 a 22 de outubro de 2004).
[85] Mainly *Opuntia ficus-indica,* and also *Nopalea cochenilifera.*
[86] *Cenchrus ciliaris* L.
[87] OLIVEIRA, M. C. **Capim buffel: Produção e manejo nas regiões secas do Nordeste**. Petrolina: EMBRAPA/CPATSA, 1993.
[88] It is worth recalling that a goat or sheep drinks between two and six litres of water a day. A hundred-head herd thus requires considerable amounts of water each day. (ARAÚJO, G. G. L. et al. A água nos sistemas de produção de caprinos e ovinos. In: VOLTOLINI, T. V. (Ed.). **Produção de caprinos e ovinos no Semiárido**. Petrolina: Embrapa Semiárido, p.69-93, 2011).
[89] ARAÚJO FILHO, J. A. **Manejo pastoril sustentável da caatinga**. Recife, PE: Projeto Dom Helder Camara, 200 p., 2013.

quantities. Additionally, the large land requirements of low-yield, extensive systems limit the habitat available for wild species. Overgrazing causes the increase of bare soil that facilitates water and wind erosion, accelerating the desertification process.[90]

The climate change projections of increasing temperatures and irregular rainfall in addition to the current the inherent fragile conditions of the soil, the increasingly smaller family units, the constant drive to production intensification and the application of inadequate practices translate into a decline in productivity, of both crops and animal husbandry. Production systems in the semiarid region, the way they are conducted, are in crisis and feed into environmental degradation processes, which further aggravate with changing climate conditions. This situation induces the impoverishment of farming families and thus forming a vicious circle of poverty and vulnerability to climate change.

2.4.4 Deforestation and degradation of natural vegetation remnants

The *Caatinga* (as the natural vegetation of the semiarid region is called) is the predominant ecosystem in the Semiarid, covering approximately 11% of the national territory. The word *Caatinga* means white forest in Tupi language and refers to the small-leaved, medium to tall, dry, light forests dominated by woody genera. The *Caatinga* vegetation of trees and bushes native to these regions, are predominantly xerophytic or drought-resistant and thus adapted to the limited water availability characteristic of Northeast Brazil. The Ministry of the Environment estimated that the *Caatinga* was deforested at a rate of 0.28% per year (2,352 km^2/yr.) between 2002 and 2008, comparable to the deforestation rate in the Amazon, emitting large quantities of carbon to the atmosphere. In 2010, little more than half (53.6%) of the original vegetal cover remained[91], the rest having been altered by human activities, i.e., transformed into pasture, agricultural land, roads, houses, villages, and towns.

What remains of the natural ecosystems of the *Caatinga* is highly fragmented and degraded. Today the vegetation is a mostly open scrub forest. The gallery forests and dry forests have been replaced mainly by open vegetation formations.[92]

According to the United Nations Conference to Combat Desertification (UNCCD), when land degradation happens in the world's drylands, it often creates desert-like conditions. Land degradation occurs everywhere but is defined as desertification when it occurs in the drylands, resulting from various factors, including climatic variations and human activities.[93] Researchers have noted that more than 50% of the Brazilian semiarid is already in the process of desertification and 94% of the Northeast region of Brazil is under moderate to high susceptibility to it, as can be seen in figure 31.[94]

Climate change and desertification remain inextricably linked because of feedbacks between land degradation and precipitation. Given these projections of future climate change in the region, there will be increased land degradation owing to droughts and increased soil erosion due to heavy rainfall events. The project must also consider other causes of desertification in the region as deforestation for fuelwood production, the exploitation of clay deposits[95], cattle raising, mining and over-cultivation.[96]

[90] KRÖPFL, A. I. et al. Degradation and recovery processes in Semiarid patchy range-lands of northern Patagonia, Argentina. **Land Degradation and Development,** v. 24, n. 4, p. 393 – 399,2013. Retrieved at: https://www.researchgate.net/publication/264700366_Degradation_and_recovery_processes_in_Semiarid_patchy_rangelands_of_northern_Patagonia_Argentina.

[91] BRASIL-MMA. **Monitoramento por Satélite do Desmatamento no Bioma Caatinga**. Brasília: MMA, 8 p., 2010. Available at: http://www.mma.gov.br/estruturas/203/_arquivos/cartilha_monitoramento_caatinga_203.pdf.

[92] GIOVANNI, M.A. and VENTICINQUE, E.M. **Fragmentation patterns of the Caatinga drylands**. Landscape Ecology. August 2018, Volume 33, Issue 8, pp 1353–1367

[93] United Nations Convention to Combat Desertification (UNCCD) United Nations Convention to combat desertification in countries experiencing serious drought and/or desertification, particularly in Africa. Bonn: UNCCD, 1994. Available at: https://www.tarimorman.gov.tr/CEM/Belgeler/collesme%20belgeleri%20arsiv/Sayfa04/S%C3%B6zle%C5%9Fmeler/UNCCD_Eng_1.pdf.

[94] VIEIRA, R. D. S. P. et al. Identifying areas susceptible to desertification in the Brazilian Northeast. **Solid Earth,** v. 6, p. 347 – 360, 2015. Retrieved at: https://www.solid-earth.net/6/347/2015/se-6-347-2015.pdf .

[95] In the Northeast, firewood represents about 30% of its energy matrix, it is used not only to supply the gypsum and ceramic industries in the semiarid, but also the steel industry in the states of Minas Gerais and Espiritu Santo. Logging is one of the main economic activities in the semiarid, employing around 700 thousand people. However, 94% of the biomass available in the market has been unsustainably or illegally extracted from the *Caatinga*. (BRASIL-MMA, 2010, as in foot-note 66 above)

[96] CGEE. **Desertificação, degradação da terra e secas no Brasil**. Brasília: Centro de Gestão e Estudos Estratégicos – CGEE, 252 p., 2016.

Desertification, a consequence of a combination of human factors and climate change, results in reduction of the natural fertility of soils, salinization and alkalization of soils and water, decreased water availability, impoverished and heavily impacted biodiversity, decreased ecosystem resilience capacity, all of which, in turn, affect the health and livelihood of local population.[97]

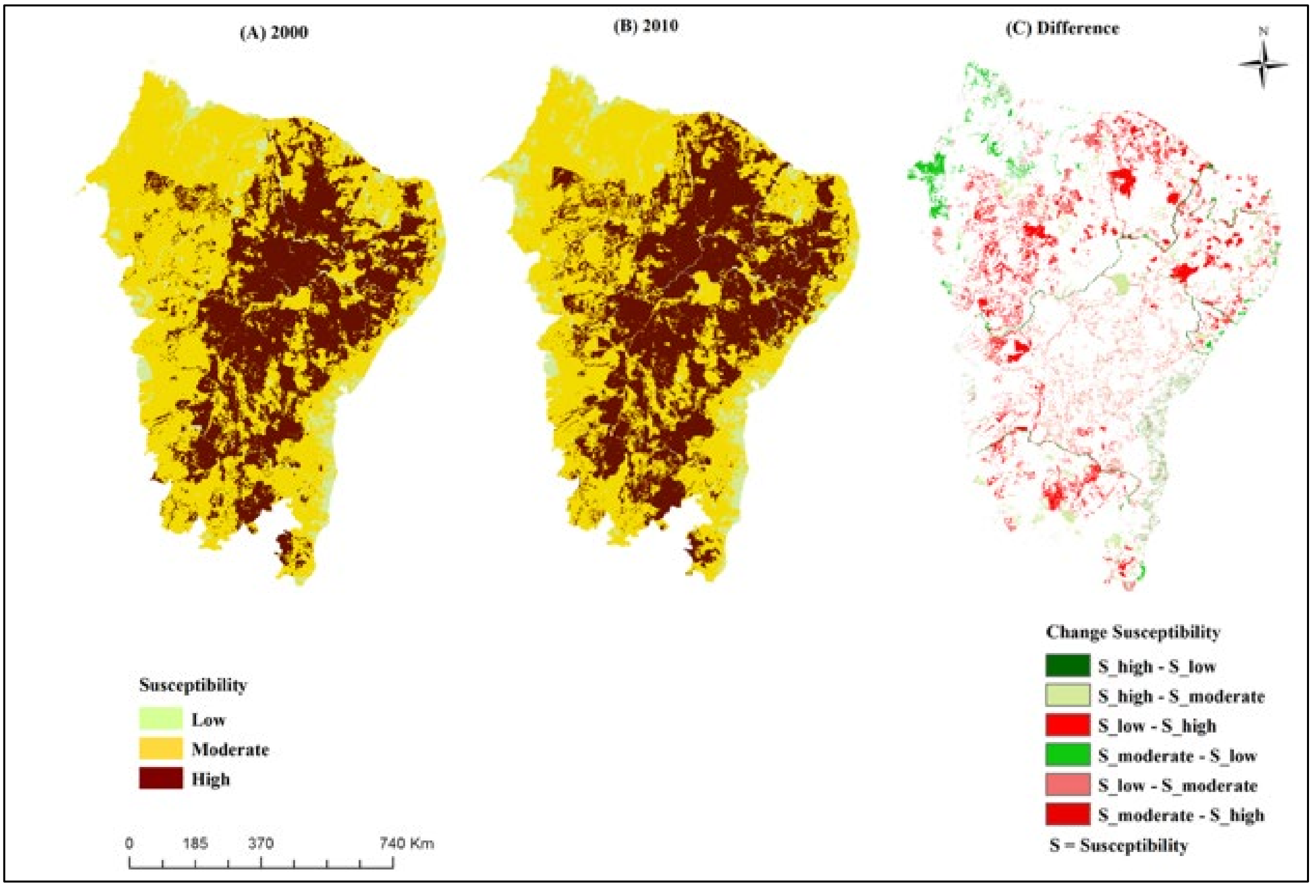


Figure 34 Areas Susceptible to Desertification in the Brazilian Semiarid Region for both 2000 and 2010, as well as the Changes that Occurred between these Periods[98]

[97] CGEE, 2016, as in foot-note 68 above.
[98] VIEIRA, R. D. S. P. et al. Identifying areas susceptible to desertification in the Brazilian Northeast. **Solid Earth,** v. 6, p. 347 – 360, 2015. Retrieved at: https://www.solid-earth.net/6/347/2015/se-6-347-2015.pdf.

3. BASELINE SCENARIO: BARRIERS THAT NEED TO BE OVERCOME

Based on the sources of vulnerability discussed above, the livelihoods of the semiarid region family farmers are under severe stress due to the combination of climate change pressures and historical degradation of the ecological and productive functions agroecosystems. This situation will aggravate due to regional effects of climate change, such as increases in maximum temperature and diminishing precipitation, more significant rainfall variability, more severe and frequent droughts, pointing towards a possible collapse of farming systems, that will significantly worsen environmental degradation, increase food and water insecurity, leading to an acute crisis in the livelihoods of this population.

Several barriers reinforce the *status quo* of unsustainability, which must be overcome to pave the way for the transformation that will help overcome the vulnerabilities. An analysis of the problems and trends apparent in these farming systems shows that many of the current practices are not sustainable, even over the medium and short term. Instead, many of these practices make systems even more vulnerable, threatening the livelihoods of families that depend on them, particularly considering climate change scenarios. There is an urgent need for sweeping changes in the stewardship of semiarid farming systems in Northeast Brazil, helping these communities to adapt to foreseen future conditions and to become more resilient.

The question arises of why these farmers continue to use unsustainable practices. Some barriers that hamper the implementation of the needed changes in practice towards adaptation and greater resilience are listed below.

3.1.1 Reduced knowledge on Climate Resilient Productive Systems (CRPS)

Practices that enhance resilience and adaptation to climate change are sparse. Farmers, technical assistance services and even researchers firmly believed that 'modern' dryland agriculture in these semiarid was not possible, except for a few specific areas where local conditions were more favorable. Successive harvest losses led to genetic erosion of traditional crop species, with a shrinking availability of seeds adapted to the harsh conditions in these regions.

Efforts have been made for quite some time to intensify livestock systems, principally through bolstering fodder production. The introduction of crops such as *palma* forage cactus and buffel-grass are good examples of this. But these two cases – although intended to increase output and productivity – instead were planted as monocultures, simplifying the system and heightening risks, leading to less resilience. Farmers were encouraged to clear the *Caatinga* to establish single-crop grazing lands.

Recently, some productive systems offering greater resilience and better adaptation to climate change have been tried out successfully, although the dissemination of this information is limited. Worthy of mention are the practices put forth by the Goats and Sheep Research Centre at the Brazilian Agricultural Research Enterprise (EMBRAPA) which proposes a system that blends crops, forestry, and livestock[99], and the agroecological consortia– a proposal promoted by the IFAD financed Dom Helder Camara Project – which has been spreading slowly over various parts of the semiarid. However, these have not been absorbed yet by the mainstream technical assistance providers, and implementation examples are few and far between, with limited contact among them. It is necessary to scale up these examples, multiply and regionalize the climate-resilient agricultural models available.

3.1.2 Low investment capacity and physical labor availability

Many innovative approaches that increase resilience to climate change are expensive, <u>requiring financial investment and much labor</u>. However, families in this region do not have the necessary funds available (see vulnerability in section 2.4). Furthermore, the demographic dynamics in the region are such that young people are departing, leaving behind an aging population – which means that, in so many cases, the family workforce is also thinning out. The hard-physical labor necessary is another factor explaining the limited availability of options.

[99] ARAÚJO FILHO, J. A. Manejo pastoril sustentável da caatinga. Recife, PE: Projeto Dom Helder Camara, 2013. 200 p.

A transition in modes of production is not immediate, and it requires that the involved families need to be patient before they can reap tangible results, a situation that differs from the logic that governs standardized interventions in the context of conventional agriculture. Especially at the beginning of the implementation of a climate-resilient productive system, families may find it difficult to 'believe' in the chosen course. Therefore, it is essential that the resilient systems' implementation is coupled with a dynamic monitoring system that can reveal some impacts linked to indicators in the short term. Participating in exchange networks with the presence of farmers that are more advanced in climate-resilient practices is also an incentive for those who wish to shift their production models.

3.1.3 Aging and masculinization of rural population

The population of the semiarid northeastern region has aged when comparing data from 2000 to the 2010 Census, reducing the proportion of people under 15 years old and significantly increasing the percentage of people over 60 years old. The ratio of young people in the total population decreased from 33% to 26.5%, at the same time as the proportion of people over 60 reached 10.3%, compared to 8.4% in 2000.

Youth exodus to urban areas intensifies the aging of the rural population. The largest gap migrations occur for the population ranging from 16 to 35 years of age. Whereas in 1991, no northeastern municipality presented a rural population aging index[100] above 20%, in 2010 indices above 25% were found in most rural towns in the region.[101]

Another important dimension of analysis of the selective exodus is the masculinization of the rural population. In rural areas, the male population is higher than the female population in all age groups. This female exodus is attributed to traditional labor division, exclusion of women from land inheritance, lack of perspective in the job market and because females obtain higher educational degrees than males in rural regions.[102]

It is necessary to engage youth (with a focus on women) to overcome this challenge, making the agricultural activity interesting and intellectually challenging. Developing mechanical tools that facilitate work and save labor will make agricultural activities lighter and more pleasurable. Engaging the entire family in collective mobilization mechanisms, such as *mutirões*[103] that provide dynamics of mutual aid between families, is a way to alleviate the burden of manual labor and to foster intergenerational interaction.

3.1.4 The limited capacity of collective action among family farmers

The rural community can be characterized by the existence of an area or territory, a sense of belonging, and a system of social institutions that organize local life. These include family relationships, proximity networks and reciprocity mechanisms (including joint efforts - *mutirões*). These mechanisms allowed the performance of various types of collective action, the management of shared resources, as well as the holding of community parties, organization of religious events, etc. But it is common to hear that traditional communities are 'disorganized'. This expression does not correspond entirely to reality. On the other hand, these structures do not work equally well in all communities, and, in some cases, the farmers themselves claim that there is a significant 'erosion' of traditions.

The ancestral mechanisms that organized communities no longer meet all the demands of families' activities and the actions of other social actors with whom communities establish relationships. Therefore, they have resorted to new forms of organization, these include community associations, unions of rural workers, cooperatives and municipal or regional associations. But it is worth questioning the efficiency of these new entities in terms of their ability to organize collective action for sustainable development.

One of the barriers that reinforce the status quo of unsustainability, mentioned earlier, involves the role of 'community associations' as an effective means of representing and organizing collective action at the local level. Regarding the specific issues of women, youth and ethnic groups, they are often not sufficiently

[100] This index measures the ratio between the elderly aged 65 and over and the young population aged 17 years or less.
[101] MAIA, A. G.; BUAINAIN, A. M. O novo mapa da população rural brasileira. **Confins,** v. 2015, n. 25, p. 1 - 25, 2015.
[102] As in footnote above.
[103] Collective mobilization process for mutual assistance of a free character, especially between neighbouring farming families, for preparing fields, harvesting, building a house, etc.

represented among the full range of community demands and are often marginalized. At the same time, the governance mechanisms of these associations are often flawed, leading to situations in which leadership roles/positions remain for long periods in the hands of a person or a tiny group of members who are not necessarily the most capable or suitable for the task. Due to these factors, most existing community associations will need support, especially in terms of capacity building, if they are to be, in the context of Project implementation, an efficient tool for implementing climate resilience initiatives.

Mobilizing multiple families from the same region in *mutirões* (see the previous section) could be a fruitful mechanism for promoting (or reactivating) horizontal cooperation and collective action at the local (mainly community) level. These practices are also fundamental because they favor social inclusion, strengthening the active participation of women and youth in family units and the exchange of knowledge and practices through joint efforts and exchanges. A "revival" of this traditional practice could have a beneficial effect on community associations.

It is also important to mention organizations that bring together farmers at a supra-Community level. Rural Workers Unions (STRs) are structured at the municipality level. They are present in practically the entire semiarid region. But the trajectory of these organizations has made them deal with issues such as rural pensions. Although there were some examples in the 1990s of STRs that embraced the cause of agroecological peasant production, this strand was virtually extinguished in the 2000s.

Finally, it is worth mentioning cooperatives. There was, at a certain period of the last century, very significant proliferation of these throughout Brazil. But the northeastern cooperatives had many problems. On the one hand, they took in a tiny portion of family farming. On the other hand, the scarce mobilization of cooperative members, coupled with poor management, has caused many of these cooperatives to fail. Although there is a timid process of resumption, the presence of cooperatives in the semiarid region is lower today than in the other areas of Brazil.

3.1.5 Difficult market and capital access

Family farmers in the semiarid region find it hard to sell their products on the market, a fact that discourages investment and innovation. These difficulties may derive from the widely dispersed and reduced scales at which individual farmers work as well as the problem of meeting requirements for marketing products (such as state or federal legislation), thus demanding a higher level of organization.

Public health regulations were developed considering agroindustry models and are extremely difficult to implement for small homemade food items, hampering the latter's access to the market.[104] Many of the products that must comply with stringent health regulation processes (such as jellies, cookies and dairy products) are produced mainly by women since they tend to engage more actively in processing stages within the productive arrangements. National regulation recognizes that food products express cultural identities, revealing traditional know-how, in addition to cultivating a relationship with the natural resource base and regional biodiversity, and thus, there is a need to preserve the artisanal characteristics of food.[105] In practice, each state must develop regulations, and few are those that have done this.

Considering these hurdles, a starting point would be the construction of strategies for the legitimization of traditional products. A viable alternative involves the stimulation of short production circuits, characterized in terms of the approximation between production and consumption and guided by aspects such as trust, quality, transparency and locality. Another measure involves the encouragement of cooperatives, which make it possible to simplify procedures and adapt them to the technical, cultural and socioeconomic conditions of small-scale productions.

Government food purchasing policies (mainly the PAA Food Security Program and the PNAE School Meals Program, see section 3.2.1 below for more details) opened up market access channels that have been widely

[104] The National Health Surveillance Agency (ANVISA), linked to the Ministry of Health and corresponding state agencies, has strict standards. Animal products, including honey, must comply with federal standards as defined in the Federal Inspection System (SIF). There are also State Inspection Systems (SIE) and Municipal Inspection Systems (SIM) and an attempt to integrate them into a single system of attention to agricultural health standards (SUASA).

[105] RDC No. 49/2013, in which there is a guideline that aims to "protect artisanal production in order to preserve traditional customs, habits and knowledge, in the perspective of multiculturalism of peoples, traditional communities and family farmers."

used by family farmers. However, these policies have been cut back very significantly since 2014 due to the economic crisis, thus hampering market access for this segment. It will be necessary to strengthen other alternatives that don't require public support, such as local and regional fairs, online sales, and public-private partnerships. Short marketing circuits such as local markets or fairs are favorable to social inclusion, insofar as they favor the direct participation of women, who tend to be very active in these spaces, and to strengthen the processes of sociability and spontaneous processes of learning and to enable a closer rural-urban relationship.

3.1.6 Deforestation 'incentive'

Although it doesn't have this intention, the provision of credit and conventional technical assistance for the implementation of pastures in monoculture has, in practice, acted as an incentive for deforestation. The establishment of this type of pasture is generally viewed as a factor that increases the value of the land when compared to the value of an area with the natural habitat, thus promoting the elimination of the *Caatinga*.

Besides, firewood and charcoal for industrial and commercial purposes constitute the most important demand for wood products from the *Caatinga*. Official estimates indicate that these activities consume 25.1 million esters/year[106]. This demand cannot be met from current areas under a sustainable forest management regime. Approximately 2.5 million ha are needed to meet the current demand for wood products, but only 94,000 ha were under a sustainable management regime in 2010 (which produced 1.5 million esters/year). This implies that 94% of the wood and charcoal in the market comes from unsustainable logging, whether authorized or not.

The abundant supply of firewood and charcoal from deforestation keeps wood and charcoal at low prices and prevents the widespread adoption of mechanisms that promote sustainable use and management of the *Caatinga*.[107] This is important, as Sustainable Forestry Management Plans (PMFS in Portuguese) requires landowners to comply with formal obligations (e.g., annual reports, payment of fees) and cumbersome procedures.

It is necessary to create a 'forestry-friendly culture' in which sustainable forest management is perceived as a productive activity that deserves careful planning and organized management. Integrating forest management with agricultural activities can generate more jobs and diversify the household's income.

3.1.7 Key challenge

The climate stressors and the vulnerability sources aggravate the negative cycle caused by the inadequate practices and the barriers mentioned above. This process translates into a decline in productivity, of both crops and animal husbandry. Production systems in the semiarid region are in crisis and feed into social and environmental degradation processes, which induces the impoverishment of farming families and ecosystem services.

3.2 Existing public policies, strategies and projects/programs

The federal government has several policies and programs that try to tackle the vulnerability sources described above. The main ones are described in the following paragraphs. At the end of this section, we will also briefly present other existing policies and projects/programs.

[106] GARIGLIO, M. A. et al., Eds. **Uso Sustentável e Conservação dos Recursos Florestais da Caatinga**. Brasília: Serviço Florestal Brasileiro, p.368 ed. 2010. Available at: http://www.mma.gov.br/estruturas/sfb/_arquivos/web_uso_sustentvel_e_conservao_dos_recursos_florestais_da_caatinga_95.pdf .

[107] Like the Sustainable Forestry Management Plans (Planos de Manejo Florestal Sustentáveis [PMFS]) created in the 90's by IBAMA (executive organ of the National Environment Policy) with support by international cooperation agencies like UNDP and FAO.

3.2.1 Poverty Reduction and Family Farming

The most prominent poverty reduction program is *Bolsa Família*, a conditional cash transfer program created Federal Government in 2004. It consists of financial assistance to poor families with pregnant women, children and teens between 0 and 17 years old with extremely poor per capita income.[108] The Program has three main axes: (a) income transfer to promote immediate poverty alleviation; (b) conditions that reinforce access to fundamental social rights in education, health, and social assistance; (c) and complementary programs to strengthen families, so the beneficiaries can overcome their social vulnerabilities.

The National Program for Strengthening Family Farming (PRONAF) was launched in 1996. In 2003 it was transformed to finance investments and current spending loans for individual or groups of family farmers in seventeen different modalities, including specific credit lines for women and youth. The program operates through public banks, with the Bank of the Northeast (*Banco do Nordeste – BNB*) being the chief financial agent in the Northeastern region. The program budget in 2017 was R$ 27 billion to finance investments and short-term loans for family farmers.

In addition to *Bolsa Familia* and PRONAF, other relevant programs which target family farmers include:

a. the Agrarian Reform Program (*Programa Nacional da Reforma Agrária - PNRA*), under the responsibility of the National Institute for Colonization (INCRA), settles and registers families claiming land in the Unified Registration (*Cadastro Ún*ico);
b. the Agrarian Credit Program (*Programa do Crédito Fundiário – PCF*), a credit program that allows rural farmers to acquire their land to combating rural poverty and strengthen family farming;
c. the Harvest Guarantee (*Garantia Safra*) Program, which enables families to receive a compensation in case of loss of harvest due to persistent drought or excess of rains;
d. the Family Agriculture Price Guarantee Program (*Programa de Garantia de Preço da Agricultura Familiar - PGPAF*), which sets minimum prices for the main products of family agriculture;
e. Proagro Plus Insurance (*Seguro Proagro Mais*) which protects credit takers of PRONAF in case of harvest loss. It is multi-risk insurance, covering losses due to climatic adversities and diseases or pests while recognizing traditional production methods of family farmers, such as intercropping, traditional, local or creole cultivars.
f. Food Purchase Program (*Programa de Aquisição de Alimentos – PAA*) creates an institutional market for products produced by family farmers and their organizations through a bidding system. The acquired products are donated to social institutions (hospitals, care institutions, schools) and people in situations of food and nutritional insecurity (who receive food baskets), or destined to the formation of public stocks.
g. National School Meal Program (*Programa Nacional de Alimentação Escolar – PNAE*), requires that at least 30% of resources spent on school meals go to family farmers and cooperatives, and works with simplified procurement processes.

Other credit programs, not necessarily oriented for family farmers, but that may also be available to them are:

i) ABC Program for investments to reduce CO_2 emissions in agriculture;
ii) Agriculture Modernization and Natural Resource Conservation Program[109];
iii) Promotion of Technological innovation in agricultural production Program[110];
iv) Program for Building and Expansion of Storage Infrastructure[111];
v) Agricultural Machinery Modernization Program[112];
vi) Incentives for Irrigation and Greenhouse Production Program[113]; and
vii) Other credit lines for Cooperatives. The Bank of Brazil and BNDES are the main financial agents in the public sector and usually provide funds for some of the Programs and credit lines already mentioned. As mentioned above, the Banco do Nordeste is also an active financial agent in the northeastern region.

[108] Extremely poor households are defined by a monthly per capita revenue between R$89 up to R$178.
[109] Programa de Modernização da Agricultura e Conservação de Recursos Naturais – Moderagro.
[110] Programa de Incentivo à Inovação Tecnológica na Produção Agropecuária – Inovagro.
[111] Programa para Construção e Ampliação de Armazéns –PCA.
[112] Programa de Modernização da Frota de Tratores Agrícolas e Implementos Associados e Colheitadeiras – Moderfrota.
[113] Programa de Incentivo à Irrigação e à Produção em Ambiente Protegido – Moderinfra.

To stimulate the production and consumption of native products, the federal government launched the National Plan to promote Socio-Biodiversity Supply Chains[114] and the Policy to Guarantee Minimum prices for Socio-biodiversity Products.[115] These programs identified 17 species used by gatherers (the so-called 'extractivist') communities from several biomes and guarantee a minimum value when the market price is lower than the minimum price established by the National Supply Company (*Companhia Nacional de Abastecimento – CONAB*).

3.2.2 Food and Nutrition Security

The Project is consistently aligned with the main policies and priorities for food and nutrition security at the national level.

The National Plan for Food and Nutrition Security (*Plano Nacional de Segurança Alimentar e Nutricional – PLANSAN*) is the main instrument of the Brazilian National Policy on Food and Nutrition Security.[116] The Plan summarizes the proposed actions to be taken by the federal government to respect, protect, promote and guarantee the right to adequate food to all Brazilians. The PLANSAN is guided by the National Policy on Food and Nutrition Security (PNSAN) and is built in an inter-sectoral manner by the Inter-ministerial Chamber of Food Security and Nutrition (CAISAN), that includes 21 ministries, on the basis of the priorities established by the National Council for Food and Nutrition Security (*Conselho Nacional de Segurança Alimentar e Nutricional – CONSEA*). Building on the achievements of the first Plan and especially on its multisector approach, the PLANSAN II enhances its focus on key issues, such as: strengthening of agroecological food systems; supporting indigenous peoples and traditional communities' access to public policies, especially those related to family farming; increasing the public purchase of food products from family farming – by strengthening PNAE and PAA; recognizing the significant contribution of women in agriculture and family farming, especially in the conservation of natural resources, and enhancing their access to public policies and; strong concern for availability of safe and clean water, including the revitalization of watersheds and springs.

3.2.3 Indigenous Peoples and traditional communities

Established in 2007, the National Policy for the Sustainable Development of Traditional Peoples and Communities (*Política Nacional de Desenvolvimento Sustentável dos Povos e Comunidades Tradicionais – PNPCT*) seeks to promote the sustainable development of traditional peoples and their communities, including indigenous peoples. One of the leading implementation tools of the PNPCT is the Sustainable Development Plan, which aims to inform and guide the implementation of the Policy. In 2012, the Brazilian government launched the National Policy for Environmental and Territorial Management of Indigenous Lands (*Política Nacional de Gestão Territorial e Ambiental de Terras Indígenas – PNGATI*). The Policy calls for the environmental protection and full participation of indigenous peoples in all processes that affect their lands, stressing the need to request and obtain indigenous people free, prior and informed consent (FPIC) before taking any actions in indigenous territories. The policy also provides for the participation of representatives of indigenous peoples in institutions in charge of regional and national environmental policies that affect their territories.

3.2.4 Water Access

As explained above, the semiarid northeastern region has age-old water scarcity problems that have been addressed, to a greater or lesser extent, by several government programs and policies. A major infrastructure project, which is still being implemented, is the transposition of the São Francisco River, which started in 2007 and parts of which started in 2017. This project will divert water from the San Francisco River to benefit 12 million people in four northeastern states.

Both the One Million Cisterns Program by MDS and the Freshwater Program by MMA are billed to be strategic partners in this Project. The Cisterns Program, financed by the Ministry of Social Development (MDS) since 2003, targets low-income rural families, affected by drought or lack of water, and residing mainly in the

[114] National Plan for the Promotion of Socio-Biodiversity Product Chains.
[115] Minimum Price Policy for Socio-Biodiversity Products.
[116] Established by Decree no.7.272 / 2010. PLANSAN I (2012-2015) was launched in 2015, followed by PLANSAN II (2016-2019).

semiarid region. The program currently supports the deployment of more than 15 different types of 'social technologies'[117]. Since its creation, more than 1 million water 'social technologies' have been implemented with Program support, including 877 thousand plate cisterns for household consumption, 145 thousand cisterns for food production and 5 thousand school cisterns. The Freshwater Program by the Environment Ministry implements a permanent public policy aimed at accessing good quality water for human consumption in low-income populations of the semiarid, through the implementation, recovery, and management of desalination systems since 2004. State Plans have the goal of serving 25% (2.5 million people) of the rural population of the semiarid by 2019. In the 2nd phase of the Freshwater Program (2019-2024), the goal is to have installed 1,727 desalination systems and to implement 103 'Biosaline' productive units, benefiting approximately 1.19 million people.

Other water access programs worth noting are the Sustentar Program and Salta-Z supported by FUNASA/Ministry of Health. These programs seek the sustainability of sanitation actions in rural areas, through the training of managers and operators in diverse alternatives of management, operation, maintenance and water quality control of the water supply systems. Also, the Sustentar Program involves the community served, with education in health and environmental sanitation. The National Water Agency (*Agência Nacional de Águas – ANA*) indirectly stimulates the Payment of Environmental Services policy and directly supports ways of preserving water resources, such as the construction of infiltration terraces and basins, the re-adaptation of vicinal roads, the recovery and protection of springs, the reforestation of permanent protection areas and legal reserves, rural sanitation projects, collection and recycling of waste.

The National Policy to Combat Desertification and Mitigation of Drought Effects and its instruments, as well as the National Commission to Combat Desertification (CNCD), were sanctioned in July 2015. This law instructs how to map and diagnose desertification processes, including land degradation in arid, semiarid and dry sub-humid areas resulting from various factors and vectors, including climatic variations and human activities.

3.2.5 Environmental Licensing

Environmental licensing was instituted by Law nº 6.938/81 as one of the necessary instruments for the protection and improvement of the environment (art. 9th, IV), as it verifies the possibility of negative environmental impacts caused by the construction, installation, expansion and operation of establishments and activities that use environmental resources, as well as establishes the necessary measures for their prevention, repair and mitigation.

Environmental licensing is the procedure whereby the competent environmental agency licenses a potentially polluting activity after technical analysis, which imposes on the entrepreneur a series of measures aimed at maintaining the ecologically balanced environment. Thus, the scope of environmental licensing is to reconcile economic development with environmental preservation.

To discipline the environmental licensing aspects established in PNMA, Conama Resolution nº 237/97 was issued, which deals specifically with environmental licensing.

Failure to comply with any conditions, restrictions, requirements and environmental control measures defined by the environmental agency as conditioning factors may lead to the suspension or cancellation of the licenses related thereto, without prejudice to civil, administrative and, in certain cases, criminal liability.

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[117] The concept of social technology (ST) ('*Tecnologias Sociais*' in Portuguese) was developed in Brazil during the decade of 2000. Although there is no official definition for this concept, it can be defined as a way to design, develop, implement and manage technology oriented to solve social and environmental problems. In more practical terms, STs are understood as products, techniques or methods that have a low cost and can be replicated, developed and/or applied in interaction with a community, which represent social transformation solutions through the sustainable use of local resources. Examples of STs are: small rainwater harvesting cisterns for domestic use and larger ones for backyard garden irrigation, ecological stoves (*eco-stovess*), farm water reservoirs (*trench barriers*), household greywater treatment systems (*biowater reuse system*), underground dams. (FERNÁNDEZ, L. et al. Synergies and trade-offs between climate change mitigation and adaptation strategies: lessons from social technologies in the semiarid region of Bahia, Brazil, Latin America. **Latin American J. Management for Sustainable Development,** v. 3, n. 1, p. 1-18, 2016; and REDE-DE-TECNOLOGIA-SOCIAL, Ed. **Tecnologia Social e Desenvolvimento Sustentável: contribuições da RTS para a formulação de uma política de Estado de Ciência, Tecnologia e Inovação**. Brasília, DF: Secretaria Executiva da Rede de Tecnologia Social (RTS)ed. 2010.

a) Environmental licenses or permits

The Conama Resolution nº 237/1997 establishes all the steps that must be followed in the licensing process (art. 10) and defines the environmental licenses to be issued by the competent environmental agency, namely the Preliminary Licenses - LP, Installation - LI and Operation - LO (art. 8th).

The LP is granted in the preliminary phase of the project planning, where the environmental agency approves, through mandatory prior inspection, the location and design of the project, certifies the environmental viability from the analysis of possible environmental impacts and establishes the basic requirements and conditions to be met in the next phases (art. 8th, I).

After analyzing the specifications contained in the plans, programs and projects presented, including the environmental control measures and compliance with the conditions established in the LP, the environmental agency will issue the LI, authorizing the installation of the project (art.8th, II).

Finally, the LO will be granted after the verification of the effective compliance with the conditions of the previous licenses, authorizing the operation of the project (art. 8, III), after verification of the effective compliance with what the previous licenses determine, such as the control measures. conditions and conditions determined for the operation.

It is emphasized that it is essential to observe the conditions, restrictions, requirements and environmental control measures required by the environmental agency as conditions in the licenses, given that their failure to comply may result in the cancellation of the license, civil and administrative liability and, in certain cases, criminal liability.

In addition to the licenses provided for in Conama Resolution number 237/97, the licensing process also requires the issuance of authorization for the capture, collection and transportation of fauna; land use certificate; authorization for vegetation suppression; authorization for archaeological prospecting and salvage and reserve of water availability/granting the right to use water resources, among others.

In this context, an emergency measure has been taken by every state of the semiarid stating that all infrastructure works and activities aimed at mitigating the effects of droughts are either exempt from the environmental licensing process or have a simplified licensing mechanism in place. The following activities considered in the project are exempted from environmental licensing:

- Construction and installation of cisterns, dams and other equipment for the abstraction and retention of water of any kind, shape or model.
- Implementation of irrigated production systems using micro sprinkler or drip technology in areas of up to 1 ha (one hectare),
- Installation and recovery of wells up to 50 m deep, as well as artificial reservoirs, dams or barriers, with up to 2 ha of the water surface;
- Purchase of animals with health certificates issued by the responsible bodies
- Works and services of soil correction;
- Construction of fences, corrals and machine sheds;
- Agricultural and livestock activities carried out in dry regions that are not subject to irrigation, will be exempt from environmental licensing according to the State Laws in the semiarid.

The activities contemplated in the project must comply with the following regulations at the federal and state levels:

Bahia

According to Law 10,431/2006, undertakings and activities necessary to mitigate the environmental, social and economic effects of an emergency or public calamity resulting from drought shall follow a specific procedure for simplified environmental licensing. The application for the simplified environmental licensing should be addressed to the Institute of Environment and Water Resources – INEMA.

Ceará

The State Council for the Environment- COEMA, through resolution No. 01 of February 2018 establishes a review of the procedures for Simplified Environmental Licensing for emergency works required to cope with drought in the State of Ceará. The State Superintendence of the Environment – SEMACE will proceed to the analysis of the framework of the application of the Resolution COEMA Nº 10 of June 11, 2015.

Paraiba

According to the administrative standard Nº 125 of 2015 issued by SUDEMA (Paraíba's environmental authority), cisterns, small dams and public works considered goods of common use - such as desalination facilities, are exempt from environmental licensing process provided they do not involve further deforestation or environmental degradation.

Pernambuco

Decree No. 38146 of 2012 establishes procedures for the Simplified Environmental Licensing of emergency works necessary to confront drought in the State of Pernambuco. The State Agency for the Environment - CPRH will analyze the framework of the application.

Piauí

The Secretariat of Environment and Water Resources - SEMAR will analyze the framework of the application of Decree No. 14921 from 2012 which regulates the Simplified Environmental Licensing for the same activities mentioned above.

Rio Grande do Norte

Institute of Sustainable Development and Environment of Rio Grande do Norte -IDEMA, through Ordinance No. 55 of 2013, resolves the activities and circumstances under which a Simplified Environmental Licensing applies.

Sergipe

The Council of Environment of the State of Sergipe- CEMA / SE will analyze the framework of the application of Administrative Standard. 01/2009.

3.2.6 Climate Change

In 2015, Brazil submitted its Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC). Brazil is committed to reducing greenhouse gas (GHG) emissions by 37% below 2005 levels by 2025 and, as a subsequent indicative contribution, to reducing GHGs by 43% below 2005 levels by 2030. The Government of Brazil (GoB) is committed to the implementation of its NDC, including full respect for human rights and the rights of vulnerable communities, indigenous peoples, traditional communities and workers in sectors affected by corresponding policies and plans, and are promoting gender-sensitive measures. The Federal Government is equally committed to achieving its NDC targets as it works to eliminate extreme poverty and reduce inequality. A large part of the NDC target is based on reducing emissions from deforestation and degradation (REDD).

The NDC goals reaffirm some prior Brazilian commitments and update others. Indeed, most of the Brazilian targets are already embedded in existing laws and national plans. Including them in the NDC is essential to inform the international community about Brazil's ambitions to strengthen and consolidate these policies in domestic debates and to attract investment to meet the goals.

The NDC's goal of restoring and reforesting 12 million ha (7 million ha of tree plantation plus 5 million ha of restoration) will be accomplished by complying with its Native Vegetation Protection Law ("Forest Code"), and the subsequent National Plan for Restoration of Native Vegetation (PLANAVEG). According to the Forest Code, some set-aside areas - e.g. Legal Reserves (*Reservas Legais - RLs*) and Permanent Preservation Areas[118] (*Áreas de Preservação Permanente - APPs*) – for conservation can be sustainably harvested and include the partial use of exotic species, such as pines and eucalyptus, interplanted with native species, which could mitigate the cost of restoration and even provide profits. The implementation of PLANAVEG should contribute to the achievement of this commitment, regarding the recovery of the native vegetation of APPs and RL and areas of low agricultural productivity.

PLANAVEG applies the same logic used to define the national recovery goal of 12 million ha to regionalize this amount among the six Brazilian biogeographic regions. The values indicate that most of the defined recovery goal is concentrated in the Amazon and Atlantic Rainforest (76%), while the *Cerrado* represents 17%, the *Caatinga*, 4% (500,000 ha), and the remaining 3% divided among the *Pantanal* and *Pampa*. PLANAVEG recognizes that in the family agriculture context, "the implementation of agroforestry systems for the composition of Legal Reserves can also contribute to food security, nutrition, income, health, shelter, social cohesion, energy resources, and environmental sustainability." Other relevant instruments of the Forest Code are the Environmental Rural Registry (*Cadastro Ambiental Rural - CAR*) and the Environmental Compliance Program (*Programa de Regularização Ambiental – PRA*).

The social dimension is at the core of Brazil's adaptation strategy, bearing in mind the need to protect vulnerable populations from the adverse effects of climate change and enhance resilience. In this context, Brazil is working on the design of new public policies, through its National Adaptation Plan (*Plano Nacional de Adaptação à Mudança do Clima – PNA*), in its final elaboration phase. The active involvement of stakeholders, at all levels, will contribute to the formulation and implementation of Brazil's National Adaptation Plan.

In this context, the country National Adaptation Plan puts forward cross-sector adaptation strategies to address the wide range of risks that climate change is creating and is the means to implement the adaptation aspect of the National Determined Contribution. The National Adaptation Plan also will establish guidelines to implement adaptive measures to increase climate resilience in 11 sectors and themes.

The NDC presents the strengthening of the Low Carbon Emission Agriculture Program (*Plano ABC – Agricultura de Baixa Emissão de Carbono*) as the primary strategy for sustainable agriculture development and commits to restoring 15 million ha of degraded pasturelands, enhancing 5 million ha of integrated cropland-livestock-forestry systems and restoring and reforest 12 million ha of forests by 2030. The ABC Plan is one of the sectorial plans devised under the National Policy on Climate Change. Its overall objectives are: reducing greenhouse gas emissions in agriculture; improving the efficiency in the use of natural resources; increasing the resilience of production systems and rural communities; and promoting adaptation to climate change in the sector. One of the main instruments of the policy is the National Plan of Agroecology and Organic Production (*Plano Nacional de Agroecologia e Agricultura Orgânica – PLANAPO*), known under the name of 'Agroecological Brazil', conceived with the participation of various sectors of civil society.

3.2.7 Other Related Projects and Programs in the Semiarid

The sections above show that the federal government has instituted, over the last 25 years, several policies and programs designed to support family farmers, and before the economic crisis, there was a significant reduction in poverty in rural Northeast Brazil. States and municipalities, as well as NGOs, also have implemented projects and programs to strengthen family agriculture, many of which are in partnership with international funding organizations (IFAD, World Bank, European Union, Inter-American Development Bank, Global Environmental Fund). However, there is a clear gap in programs to support family farmers in a transition into more climate-resilient agriculture in the semiarid, considering that most of the recent and on-going initiatives mainly focus on poverty reduction. The current project seeks to integrate the climate policies with water management and poverty alleviation programs to improve ecosystem services and support family farmers in the adaptation to climatic change.

[118] APPs are mandatory on hilltops, steep slopes, coastal shrublands, mangroves, wetlands, around springs, and along watercourses and reservoirs.

- BNDES initiatives

Over the years, the primary financial support provided by BNDES to States for family agriculture has been for the Northeast region with non-reimbursable funds from the BNDES Social Fund. There are on-going projects in seven states of the region - Alagoas, Bahia, Ceará, Maranhão, Paraíba, Piauí, and Sergipe. Most of them support collective family farming economic arrangements (cooperatives and associations) which are focused on production processing and marketing.

Regarding water harvesting and storage techniques and structures, BNDES has already provided support for the installation of 24,000 large cisterns (the model for production) in nine States of the Brazilian Semiarid. Another 6.8 thousand large water cisterns are planned. One-third of the benefited families are also assisted by the Program for the Promotion of Rural Productive Activities (*Programa Fomento Rural*) of the Ministry of Citizenship.

BNDES, in partnership with Banco do Brasil Foundation (*Fundação Banco do Brasil – FBB*), have already financed seven agroecology, 'extractivism', and organic production networks in the Northeast. Currently, two selection processes are underway within the Ecoforte Program for Strengthening and Expansion of Agroecology, Extractivism and Production Networks (*Programa de Fortalecimento e Ampliação das Redes de Agroecologia, Extrativismo e Produção Orgânica - Ecoforte*), which involves various governmental agencies, as well as several organizations, form the private sector. BNDES has also provided financial support for the implementation of 3,300 Integrated and Sustainable Agroecological Production (*Produção Agroecológica Integrada e Sustentável – PAIS*) units, in partnership with NGOs pf the semiarid region.

BNDES Social Fund resources have been used, through the AP1MC association *(Associação Programa 1 Milhão de Cisternas – AP1MC)*, to install 440 community seed-banks. This initiative aims to reinforce existing community practices of self-organization that help maintain local biodiversity (including crop biodiversity).

A partnership between BNDES and Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA*) was established to implement the InovaSocial Program. It aims to contribute to the productive inclusion of family farming through the strengthening of farmer networks focused on: i) the production, processing, and marketing of goat and sheep products, ii) rescue, preservation, multiplication, storage, distribution and commercialization of agroecological seeds.

The Productive Semiarid Project (*Projeto Semiárido Produtivo*), executed by the Regional Institute of Small Agriculture (IRPAA), is also being implemented in the Northeast region with the support of BNDES's Social Fund. The initiative has the goal of structuring productive family units for processing and commercializing products from family farming to promote and spread practices of coexistence with the Semiarid environment[119].

- IFAD's work

IFAD has been operating in the Northeast of Brazil since 1978. Currently, the agency's finance portfolio sums US$ 450 million, reaching 350 thousand families with six projects. IFAD has 5 State projects in Piauí, Ceará, Paraíba, Sergipe, and Bahia. A sixth project is implemented in partnership with the Secretariat of Family Farming and Cooperativism (*Secretaria da Agricultura Familiar e Cooperativismo*) of the Federal Government. It refers to the second phase of Dom Helder Câmara Project and covers 11 states - Minas Gerais, Espírito Santo and the 9 States of the Northeast.
These projects support the productive structuring of family units through nom-reimbursable investments. The beneficiary families receive technical assistance services (TAS) for two to three years, aiming at strengthening organizational and technical capacities according to the principles of agroecology. The main supported

[119] The phrase 'coexistence with the semiarid' of the region refers to a set of different networks, local ideologies and actions, having as a common trait the attempt to help vulnerable communities to adapt themselves to living under semiarid climate conditions. Most of the strategies proposed and developed within this movement involve the use of ST, considering that traditional or more elaborate technological solutions are not appropriate for the social, environment and economic context of the semiarid region. (FERNÁNDEZ, L. et al. Synergies and trade-offs between climate change mitigation and adaptation strategies: lessons from social technologies in the semiarid region of Bahia, Brazil, Latin America. **Latin American J. Management for Sustainable Development,** v. 3, n. 1, pp. 1-18, 2016.)

productions are those of the Brazilian semiarid: cashew and other native fruits (such as *umbú, licuri, caatinga passion fruit, cajá, mangaba*), beekeeping, the breeding of small animals (sheep, goats, pigs and poultry), including the production and storage of fodder, and the production of vegetables and medicinal plants in irrigated gardens. IFAD financed projects have also included the structuring of cooperatives for the creation and strengthening of processing units with both physical investments and capacity building (administrative, financial and commercial).

These projects also finance the installation of water access social technologies, such as production cisterns with cemented catchment areas, trench water tanks, underground water barriers, graywater reuse equipment.

Since 2011, IFAD has funded the Semear Program, whose primary objective is knowledge management. The activities carried out have allowed the identification of good practices, and the dissemination of the results and methodologies used. Numerous exchanges and learning initiatives have been organized mainly in the Northeast region. Some South-South cooperation activities with other Latin American and African countries also allowed knowledge sharing between farmers and technical staff involved in the project.

Most of these projects have provided support for the construction of processing units (processing of fruit, milk, honey, cassava, among other products) usually conducted by cooperatives. Whenever these units have idle capacity, the technical teams are responsible for connecting project beneficiaries to these cooperatives and existing units to add value to production and improve market access conditions. With this same perspective, family farming fairs or markets were structured in local towns and constitute a fundamental form of direct sale and weekly marketing of *in natura* of fruit, vegetables, honey, poultry, eggs, medicinal plants, and cheeses. The project is responsible for inserting the beneficiaries in these fairs for income improvements. Women's involvement is essential in these fairs and related production processes. Thus, this initiative is strategic for ensuring they have direct access to better revenue.

These projects have left a remarkable legacy on at least three levels. First, impacts are clear within state secretariats that adjusted their knowledge and experience, becoming familiar with the procedures for implementing such projects. Private and public technical assistance, or rural advisory services[120], providers also accumulated experiences and practice. In most cases, this second group of actors got involved in field implementation initiatives. These organizations can be mobilized again because of their strong and updated capacities on specific themes. Finally, these projects also allowed the strengthening of farmers' communities and families who received productive investments, training, and technical assistance services. They are now more prepared than other farmers to use social technologies and different types of actions financed by the Project.

The activities carried out by these other projects and programs will be considered for the selection of beneficiary municipalities, seeking to optimize the complementarity of resources and avoiding overlap.

- Other initiatives

There are also several non-governmental initiatives that develop climate-smart agriculture. We will mention the 'Intelligent and Sustainable Agroclimatic Modules Program' (*Programa Módulo Agroclimáticos Inteligentes e Sustentáveis – MAIS*), financed by the Proadapt fund and other donors, has worked on community-based adaptation strategies and helps family farmers develop a more resilient agriculture in the Jacuípe Basin, a semiarid region of the State of Bahia[121]. The program has engaged about 650 farmers, increasing their production by 63% and their income by 204%. In addition, more than 3 tons of CO_2 emissions can be offset for each restored pastureland. A second initiative that deserves mention is the FAO and Environment Ministry (*Ministério do Meio Ambiente – MMA*) REDESER (small scale) project, working with GEF funding, that is working on ways to reverse desertification process through agroforestry practices and productive systems[122].

[120] The term 'Rural Advisory Services' includes technical assistance for agriculture and animal husbandry, and goes beyond, including other necessary advisory services. (ADOLF, B. **Rural Advisory Services Worldwide**. Lindau, Switzerland: GFRAS, 2011. Available at: http://www.g-fras.org/en/knowledge/gfras-publications/file/6-rural-advisory-services-worldwide).

[121] From the UNFCCC website: https://unfccc.int/climate-action/momentum-for-change/financing-for-climate-friendly-investment/mais-program-climate-smart-agriculture.

[122] See FAO website at: http://www.fao.org/brasil/noticias/detail-events/pt/c/1073924/.

We will also refer to other well established agroecological initiatives, fostered by NGOs, that have developed different types of 'climate-resilient production systems'. For example, Centro Sabiá has worked on agroforestry systems in the state of Pernambuco, while PATAC and AS-PTA have provided support to family farmers to develop their own resilient systems in Paraíba State. One recent interesting example is the 'Cotton in Agroecological Intercropped Plots Project' (*Projeto Algodão em Consórcios Agroecológicos*), that is being implemented by a group of NGOs working in different states, with the financial support of the C&A Foundation and the Porticus Foundation. The 'agroecological intercropped plot' initiative that produces certified organic cotton, as well as other food crops, was started by the IFAD-funded Dom Helder Camara Project (Phase 1) several years ago[123].

The proposed Project will build upon previous work by strengthening and expanding climate-resilient productive models, along with nurseries and seedbanks, improving the availability of suppliers and building knowledge networks of farmers practicing agriculture adapted to the current and expected climate conditions. It also brings a fresh look at rural youth and technology integrating climate adaptation measures with water management and income generation to improve ecosystem services and support the vulnerable population in overcoming climatic stressors.

[123] SANTIAGO, F. et al. Algodão em consórcios alimentares agroecológicos: Uma experiência de desenvolvimento sustentável no Semiárido nordestino. In: BALSDI, O.; CRUZ, M. D., *et al* (Ed.). **Transferência de tecnologia e construção do conhecimento**. Brasília (DF): Embrapa, 2013. p.249 - 283.

4. THE ADAPTATION SCENARIO, WITH THE PLANTING RESILIENCE IN RURAL COMMUNITIES OF THE BRAZILIAN SEMIARID PROJECT

The resilience of the target households depends on reliable access to both food and water, and without these landscape restoration activities, under conditions of climate change, these households will face increasing water and food insecurity, which would eventually render their livelihoods unsustainable.

The **Planting Climate Resilience in rural communities of the Northeast (PCRP)** will work towards shifting the prevailing paradigm, assuming it is possible to transform family farmers' productive systems in the semiarid, enabling an increase of their production while simultaneously improving their capacity to face the challenges posed by ongoing climate change. The project's primary goal will be to transform present-day farming systems, to attain resilient and productive systems performing restored ecosystem functions, which in turn, will both increase and stabilize family income and food security while incentivizing young generations to remain active in agricultural activities. The partnership between IFAD, GCF and the Government of Brazil (GoB) through a major national Bank (BNDES) will mobilize resources and disseminate lessons too many levels of government, as well as to other regions in Brazil and abroad.

4.1 Theory of Change

The PCRP aims to achieve the following goal: If family farmers in the semiarid NEB transform their productive systems, then they will be able to increase production while improving their autonomous capacity to face the challenges posed by ongoing climate change, because the adoption of climate resilient practices will result in farming systems that perform restored ecosystem functions. These systems will have climate change adaptation and mitigation benefits, increasing and stabilizing family income and food security while incentivizing young generations to stay active in rural activities. The PCRP will work with the most marginalized and vulnerable groups of the poorest region in Brazil. The partnerships between IFAD, GCF, and Government of Brazil and BNDES will mobilize resources and disseminate lessons to many levels of government in other regions in Brazil and abroad.

The climate stressors and vulnerability sources (described above) result in a number of climate change impacts. The predominant farm production of monocultures and top-down application of static technological packages are clearly not resilient to these impacts, as presented above, and are a driver of deforestation and land degradation. Historically, the government response to climate stress in NEB has focused on conventional solutions such as dams, wells, and diversion of waterways. Such investments are expensive, may not reach family farmers or respond to their needs, and do not increase farmer's autonomous capacity to face further climate shocks. Hence, the PCRP proposes to implement diversified agricultural systems that provide farmers with the knowledge and tools to increase their own resilience at the family and producer's organizations level, allowing the most vulnerable to absorb climatic shocks without overt reliance on large infrastructure projects or external emergency response measures. The selected development pathway responds equally to the climate stressors affecting the region and the socioeconomic context of family farming in NEB. In that context, the socioeconomic criteria used to define the most adequate climate resilient practices are the following: (a) low-cost, given the limited capacity farmers have to spend and make investments, (b) can be implemented by workforce available to family farmers, (c) provide a guarantee of acceptable production and income, (d) contribute to GHG emission reductions, (e) have low or minimal environmental impact (Category B or C), (f) promote the inclusion of women, youth and traditional communities, and (g) can be scaled up.

The project will consist of three components that reinforce one another to promote climate resiliency as well as emission mitigation: 1) Climate Resilient Productive Systems (CRPS); 2) Water Access for production; and 3) Knowledge Management and Scaling-Up.

Implementation of diversified agroforestry systems that will increase local water availability in the productive system -CRPS-CRPS, as proposed under Component 1 (Output 1.1), will influence hydrological conditions across the landscape. The Caatinga is a rich productive area, with fertile soils, where temporary streams and wetlands exist, making up a biome with good capacity for agricultural production, provided that adapted vegetation is used, with adequate arrangements and techniques appropriate to the levels of humidity and solar radiation. Activity1.1.4 will provide a supportive network for farmers to exchange best practices, stimulate entrepreneurship and innovation as well as foster active leadership of women and youth.

The water access solutions proposed in Component 2 (Output 2.1), such as rainwater harvest and storage, if accompanied by the current agricultural model, may be temporarily palliative – subject to severe water loss due to high evapotranspiration from heat and wind – but productivity would remain limited. In fact, water investments in the semiarid must be complemented by soil recovery practices promoted in Component 1, to allow infiltration of rainwater, increase soil biomass rate, create shade and wind shelters to reduce evapotranspiration (which can exceed 2,000 mm/year). The specific flora and fauna in the semiarid have developed a high capacity to access and store water (in roots, trunks, stems and leaves), resulting in a biota capable of supplying more water than needed for growth and reproduction, adding surplus water to the system. The first years of the CRPS implementation are the most vulnerable, so output 2.1 will increase the availability of water in the system, reducing impacts of droughts, while the system is still fragile.

Knowledge management, policy dialogues, communication, and monitoring and evaluation (M&E) activities under Component 3 (Output 3.1), meanwhile, will allow the investments under Components 1 and 2 to be sustainable and scaled up to other states in the region and dryland areas, including other countries, resulting in the intended paradigm shift in approaches to climate adaptation and mitigation.

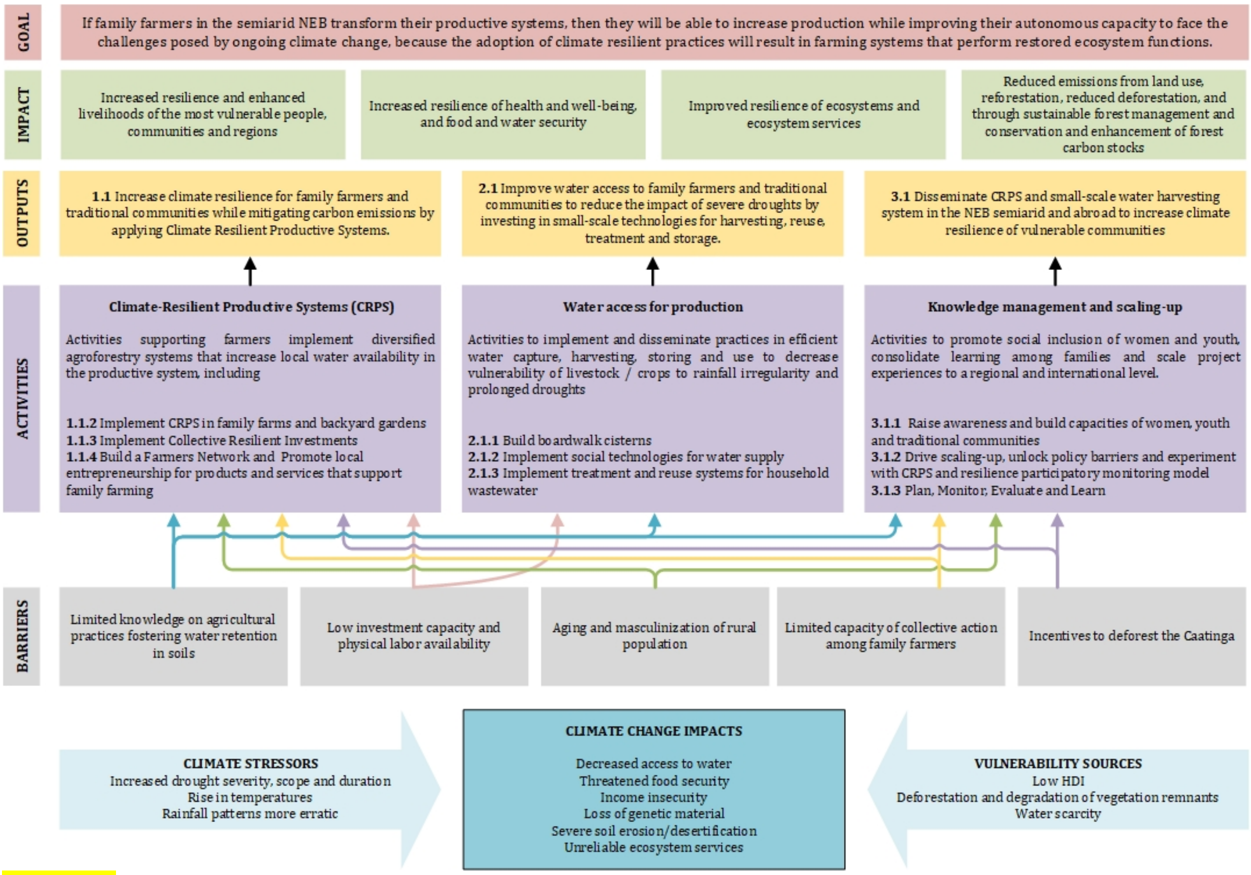

Figure 42. Theory of Change (Source: Developed by IFAD).

The Theory of Change (TOC) in Figure 42 shows that the project was built considering the existing vulnerabilities as well as potential climate change impacts. The activities were designed to overcome the barriers family farmers face in shifting their agriculture, animal husbandry, and extractive productive activities to one characterized by promotion of dense, stratified and diversified systems (CRPS), farmer-led technology development, and active leadership from women and youth, thereby enabling farmers to build resilience capacities and adapt effectively to the impacts of climate change.

The project's youth and gender transformational focus ensure greater opportunities for women and youth in all three components. Participation of traditional, indigenous and afro-descendant (quilombola) communities will also be prioritized.

4.2 Proposed alternatives

4.2.1 Project proposal design parameters

During the Project design process, IFAD promoted different forms of stakeholder consultation, including field visits, meetings with various institutional stakeholders, as well as a full-sized consultation workshop. IFAD also organized a brainstorming process with the Project design team on this issue. This process discussed different facets of the Project's design. One crucial point was the choice of technical proposals, considering the institutional, informational, regulatory, behavioral, technological, engineering, financial aspects.

In order to choose the set of proposals the Project will work with, that will help adapt to the climate signals and reduce vulnerability drivers identified above, as well as mitigate climate change emissions, a set of design parameters were used. These parameters consider the barriers to change discussed above (section 3.1), as well as other important references, such as their environmental impact.

Note that IFAD's target beneficiaries are always the most vulnerable group, the poorest of the poor. Given this target beneficiary, the Project's main design parameters are:

- Low-cost solutions

One of the key barriers that bolster the present status quo refers to the limited capacity farmers have to spend and make investments. Because of this, the Project proposes to implement alternatives that are low cost to install and maintain and that, in this domain, could be replicated easily by other family farmers.

- Can be implemented by workforce available to family farmers

As seen above, the demographic dynamics in the region, which includes an important migratory contingent of young people as well as an aging population, mean that family labor is becoming scarcer. In addition, the hardship involved in this type of work, often of a manual nature, is another factor that makes labor availability more restricted. Therefore, the solutions proposed by the Project must not require a large amount of labor in their implementation or operation. They must be simple enough to be replicated by other family farmers. In Brazil, these are called "social technologies".

- Provide a guarantee of acceptable production and income

As stated in the section describing the context, the current crisis in the production systems of the northeastern semiarid region means that both agricultural and livestock production are declining. In addition, extreme events (such as droughts) are responsible for significant losses. Therefore, the productive proposals worked by the Project must guarantee an acceptable agricultural production while reducing risks from extreme droughts.

- Environmental impact within Category B or C

Although specially selected for their adaptation functions, most of these measures will also contribute to CC mitigation by reducing GHG emissions, avoiding carbon emissions and promoting sequestration. None of the solutions will have significant and lasting negative social and environmental impacts.

- Promote the inclusion of women, youth and traditional communities

Considering the present situation in which rural women and youth of the semiarid region have access to fewer opportunities, the Project deems it is absolutely necessary to engage youth and women. One way to do this is by making the agricultural activity more interesting and intellectually challenging, as well as making it more productive for these specific groups. In this sense, Project proposals features and characteristics must be such that they favor access and implementation by women and youth. In the case of traditional communities, the chosen technical proposals must also respect their specific needs, requirements and possibilities.

4.2.2 Project's proposals

Seeking to increase the resilience of farming families to the conditions created by climate change, the Program will work with an agro-ecosystem approach to promote the adaptation of family and community production and subsistence units to these new conditions. This approach will lead the Project to work primarily with Climate Resilient Productive Systems (CRPS), through the implementation of:

a) Water collection and storage at household level, allowing the multiplication of other productive proposals such as CRPS, nurseries, etc.

b) CRPS (in dryland situation), seeking to diversify and 'complexify' (in order to multiply the number of tree, shrub and herbaceous species present) the production systems to maximize biomass production and soil cover. It is understood that these new 'more complex' systems will favor soil conservation as well as soil moisture retention while also allowing better water management in the production system. They should also allow the growth and diversification of plant and animal production, thus contributing to higher food and nutritional security and increasing the income of beneficiary families.

c) Within the framework of the implantation of CRPS, special attention will be given to sustainable management in wider areas of *Caatinga* (where they exist), often under collective / community management, to maximize the use of their products. such as fodder, fruit, honey, etc. In these cases, 'ecological' stoves and biodigesters may also be implemented as a way of reducing the pressure on the *Caatinga* vegetation.

d) Community seedbanks will be encouraged to ensure diversity of local genetic material.

e) The implementation of CRPS backyards, seeking to enhance the production of food, forage, medicinal herbs and also animal production for greater food security and income generation.

f) Installation of pilot biosaline production units at the desalination plants in operation.

For implementing these specific alternatives listed above, as well as for overcoming the several barriers already mentioned, the Project will need to also work on the following dimensions:

g) strengthening the different forms of organization of the beneficiary population in order to build capacity, promote greater autonomy and expand the ability to do work in family units and in the community;

h) supporting the initiatives of the families served regarding market and capital access;

i) creating conditions so that some schools in the region can fully incorporate the focus of maximum adaptation and resilience CRPS in their youth formation agenda;

j) encourage the development of tools and services that will decrease the labor burden of the family farming activities;

k) promoting dialogue and advocacy in pursuit of the creation/strengthening of public policies that can support the dissemination of adaptive and resilient systems;

l) promoting the communication of the results of efforts to implement adaptive and resilient systems, with a view to spreading knowledge about them to other regions, states and countries.

4.2.3 Technical analysis of the Project's proposed alternatives

The climate stressors and vulnerability sources result in a number of climate change impacts. The predominant farm production of monocultures and top-down application of static technological packages are clearly not are not resilient to these impacts. FAO[124] (based on IPCC)[125] classified practices to improve farmer's climate resiliency into: integrated nutrient management, improved agronomic practices, tillage and residue management, water management, and agroforestry. These practices are often referred to as Climate Resilient Agriculture, and can consist of several methods, arrangements, and technologies. What climate resilient is in one biome or production system may not apply to another. Climate challenges are also varied in any given geography, and adaptation solutions depend on volume of the area and resources available to the farmer. Thus, given the vulnerabilities, ecosystem characteristics and potential changes in climate, climate resilient agriculture for family farmers in the Brazilian semiarid translates into practices that increase availability, flow and retention of water in the system. Pragmatically, it means simultaneous implementation of the following practices and principles, (which are hereby denominated CRPS): (i) soil preparation: maintenance of dispersed trees, setting up cradles and natural fertilization; (ii) soil protection: soil cover and biomass production with resilient plant varieties; (iii) water management: capture and storage (both in soil and vegetation), level curves and terraces; (iv) planting: stratification, diversification and densification with herbaceous, shrub and tree species maximizing photosynthetic capacity; (v) management: active pruning and thinning; and (vi) Grazing: pasture rotation, fences and silage.

While CRPS practices have the potential to yield sustainable land-management benefits and increase production, they require a significant change in habits, culture and investments. GCF support will enable farmers to take a longer-term perspective in anticipation of the significant financial, economic and livelihood benefits achievable through the application of adaptation measures relative to the declines in production and income that are anticipated to result from the effects of climate change. It responds to the urgency that climate change projections give to the application of these practices, and recognizes that for them to function effectively as adaptation measures, they must be applied as part of a larger-scale program and be calibrated and adjusted based on the specific needs, priorities and cultural context, both at the regional and family-productive-units levels.

These principles are interlinked and their benefits are synergic, meaning they must be implemented together. Assembling an agricultural system with these elements makes it a water producer, not a consumer, which is the correct approach for a region with low water availability. Table 1 below presents the direct adaptation benefits that each principle provides to the family farmer. In addition, CRPS will provide higher diversity and availability in food, diversity of income streams that can buffer against climate and market shocks as well as induce a net farm output/yield income stability, increase availability of food and incomes, reduce carbon emissions and improve ecosystem services.

Table 3. Principles and practices of climate-resilient production systems in the Semiarid

Practices / Adaptation Benefits	Retain soil moisture	Recharge soil moistue	Increase organic matter in soil	Increase photosynthesis	Increase soil carbon	Capture water	Capture humidity in air	Improve microclimate	Reduce erosion
(i) Soil Preparation: Maintenance of dispersed trees, micro-valleys and natural fertilization	X		X	X				X	X
(ii) Soil Protection: Soil cover and biomass production with resilient plant varieties	X		X		X	X	X		X
(iii) Water retention: level curves and terraces		X				X			X
(iv) Planting: Stratification, diversification and densification			X	X		X		X	X
(v) Management: Active pruning and thinning;				X				X	
(vi) Grazing: Pasture rotation and fences.			X	X	X				X

As suggested in the previous section, the Project proposes to support the implementation of technical proposals to increase the resilience of family production units. This implementation of innovative plans should assist in

[124] Branca G, McCarthy N, Lipper L, Jolejole MC. Climate Smart Agriculture: A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits for Improved Cropland Management. Rome, Italy: Food and Agriculture Organization; 2011, pg. 1–42.

[125] IPCC. 2007. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Chapter 8-Agriculture. Climate Change 2007: Mitigation. Cambridge, United Kingdom and New York, NY, USA Cambridge University Press.

the configuration of Climate Resilient Production Systems (CRPS), thus contributing to the improvement of the management of productive units mentioned here. These proposals will be discussed briefly in the following paragraphs.

Resilient agrosilvopastoral systems (in dryland situation)

The implementation of CRPS will be achieved by the simultaneous application of the following management principles and practices:

(i) Specific soil preparation, eliminating burning, maintaining pre-existing trees and preparing 'cradles' to retain more moisture (when necessary) and use of organic fertilizer;
(ii) Soil protection through on-site biomass production with resilient plant varieties and their application to maximize soil cover;
(iii) Water management, with specific initiatives aimed at its collection and storage (both in soil and vegetation), through contours and terraces and the planting of plant species that have the characteristic of storing water;
(iv) Construction of a suitable 'architecture' or 'structure' for the system by diversification, high-density planting and stratification. This requires a right choice of the species to be planted, including herbaceous, shrub and tree species in order to maximize the photosynthetic capacity of the plot;
(v) Agrosilvipastoral management, through practices such as pruning and thinning, seeking to eliminate senile plants and stimulate the vegetative vigor of the set; and
(vi) Forage management of the system, which will require the implementation of fences (to control grazing), as well as the performance of collection practices and eventually forage processing, to be provided to the herds. For details, see APPENDIX I.

There are many types of systems that fit the definition above. Some may be simpler, with fewer species. Others may be more complex, with high biodiversity and intensive management. The actual shape depends on the local situation in terms of available environmental resources (soil type, existing vegetation, rainfall, etc.), farmers familiarity with crops, markets, area availability or family needs and choices.

The implementation of these systems will allow a very significant increase in the number of trees, shrubs and herbaceous species in a given plot or area, boosting biomass production and ensuring better soil cover. These more "complex" production systems will stimulate photosynthesis and carbon fixation, promote soil conservation, and retain soil moisture, allowing for better water uptake and conservation, which will make these systems more resilient to soil temperature increase and higher variability of precipitation caused by ongoing climate change. The expansion and diversification of crops and livestock in these areas will provide greater food and nutritional security while allowing beneficiary household income to grow and provide a buffer against climate stressors.

The Project will encourage farmers to apply resilient production principles and practices to establish various types of CRPS. Given the characteristics of the Semiarid, supported resilient systems - especially those in rainfed conditions - should be deployed and managed to increase system availability, flow, and retention.

Figure 35 Agroforestry of forage production in the dry season - Sertão de Pernambuco.

In the Semiarid region the animal component of the systems is essential. Practically all families raise at least some ruminant heads, be they goats, sheep or cattle. For this reason, forage production is always an essential element, sometimes being the farmer's priority. Thus, concrete examples of agroforestry systems implemented in family units combine annual food and fodder crops with perennial plants that also provide human food (fruits, for instance), fodder, and other products (such as wood, firewood, fiber, honey, etc.). Over time, this combination may change, reducing the space available for short-cycle crops, and with tree species becoming more important.

The Centro Sabiá and *Caatinga* entities, which work in the semiarid region of Pernambuco, conducted a survey of 15 families that work with already consolidated agroforestry systems. Some of the results of this research are very useful as they allow the characterization of these systems. All systems surveyed are multispecies, having incorporated several shrub and tree species. But the diversity of shrubs and trees is not homogeneous: while the case with the least variety had 7 species of this type, there was a system with 41 species of woody plants. Of the 22 most common shrub and tree species for the 15 surveyed cases, 14 were fruit trees (cashew, mango, cashew, orange, guava, etc.). Of the remaining 8, there are some exotic species that are at the same time "fertilizers" (for being leguminous) and forage: these are *gliricidia*, *leucena* and *moringa*. The most popular native trees were the thrush, the *catingueira* and the *canafistula*. These three native species are forage, having other uses as well.

This research presents production data from only one case, shown in the following table.

Table 4 Production of the agrosilvipastoral system of the family of V and S, Sertão do Araripe (PE), for the year 2014[126]

Products	Amount
Harvest Products	
Beans (macassar beans, fava beans, *guandú*)	90 kg
Grains (corns)	100 kg
Cucurbitaceae (*jerimum*, pumpkin)	150 kg
Roots (manioc)	1,000 kg
Livestock Products	
Poultry (chickens – meet)	20 kg
Poultry (chickens – eggs)	104 dozens
Vegetables	
Lettuce, arugula, tomatões, cilantro, chives, string beans, etc. (18 types)	Approximately 100 kg
Fruits	

[126] GONÇALVES, A. L. R.; MEDEIROS, C. M. D.; MATIAS, R. L. A. D. **Sistemas agroflorestais no Semiárido brasileiro: estratégias para combate à desertificação e enfrentamento às mudanças climáticas**. Recife, PE: Centro Sabiá - Caatinga, 2016. 136 p.

Papaya, passion fruit, Orange, acerola, banana, cashew, cajá, etc. (30 types)	Approximately 3,000 kg
Other Products	
Seeds, seedlings, fodder, firewood, native fruits for processing (*cambuí* and *murta*) and flowers.	--

These data do not inform the area's productivity since the surface occupied by the system does not appear. But they are useful for presenting very clearly the great diversity of products it provides to the family.

This research was also interested in analyzing the capacity of these systems to produce biomass and fix carbon. The study of the 15 selected systems showed that carbon accumulation ranged from 6.8 to 50.6 metric tons per hectare throughout its implementation, which corresponds to approximately 36 to 186 metric tons of CO2 equivalent. The average is 78 metric tons of CO2 equivalent. These figures highlight the importance that agroforestry systems can have in mitigating greenhouse gases in *Caatinga*.

Another study recorded the experience of a farming family from the Cariri region of Ceará. It studied the perception of the family about the various types of results obtained with an agroforestry system of just over 3 hectares with approximately 10 years of existence. The following table summarizes perceived results.

Table 5 The Perception of Economic and Environmental Results after SAF Implementation (Sítio Tabuleiro - CE)[127]

Dimension	Results
Environment improvement	- Favorable microclimate - Presence of birds and other wildlife - Advantages of working in the shade - No pests
Soil improvement	Ground cover (Burlap)
Short-cycle Crops	Corn, macassar beans (*Vigna unguiculata*), fava beans, various vegetables.
Fruit cultivation	In total, there are 23 fruit species, including acerola, mango, cashew, *umbú*, orange, guava, banana, etc.
Forage cultivation	Palma (*Opuntia sp.*), elephant grass (*Pennisetum purpureum*)
Presence of native woody species	A total of 19 species of this type were recorded, including *angico, sabiá, catingueira*, *pereiro, fava d'anta, aroeira*, etc..
Other tree species	Leucaena

It should be noted that this system includes an important animal component. This herd is fed with fodder and other food harvested in the area and provided. This way, the family raises a flock of 30 goats (confined), pigs and birds (60 free-range chickens). In addition, the household also produces and sells fruit pulp and earns a small income from 'rural tourism' as a result of the frequent visits they receive[127].

CRPS backyards

Virtually every family unit in the semiarid NEB has a backyard. These productive backyards, often located around the family home, are already part of the traditional semiarid peasant systems. In the more conventional format, these backyards can be characterized by a certain diversity of species. They are almost always closely linked to a water source, even if precarious that allows irrigation. The fundamental objective of these systems, which are located near the residence, is to contribute to the sovereignty and food and nutritional security, the health and well-being of the family. Women often play a crucial role in maintaining and managing backyards, which we can call agroforestry or CRPS[128].

More recently, innovations have been introduced in the semiarid region that has allowed these backyards to evolve into a model of resilient agroforestry backyards. Some innovations, such as the installation of production tanks or gray water reuse systems, as well as new agroecological cultivation techniques (including systematic soil cover, a significant increase in the diversity of cultivated species, a substantial increase in tree presence, the introduction of economical flower beds, organic fertilization via compost, earthworm humus, etc.) have shaped this new backyard model, which can also be characterized as an agroforestry system or, more precisely, as a CRPS. The frequency of irrigation, the proximity of the house and the leading role of women farmers are elements that characterize these spaces, distinguishing them from the dryland agroforestry systems, treated in the previous section.

This CRPS backyard, often also called an agroecological or agroforestry yard, comprises the production of food crops (vegetables, roots, etc.), fruits, medicinal and ornamental plants, spices, fodder. It combines herbaceous, shrub and tree species. It also includes the raising of small animals (mainly birds), which derive most of their food from backyard crop production. Given these characteristics, the implementation of these agroforestry yards also follows the defining principles of resilient systems mentioned above.

Currently, these yards are spreading throughout the Semiarid region, thanks to the efforts of several entities that support sustainable development in the region. In this list, it is worth mentioning several projects that were financed by IFAD, such as the People of Value Project (BA), the Sertão Project, among others. The P1 + 2 Program, along with the implementation of Social Water Collection and Storage Technologies, is also working on the implementation of agroecological backyards.

These renewed subsystems have been very interesting in terms of production and productivity. Recent research, still unpublished, notes that "although they occupy proportionally small portions of the territorial

[127] SILVA, T. T. D.; DRUMOND, M. A.; BAKKE, I. A. (2014) and SILVA, T. T. D. et al. (2014), as in foot-notes 125 and 126 above.
[128] MICCOLIS, A. et al. **Restauração Ecológica com Sistemas Agroflorestais: como conciliar conservação com produção. Opções para Cerrado e Caatinga.** Brasília: Instituto Sociedade, População e Natureza – ISPN/Centro Internacional de Pesquisa Agorflorestal – ICRAF, 2016. 266 p.

extensions of agroecosystems, domestic (agroforestry) yards produce, on average, 34% of the aggregate value generated by the agricultural work of families. Just over half of this amount (51%) was converted into monetary income, and the remaining was consumed by families."

We will cite here the case of a family from the municipality of Santa Filomena, in the *Sertão* of Pernambuco. This family received a drinking water tank as well as a production tank. Over time, it set up agroforestry backyard. In a 2014 visit, it was possible to identify 69 plant species in the backyard, including vegetables (coriander, lettuce, peppers, etc.), medicinal plants (pomegranate, holy grass, etc.), fruit (orange, acerola, pine cone, etc.). This yard produces food for the family, but also allows the commercialization of various products, such as the 50kg of guava that, in the same year 2014, was sold by the family in their own community. There is also the case of a farmer from Sertão do Pajeú, who, after calculating the production, sales and costs of her backyard production activities, concluded that the "income generated by the commercialization of food grown in the backyard (...) reaches about a minimum wage per month." And this researcher reports that the positive relationship between female farmer, income and productive yard appeared in virtually all interviews conducted with female farmers in this research.

Caatinga Sustainable Management Areas

The Project will implement larger areas of collective sustainable management of *Caatinga* to achieve the full potential of its products and restore ecosystem services. The integration of native forests into traditional production systems favors the maintenance of forest cover in large rural areas, allowing what could be called 'sustainable landscape management'.

It is possible to classify in this category the system known as the Sustainable Agrosilvipastoral Model SAF-Sobral, which was developed by EMBRAPA Caprinos e Ovinos (with its headquarters in Sobral - CE). This model, which includes agricultural crops, animal husbandry (mainly goats and sheep) and use of *Caatinga* products, attaches primary importance to sustainable *Caatinga* management practices, with the aim of ensuring sustainability to the use that families traditionally make of these areas, restoring them and protecting the Biome's soils, waters, and biodiversity.

The fencing of the area and other intervention techniques in the natural vegetation - lowering, thinning and enrichment - that are part of this system seek to promote the regulation of grazing and generate more fodder for the animals (sheep, goats and cattle), potentiate flowering, thus benefiting beekeeping, and optimizing the regeneration of the *Caatinga* vegetation, making the areas more productive in terms of forage and supply of cuttings, firewood, fruits and seeds.

The Sertão Project (GEF-FIDA-MDA) worked with this practice. It monitored the economic results of *Caatinga* management in 2013 and the data identified an annual income of an equivalent (at the time) value of \$ 3,330 /hectare/year per household with meat, honey, cuttings, firewood and medicinal plants. This performance was considered quite positive given the low rainfall that year. A study by EMBRAPA indicates that this system, when compared to conventional land use, yields 50.6% more in terms of household income, employing 25.9% more labor. On the other hand, it uses only 26% of the conventional system area for the same number of animals[129].

[129] ARAÚJO FILHO, J. A. et al. Sistema de Produção Agrossilvipastoril no Semiárido do Ceará. 2nd International Conference: Climate, Sustainability and Development in Semiarid Regions. Fortaleza, Ceará 2010.

Figure 36 **Areas of managed *Caatinga*, in the rainy season and the dry season, Ceará.**[130]

Initiatives called *recaatingamento* (which originated with the IRPAA's Recaatingamento Project), aimed primarily at preserving and restoring the *Caatinga* of *Fundos de Pasto.* They closely resemble the SAF Sobral system, incorporating the same general principles of resilient systems and many of the practices advocated by the Sobral system. The starting point of this proposal is the isolation of the area (by the implantation of fences) to allow effective management of the herds (starting this management by the total exclusion at first) and some interventions (called hydro environmental actions), such as the stone bushes, which deal with soil management with the aim of reducing soil losses and obtaining higher retention of the scarce rainwater that falls in the region. ‘Techniques of environmental restoration', which aim to accelerate the recovery processes of the *Caatinga* vegetation, are also implemented.

Other actions associated with these will seek to increase the productive potential of these areas. Thus, for example, more native fruit trees (such as *umbú*) will be introduced, which will take advantage of the fact that the areas will be with no animals for a while to be able to settle properly. Over time, these fruit trees will increase the yield of the areas. The development of a herd and *Caatinga* management plan should be formulated and implemented by the communities served, seeking to balance the extractions made from *Caatinga* with its regeneration and conservation needs.

Parallel economic activities such as meliponiculture, poultry farming and the processing of *Caatinga* fruits may also be supported, seeking to provide other complementary sources of income derived from ruminant breeding. Finally, some other investments should be associated with this type of intervention, such as 'ecological stoves' and biodigesters, which should be implemented in the homes of families using these areas, with the aim of reducing the use of *Caatinga* firewood.

Selection, storage and guaranteed availability of climate-resilient crop seeds with community seed banks

Over the years, farming in the semiarid region has suffered a dangerous process of genetic erosion of agricultural seeds. Genetic erosion is the term used to name better the process of disappearance of Creole seeds, added to the critical regression of accumulated knowledge and peasant culture from generation to generation on the subject.

In recent decades, the conventional ways of seed entry into the region have not been locally based. This process has led to a scenario of dependence on external seeds, which, for the most part, are inadequate to the semiarid climatic reality. With the abandonment of their own seeds, the family farmers start depending on the seed market to produce their own food, so that without money they could not cultivate the land. As a result, farmers often missed the first rains that were considered strategic for a good harvest. This reality has resulted in the weakening of family farming, creating dependency and demotivating farming families.

In this context, the Community Seed Banks (or Houses) social technology proposes to create a collective space in which family farmers can rescue old practices of preservation, multiplication and selection of seeds adapted

[130] ARAÚJO FILHO, J. A. Manejo pastoril sustentável da caatinga. Recife, PE: Projeto Dom Helder Camara, 2013. 200 p.

to the region. It also serves as an educational space, where the exchange of experiences takes place, and a reference in the context of strengthening family farming and preserving biodiversity.

Seed Houses operate through the deposit and loan system. Members meet, establish the group's demand seed quantity and variety, and stipulate the amount each member must deposit to begin work. At the time of planting, the partners will have the right to borrow seeds for planting their fields. The stock is controlled through local coordination, using control sheets (membership registration, receipt and inventory control).

Community Seed Banks are organizational structures that provide adequate access to quality seeds at the right time for planting. They act as reserve buffer stocks in the ongoing process of coping with times of adverse weather. They also act as a space for mobilization and debate in the construction of a proposal for a harmonious and sustainable coexistence with the semiarid reality. Community banks also function as a strategic grain storage space for the food and nutritional security of families, especially during the most significant periods of food scarcity, caused by the full use of family stocks. Without them, households used to borrow food from individuals and had to repay 100% after the following year's harvest.

Biosaline production

While the challenge of agriculture (including irrigation here) in arid lands is not new, the increase in soil salinity and especially water scarcity are the main climate change-related stresses for agriculture worldwide, particularly in developing countries. In this context, biosaline agricultural production has been presented as a strategic possibility to enable animal and plant production in arid and semiarid regions of the world.
In the Brazilian semiarid, it is very common for groundwater to be brackish or salty. This happens most often in regions where the substrate is crystalline (which, as seen in section 2.4.2 above, represents approximately 80% of the semiarid area). The result of this is that a substantial percentage of the wells dug in the Semiarid have brackish or saltwater, unfit for human consumption. Thus, a study by the Geological Survey of Brazil Mineral Resources (CPRM), within the scope of the Northeast Water Infrastructure Registry Project, investigated the sources of supply for tubular wells located in the semiarid of the Northeast, encompassing eight states of the Northeast, the north of Minas Gerais and Espírito Santo. The survey, carried out in 450 municipalities of the Semiarid, collected samples from 15,338 wells. This study revealed that only 25% of the wells registered in this area have freshwater (<500 mg/l TDS). It also revealed that 33% had brackish water (501 to 1500 mg/l TDS), while the remaining 42% had saltwater (> 1,500 mg/l TDS). In some localities, the proportion of salty wells is even higher. In the municipality of Boa Vista, state of Paraíba, in a sample of 78 wells surveyed, only 17% had small to moderate salinity waters. In the remaining 83%, there was severe salinity[131].

This situation has left many communities and families in an extremely delicate situation regarding access to water, starting with human drinking water. This situation became particularly critical during the 'great drought' which began in 2011. This context formed the foundation for the action of the Fresh Water Program (PAD), which seeks to “promote access to good quality water for the human consumption, incorporating technical, environmental and social care in the management of desalination systems, mainly in diffuse rural communities in the Brazilian semiarid region.” By December 2018, the PAD had already installed 508 desalination plants in as many communities in the Brazilian semiarid region.[132]

Installing a desalination plant in a community creates a *sui generis* situation where this equipment produces, in addition to a certain amount of drinking water (suitable for human consumption), a relatively large amount of ‘concentrate’ (or tailings), which is water with a considerable concentration of salts. It should be noted that the ‘concentrate’ salinity logically depends on the salt content of the original water from the well. However, the salinity of the tailings will always be higher than that of the well water. A survey conducted in the municipality of Pentecost in CE showed that the salinity increase in residual water, when compared to that of the well water of origin, can vary from 20 to 41%[133].

[131] FARIAS, D. S. C. R.; FARIAS, S. A. R.; DANTAS NETO, J. **Indicação de plantas para irrigação das águas com teores elevados de sais na região de Boa Vista-PB**. Congresso Técnico Científico da Engenharia e da Agronomia CONTECC’2016. Foz de Iguaçu, PR 2016.
[132] The broad ojective of this program is to build 1,200 desalination equipements. Available at: http://noticias.ambientebrasil.com.br/clipping/2017/12/09/140672-programa-agua-doce-planeja-2018.html).
[133] NEVES, A. L. R. et al. Aspectos socioambientais e qualidade da água de dessalinizadores nas comunidades rurais de Pentecoste-CE. **Ambiente & Água - An Interdisciplinary Journal of Applied Science,** v. 12, n. 1, p. 124 - 135, 2017.

This situation makes it essential to use this ‘concentrate’ in order to maximize the use of a scarce resource (water) while minimizing the problems that its accumulation (of concentrate or tailings) and an improper destination of this ‘concentrate’ could cause[134].

Under these circumstances, the PAD recommends that tailings to be used in various ways, seeking to take advantage of the concentrate as a resource; thus, preventing it from becoming an agent of environmental degradation. PAD also proposes that the concentrate is used primarily in animal and vegetable production. The Technical Guidance Manual directs that ‘tailings’ be used to provide[135]:
- water for animals;
- irrigation for halophyte plants (*strictu sensu* biosaline agriculture);
- fish farming.

The present Project will have the task of deploying 24 biosaline production units, which should try to combine the three uses of concentrate above. This combination should be created or designed on a case by case basis as it will depend on the availability of water/concentrate (and its characteristics) as well as the needs and preferences of families/communities.

Research already conducted in the Semiarid indicates that, in fact, the ideal combination of waste-producing activities should include the three forms of use mentioned above.[136] In addition to its own product (fish), fish farming adds a significant amount of organic matter and nutrients, which is very useful for crop production to be irrigated with the modified concentrate. However, it is known that fish farming is a very complex activity, extremely demanding in its technical management. In addition, the fish farming option requires a significant amount of water (from concentrate), which requires the well flow to be high and the desalination to work longer hours per day, which is not always possible. As a result, the vast majority of the Project's biosaline production facilities will focus on water for animals and 'biosaline' agriculture.

- *Water for animals*

Since animal husbandry is an important activity throughout the semiarid region and given that these animals have a tolerance to salinity (see table below), the supply of tailing water to the herd will certainly be very common in the communities in which desalination plants work.

Different documents/authors place the tolerance limit of species of animals at different levels. Thus, a recent document from the Fresh Water Program (PAD) states that beef cattle would tolerate up to 10,000 mg/l TDS, while for sheep the limit would be 12,800 and for goats 17,000 mg/l TDS. However, other sources (see table 3 below) place the limits at much lower levels. In general, waters with TDS levels between 7,000 and 10,000 mg/l should only be provided to herds (cattle, sheep and goats) in very exceptional situations.[137,138,139]

The literature states that a goat or sheep head consumes, on average, approximately 3 liters of water per day. [140] For adult cattle, this consumption is around 50 liters/day. [141] Considering the hypothetical existence, in a community, of a herd of 300 head of goats and sheep plus 50 head of cattle, from the above values, it is estimated that this herd would consume approximately 3,400 liters of water daily. Assuming that there are no

[134] For instance, the high concentrations of salt turn this residue into a potential soil salinization agent.
[135] In addition to these uses in animal and vegetable production, the Manual suggests that 'concentrate' can have 'domestic use' (such as for sanitary discharges). (BRASIL-MMA-SECRETARIA-DE-RECURSOS-HÍDRICOS-E-AMBIENTE-URBANO. **Orientações Técnicas dos Componentes do Programa Água Doce para Implantação dos Sistemas de Dessalinização**. Brasília, DF: MMA - Secretaria de Recursos Hídricos e Ambiente Urbano. Available at: https://www.srh.ce.gov.br/wp-content/uploads/sites/90/2018/07/aguadoce_orientacoes_tecnicas_22jun15rev.pdf: 70 p. 2015).
[136] The Embrapa Semiarid research center - located in Petrolina, in the middle of the semiarid region of Pernambuco - has been researching, since the early 2000s, the theme of integrated production systems using 'desalination effluent' (PORTO, E. R. et al. **Sistema de Produção Integrado Usando Efluentes da Dessalinização**. Petrolina, PE: Embrapa Semi-Árido, 2004. 22 p.).
[137] ARAÚJO, G. G. L. et al. A água nos sistemas de produção de caprinos e ovinos. In: VOLTOLINI, T. V. (Ed.). **Produção de caprinos e ovinos no Semiárido**. Petrolina: Embrapa Semiárido, 2011. p.69-93.
[138] BAGLEY, C. V.; AMACHER, J. K.; POE, K. F. **Analysis of water quality for livestock.** Logan: Utah State University Extension - Electronic publishing, 1997. Available at: https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=https://www.google.com.br/&httpsredir=1&article=1105&context=extension_histall.
[139] RUNYAN, C.; BADER, J. Water quality for livestock and poultry. In: AYERS, R. S. e WESTCOT, D. W. (Ed.). **Water quality for agriculture**. Rome: FAO, 1994.
[140] ARAÚJO, G. G. L. et al. A água nos sistemas de produção de caprinos e ovinos. In: VOLTOLINI, T. V. (Ed.). **Produção de caprinos e ovinos no Semiárido**. Petrolina: Embrapa Semiárido, p.69-93, 2011.
[141] PALHARES, J. C. **Estimando o consumo de água de suínos, aves e bovinos em uma propriedade** Concórdia, SC: Embrapa Suínos e Aves 2005.

other sources of water for animals in the community, the herd could consume a relatively large part of the 'waste' produced by the desalination (depending on the amount produced daily).

Table 6 A Guide to the Use of Saline Waters for Livestock and Poultry[142]

Total Soluble Salts Content of Waters = (mg/l or ppm)	Comment
Less than 1,000 mg/l (1670 umhos/cm or 1.67 dS/m)	These waters have a relatively low level of salinity and should present no serious burden to any livestock or poultry.
1,000 - 2,999 mg/l (1.67-5.00 dS/m)	These waters should be satisfactory for all classes of livestock and poultry. They may cause temporary and mild diarrhea in livestock not accustomed to them, or watery droppings in poultry (especially at the higher levels), but should not affect their health or performance.
3,000 - 4,999 mg/l (5.00 – 8.35 dS/m)	These waters should be satisfactory for livestock, although they may cause temporary diarrhea or be refused at first by animals not accustomed to them. They are poor waters for poultry, often causing watery feces and (at the higher levels of salinity) increased mortality and decreased growth, especially in turkeys.
5,000 - 6,999 mg/l (8.35-11.70 dS/m)	These waters can be used with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid the use of those approaching the higher levels for pregnant or lactating animals. They are not acceptable waters for poultry, almost always causing some type of problem, especially near the upper limit, where reduced growth and production or increased mortality will probably occur.
7,000 - 10,000 mg/l (11.70 – 16.70 dS/m)	These waters are unfit for poultry and probably for swine. With 7,000-10,000 mg/l, considerable risk may exist in using them for pregnant or lactating cows, horses, sheep, the young of these species or for any animals subjected to heavy heat stress or water loss. In general, their use should be avoided, although older ruminants, horses, and even poultry and swine may subsist on them for long periods of time under conditions of low stress
More than 10,000 mg/l - (16.70 dS/m)	The risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.
35,000 mg/l - (58.45 dS/m)	Brine (sea water)

- *Biosaline Agriculture*

Biosaline agriculture is a broad term that describes agriculture conducted under a series of saline levels in water or soil, or a combination of both. A very important tool in the management of soils and waters affected by salt is the cultivation of plants capable of living in saline environments - halophyte plants. Many applied studies investigate the potential of halophyte species to be usefully used in arid and semiarid regions. Within a universe of approximately 2,600 known species of this type, various uses and impacts are possible. In general terms, some species have greater economic potential for human consumption, forage production, wood and raw materials (fibers, etc.); others have pronounced ecological potential due to their function in soil desalination, dune fixation, etc.

Thus, as stated above, the choice of which plants to be cultivated is what demands the most attention when it comes to biosaline agriculture. Unfortunately, many very common food crops - such as common bean (*Phaseolus vulgaris*), corn, and sesame - are quite sensitive to salinity and cannot be incorporated into a biosaline farming logic. But there is an important variety of plants that are capable of growing under saline soil and water conditions. Other plants, which some researchers call true halophytes, grow better in a saline environment than in the absence of salinity. In general, these species also allow the removal of salts from saline soils.[143]

It turns out that many of the saline environment plants represent a food resource for livestock. At the lowest salinity levels (<15 dS/m), both legumes and grasses tolerant to these salinity levels are able to provide 5 to 10

[142] BAGLEY, C. V.; AMACHER, J. K.; POE, K. F. **Analysis of water quality for livestock.** Logan: Utah State University Extension - Electronic publishing, 1997. Available at: https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=https://www.google.com.br/&httpsredir=1&article=1105&context=extension_histall.
[143] HASANUZZAMAN, M. et al. Potential Use of Halophytes to Remediate Saline Soils. **Journal of Biomedicine and Biotechnology**, n. 2014, p. Available at: https://www.researchgate.net/publication/263845331_Potential_Use_of_Halophytes_to_Remediate_Saline_Soils 2014.

t of edible dry matter (DM) per year, particularly when the availability of water is high. At high salt concentrations (> 25 dS/m), yield levels decrease, and plant options also decrease significantly. However, even at these high salinities, there are a variety of halophyte grasses and shrubs that can produce a good amount of edible MS per year.[144]

Worldwide, research is awakening to the issue of biosaline agriculture or halophyte agriculture. As has already been said, it is known that there are many plants already grown - food, fodder, wood, etc. - that have tolerance for relatively high levels of salinity. In Brazil, however, research on this topic is still quite recent. The Embrapa Semiarid research unit has been at the forefront of this field. Seeking to better understand the potential of biosaline agriculture for the semiarid region, researchers at this Center have been working on biosaline agriculture since the beginning of the 2000s. These surveys took into account the scarcity of good quality waters in the Semiarid to be used for irrigation. But the main motivation for this work was the challenge posed by the 'concentrate' of desalination plants that have been installed in the region since the 1990. The results of these surveys show that the main use of saline irrigated areas should be for forage production, taking into account the profile of the species that best develop under regional conditions (soil types, irrigation water type, etc.) and also considering the fact that ruminant breeding is an important economic activity throughout the region. An important part of this research has focused on the choice of saltgrass (*Atriplex nummular Lindl*.). In the tests carried out in the Brazilian semiarid, this shrub, originating from Australia, has allowed obtaining a very interesting production of good quality forage. In addition to this use, it is very important to highlight another feature of this plant: it absorbs a significant amount of salts from the soil, being considered a plant phytoextractor of salts[145] [146]. In this context, there is already research in Brazil on the potential of salt grass as a plant for salinized soil recovery [147].

On the other hand, there are already researches, implemented by Embrapa Semiarid and the National Institute of Semiarid (INSA), which are testing, under different salinity conditions, other plants better known to farmers, such as sorghum, palm forage, gliricidia (*Gliricidia sepium*), leucena (*Leucaena leucocephala*), and moringa (*Moringa oleifera*)[148,149], always considering forage production with some form of irrigation. Although none of these species behaves with the same resourcefulness shown by salt grass in high salinity situations, several of them have interesting tolerance levels, although none is what was defined above as a 'true halophyte'. These tolerant species should allow the cultivation of intercropping areas in many situations. More recent research also points to the possibility of producing seedlings of native *Caatinga* species, as the tolerance to salinity of seeds of several of these species has been proven.[150]

But cultivating an irrigated plot under the conditions mentioned above requires, in addition to a careful choice of plants to be cultivated, special attention to the practices used. Some aspects stand out in this domain. The first concerns the choice of soil type: it is important to use light soils and to avoid very shallow soils[151]. It is also relevant to use organic fertilizer generously. Finally, the irrigation system and management should allow crops to be supplied with only the water that is strictly necessary, and in such a way that it can be used to the fullest extent possible by cultivated plants (seeking to reduce direct soil evaporation). This causes the Fresh Water Program (PAD) to choose the localized irrigation system called '*xique-xique'*.[152]

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[144] MASTERS, D. G.; BENES, S. E.; NORMAN, H. C. Biosaline agriculture for forage and livestock production. **Agriculture, Ecosystems and Environment**, n. 119, p. 234 - 248, 2007.

[145] Phytoextraction uses plants that have a high rate of salt accumulation, preferably in the aerial part, in order to facilitate their removal from the area when the plant is harvested (Pequeno et. Al. 2014, cf reference below).

[146] PEQUENO, O. T. D. L.; SILVA, J. L. B. C. D.; BRASILEIRO, I. M. D. N. Fitoextração de sais através de estresse salino por Atriplex nummularia em solo do Semiárido paraibano. **Revista Saúde e Ciência,** v. 3, n. 3, p. 37 - 52, 2014.

[147] Id. ibidem.

[148] CAVALCANTI, R. S. T.; CAVALCANTI, M. L. C.; COELHO JR., L. M. C. Manejo do solo e água com o uso da agricultura biossalina: uma nova tecnologia para o Semiárido Pernambucano. III Simposio Nacional de Estudos para Produção Vegetal no Semiárido - SINPROVS, 2018. Campina Grande, PB. Anais SINPROVS, 7 a 9 de maio de 2018.

[149] SILVA, R. H. D. **Crescimento de palma forrageira irigada com água salina**. 2018. 65 p. (PhD). Programa de Pós-Graduação em Zootecnia, Universidade Federal de Viçosa.

[150] DANTAS, B. F. et al. Germinative metabolism of Caatinga forest species in biosaline agriculture. **Journal of Seed Science,** v. 36, n. 2, p. 194 - 203, 2014.

[151] SILVA, J. L. D. A. et al. Uso de águas salinas como alternativa na irrigação e produção de forragem no semiárido nordestino. **Revista Brasileira de Engenharia Agrícola e Ambiental,** v. 18, n. Suplemento, p. S66 - S72, 2014.

[152] The xique-xique system is a localized irrigation system for the application of water through perforated pipes, with a maximum hole diameter of 1.6 mm, with a distance of 20 cm between holes, often used in vegetable crops. For other crop types (eg fruit trees) the hole spacing will depend on the crop spacing (COELHO, E. F. et al. **Sistemas de irrigação para agricultura familiar** Cruz das Almas, BA: EMBRAPA Mandioca e Fruticultura, 2012. 7 p.).

Taking into account the above, the systems to be implemented by the Project will be inspired by those designed by the PAD. The installation of these systems should meet some minimum requirements regarding well flow and 'concentrate' production[153]. Respecting these requirements, in the agricultural sector, an area of approximately 0.5 hectares will be installed (which may be larger if water availability permits), close to the desalination plant and with appropriate soil type. The plant should take into consideration the particular desalination nature of the cultivated area and should be under the management of the local community entity (association, etc.) that has the responsibility to take care of the mentioned equipment. This cultivated area should allow the local organization to produce and sell the fodder produced or to establish another community form of use. As we saw in the previous paragraph, a *'xique-xique'* irrigation system will be installed. Following what has been researched about this topic, the main crop to be planted in this area will be saltgrass (*Atriplex nummularia*), which will have the purpose, besides producing fodder, to control soil salinity, ensuring the sustainability of the system. Following the principles that underlie the Project's Climate Resilient Production Systems (or CRPS) (see beginning of section 4 above), here too we will seek to diversify what will be planted in this plot by carefully choosing other plants that are tolerant to salinity, which occupy another stratum complementary to that of salt grass. Thus, seedlings of some *Caatinga* trees should be planted in this area, as well as gliricidia (*Gliricidia sepium*) and leucena (*Leucaena leucocephala*). The product of this irrigated parcel shall be fodder for the herd.[154]

Proposals aiming at greater energy efficiency:

i) Eco-stoves.

The wood stove is a traditional item of homes in rural Semiarid. The facility of burning wood, the economy of gas and the special taste of the food are some of the reasons for the preference for this type of stove.

However, farming families face some difficulties in continuing to use this type of stove:
- Getting firewood has always been hard work, which traditionally falls to women. But in recent years, they have to walk further and further to gather firewood. If it is hard work to go far, it is even worse bringing the weight back home.
- Another common problem is that wood stoves emit a lot of smoke in the kitchen environment, which ends up damaging family health, especially of women who are dealing with kitchen tasks every day.
- The third problem is that the use of firewood is a factor that contributes to the deforestation of the *Caatinga*.[155]

The efficient green stove seeks to solve those problems. There are several models of eco-efficient stoves in use in the Semiarid region, all of which work based on a better use of the heat generated by wood burning.

To illustrate and detail the above, we will take here the example of the eco-stove model that has been disseminated by the Institute for Sustainable Development and Renewable Energy (IDER). The stove is divided into a metal base, a chimney and refractory bricks that concentrate the heat in the three stove spreads and the upper plate. There are two entries with the function of inserting the wood and removing the ashes respectively. As we can see in the picture below, the hot air (in red) follows a single flow towards the burner and the chimney. The lid of the compartment where the firewood is placed must be closed during the entire period of use of the stove and should be opened only if additional firewood needs to be added to prevent the flow from going the other way.[156]

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[153] The Fresh Water Program Base Document states that a well with a flow rate of 3,000 L / hour and desalination operation for 8 hours a day, 7 days a week should produce sufficient amount of 'concentrate' to dissent a herd, raise fish. and irrigate a plot of 0.6 hectares.

[154] As previously stated (footnote 169), research conducted in the Brazilian semiarid region indicates a yield of 10.8 tons / hectare of dry matter (SILVA, J. R. R. et al. **Produção de erva-sal cultivada em diferentes espaçamentos e irrigada com rejeito de dessalinizadores no semi-árido**. 46a. Reunião Anual da Sociedade Brasileira de Zootecnia. Maringá, PR: Sociedade Brasileira de Zootecnia 2009.), which may be considered a yield compatible with many irrigated forages with non saline water (O'LEARY, J. W. A critical analysis of the use of Atriplex species as crop plant for irrigation with highly saline water. In: AHMAD, R. e SAN PIETRO, A. (Ed.). **Prospects of biosaline research**. Karachi: Karachi University, 1986. p.416 – 432; and PORTO, E. R. et al. **Sistema de Produção Integrado Usando Efluentes da Dessalinização**. Petrolina, PE: Embrapa Semi-Árido, 2004. 22 p.).

[155] AS-PTA. **Fogão ecológico. Pequeno manual de construção**. Esperança, PB: AS-PTA, 2014. Available at: http://aspta.org.br/wp-content/uploads/2014/11/Manual-de-Constru%C3%A7%C3%A3o-do-Fog%C3%A3o-Ecol%C3%B3gico.pdf.

[156] IDER. **Fogões ecoeficientes. Manual de construção**. Fortaleza: Instituto de Desenvolvimento Sustentável e Energias Renováveis (IDER); Associação Caatinga; Projeto Clima na Caatinga. Sem data. Available at: http://www.terrabrasilis.org.br/ecotecadigital/pdf/fogoes-eco-eficientes-manual-de-construcao.pdf.

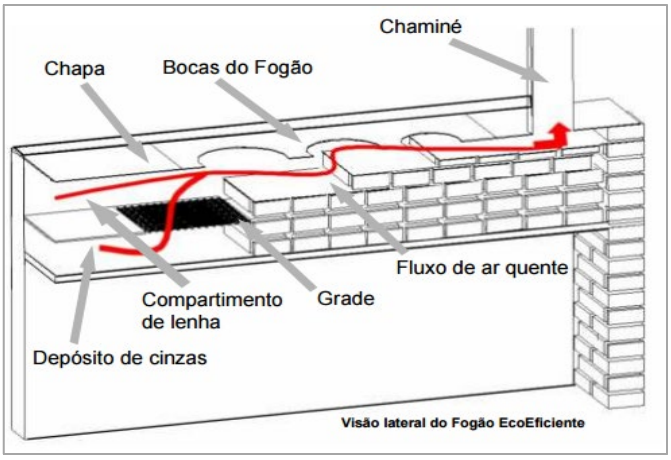

Figure 37 Eco-efficient Stove Structure.[157]

To build an eco-efficient stove, you need to use basic construction equipment, water to wet the cement and the following materials:

- 1 iron frame with embedded plates;
- 1 3" high iron pipe (chimney);
- 1 chimney cap;
- 2 bags of 25 kg refractory cement;
- 70 10x20x5cm refractory bricks

The cost of an eco-efficient stove varies greatly depending on the type, location, etc. For instance, the estimated cost of an eco-efficient IDER stove mentioned above is approximately US$ 200.[158]

Since the practice of using firewood for cooking is common in the semiarid region, several agencies, public and private, have introduced eco-efficient stoves (or eco-stoves) in the region for over 15 years, seeking to reduce the consumption of firewood. The Sertão Project / Dom Helder Camara Project (funded by GEF, IFAD and MDA) was one of these projects. Thanks to its intervention, approximately 760 eco-stoves were installed in various Semiarid Territories. The People of Value Project (an IFAD partnership with the Government of Bahia) also worked with eco-stoves.

Figure 38 Stove installed and in operation.[159]

[157] IDER, (Sem data), as in foot-note 182 above.
[158] See websites: https://tribunadoceara.com.br/noticias/ceara/familias-de-baixa-renda-da-zona-rural-receberao-do-governo-do-estado-fogoes-ecoeficientes/ e https://www.casacivil.ce.gov.br/2011/05/04/familias-da-zona-rural-receberao-7089-fogoes-ecologicos/.
[159] IDER (Sem data), as in foot-note 183 above.

A study conducted within the framework of the Sertão Project mentioned here pointed out the following advantages of eco-stoves: reduction in wood consumption by approximately 55% - which provides a reduction in pressure on the *Caatinga* ecosystem -, improvement of health conditions of the family by reducing smoke emission, besides allowing a monetary saving for the family, with the reduction of the gas purchase[160]. This lower consumption of firewood is estimated to provide an equivalent reduction in GHG emissions.

It is worth mentioning another example of this kind of larger action in Ceará, where the Institute for Sustainable Development and Renewable Energy - IDER - supported the installation of 26,500 eco-stoves, from 2007 to 2012. There are also other such initiatives working in the Semiarid, such as those of the NGOs AS-PTA and PATAC in Paraíba. However, the sum of these efforts still does not reach many families, and it is necessary to increase the volume and the pace of this action. Currently, eco-stoves of various models are available, including for purchase on the market. However, the cost and expertise required to install this type of stove make it necessary for an initiative like this Program to multiply the number of households with this appliance.

ii) Biodigesters

As explained in the previous section on eco-efficient stoves, unsustainable domestic use of firewood and also coal is a major cause of *Caatinga* deforestation. Many rural families have already adopted gas stoves - Liquefied Petroleum Gas or LPG, thus fossil fuel instead of renewables, due to deforestation that leads to difficulty in obtaining firewood. If before the use of wood or charcoal meant at least the autonomy of resources in the property, the adoption of LPG as an energy source has currently represented a factor of dependence on rural families in the region. The replacement of firewood and charcoal by LPG, therefore, impacts on the domestic economy and is a concern for certain families.

The implementation of biodigesters answers these questions positively. Biodigesters use manure as the raw material for biogas production. This input is produced on the property where they are installed. This maintains the family's autonomy from the main domestic fuel. In addition, simple maintenance does not compromise the other activities of the production unit. Biogas volumes, combined with its properties, meet the demand with quality and efficiency.

The Sertão Project (GEF-FIDA-MDA) and other action organizations for sustainable development also worked with the installation of biodigesters. These equipments are not new in Brazil. They were introduced to the country based on models from China and India. The model used by various entities (including Project Sertão and the NGO Diaconia), nicknamed Sertanejo Biodigester, is inspired by the Indian model but adapted to the reality of the Brazilian Semiarid Region.[161]

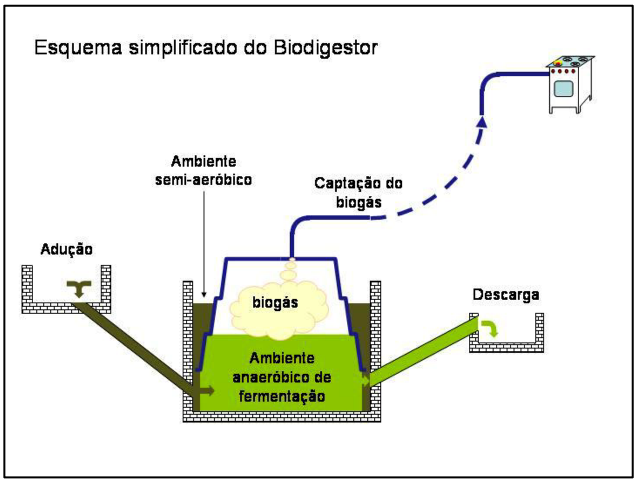

Figure 39 Schematic representation of the Sertanejo Biodigester[162]

[160] REGUEIRA, T. M. Comparação entre a eficiência de dois modelos de fogão a lenha e seus impactos sobre ao desmatamento da caatinga. 2010. 26 p. Monografia (Bachalerado em Ciência Biológicas com ênfase em Ciências Ambientais). Centro de Ciências Biológicas, UFPE, Recife, PE.
[161] MATTOS, L. C.; FARIAS JR, M. **Manual do biodigestor sertanejo**. Recife: Projeto Dom Helder Camara, 2011. 55 p.
[162] MATTOS, L. C.; KREHBIEL, J. Impacto de um biodigestor domiciliar na economia de emissões de gases de efeito estufa em uma propriedade da agricultura familiar do Cariri Paraibano. In: FARIAS SEABRA, G.;NOVAES DA SILVA, J. A., *et al* (Ed.). **A Conferência da Terra: Aquecimento global, sociedade e biodiversidade.** João Pessoa, PB: Editora Universitária da UFPB, v.III, 2010. p. 315 - 323.

As can be seen from figure 37, the Biodigester Sertanejo is composed of three main parts: in a first adduction box or load, the manure mixed with water is placed. Fermentation of the biogas-producing manure (biomass) takes place in a circular tank made of cement slabs that are covered with a capsized 3,000-liter fiberglass box through anaerobic digestion of bacteria, resulting in biogas production. From the discharge box comes the nutrient-rich biofertilizer and organic fertilizer, the end result of fermentation of animal manure. The biogas is stored in the fiberglass box, where it is led by hoses to the kitchen of the house[163].

Figure 40 Sertanejo Biodigester [164]

This equipment has generated benefits for families, such as the financial savings by reducing the purchase of cooking gas, reducing the work with firewood collection, improving the kitchen environment and, therefore, having positive health effects by reducing or eliminating the smoke generated by the burning of firewood and charcoal, as well as the reduction in the emission of greenhouse gases from the burning of LPG, firewood and coal. Mattos and Krehbiel survey data indicate that GHG emissions from the cooking activity of a typical Cariri Paraibano farming family can range from 1586 to 4348 kg CO2Eq/year, depending on the type of fuel used. After the installation of the biodigester, these values are reduced to a range of 172 to 750 kg CO2Eq/Year. This represents a 50% to over 1000% reduction in GHG emissions[165].

Water harvesting, storage and management

The Project will work with various technologies for water collection and storage, mainly for their use in agricultural production.

In terms of the technical proposals to accomplish this task, the Project will be based on the best practices that have been developed in Brazil's Semiarid during the last two decades. In this domain, the most important reference is the *1 Terra e 2 Águas* (P1 + 2) Program, implemented by ASA (Articulation of the Brazilian Semiarid) / AP1MC, in partnership with several agencies/entities, most notably MDS, BNDES, Banco do Brasil Foundation, among others. The main proposals to be used, already cataloged as Social Technologies by the Banco do Brasil Foundation[166], are the boardwalk (or *calçadão*) cisterns, the underground dams, the trench barriers, and the graywater reuse system. The project will also work on the proposal for a 'green pit'.

- *'Calçadão' Cistern*

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[163] See website: http://tecnologiasocial.fbb.org.br/tecnologiasocial/banco-de-tecnologias-sociais/pesquisar-tecnologias/detalhar-tecnologia-327.htm.
[164] MATTOS, L. C.; FARIAS JR, M. **Manual do biodigestor sertanejo**. Recife: Projeto Dom Helder Camara, 2011. 55 p.
[165] MATTOS, L. C.; KREHBIEL, J. Impacto de um biodigestor domiciliar na economia de emissões de gases de efeito estufa em uma propriedade da agricultura familiar do Cariri Paraibano. In: FARIAS SEABRA, G.; NOVAES DA SILVA, J. A., et al (Ed.). A Conferência da Terra: Aquecimento global, sociedade e biodiversidade. João Pessoa, PB: Editora Universitária da UFPB, v.III, 2010. p. 315 - 323.
[166] See website: http://tecnologiasocial.fbb.org.br/tecnologiasocial/principal.htm

The boardwalk (or *calçadão*) cistern technology consists of a $200m^2$ cemented space (the 'boardwalk') for rainwater harvesting, coupled with a reservoir or cistern, usually built with cement slabs, with a capacity of 52,000 liters of water.

The boardwalk cistern is a type of cylindrical water reservoir usually made of covered and semi-buried concrete slabs that allow rainwater to be captured and stored from a cemented catchment area or 'boardwalk'. The 3.2 m radius 1.8 m deep reservoir can hold approximately 52 m^3 of water. As it is covered and enclosed, the water stored in it is protected from evaporation and contamination caused by animal waste and other impurities brought by the wind.

The rainwater harvesting area, called the boardwalk, consists of a cemented area of 200 m^2. Its area is bounded by a curb, and it is on a higher plane than the reservoir, with a small slope to lead the water to a settling box and thence to the reservoir.

This tank has the purpose of capturing and storing water for the production of food, medicinal plants and small animal breeding, thus enhancing the productive backyards.

The estimated value for implementing a boardwalk cistern is approximately US $ 2,000.00. This includes the costs of building materials, the contribution given to the beneficiary family to the mason's payment and the materials for the enhancement of productive backyards[167].

Figure 41 Rainwater harvesting and storage boardwalk with its 52,000-liter cistern.[168]

P1 + 2 proved to be very successful in terms of adopting effective water collection and storage techniques for production, and also in training farmers to better manage this precious resource. Until November 2018, P1 + 2 installed more than 101,000 production tanks in the various states of the Semiarid. Of these, over 23,000 were built in the semiarid region of the state of Bahia alone.

There are studies that speak about the results obtained in the implantation of this social technology. Thus, research jointly conducted by INSA and ASA showed that the implementation of domestic and especially production ('boardwalk') cisterns positively affected household economies, as demonstrated by an economic analysis in Cariri, Paraiba. This analysis compared household economies before and after accessing water infrastructure. It was found that, with the presence of DC (domestic cisterns) and PC (production cisterns), families obtained 3.3 times higher profitability than without technologies, in terms of gross and agricultural

[167] Retrieved at: http://tecnologiasocial.fbb.org.br/tecnologiasocial/banco-de-tecnologias-sociais/pesquisar-tecnologias/cisterna-calcadao-para-potencializacao-de-quintais-produtivos.htm.
[168] This photo was taken by a member of the Project design team.

income[169]. A second survey, conducted in the municipality of Jardim, Cariri Cearense, reached similar conclusions. There was a significant difference favorable to the group of beneficiaries of the P1 + 2 Program compared to non-beneficiaries, both in terms of a Quality of Life index and household income. Considering the average annual agricultural income of beneficiaries and non-beneficiaries, a difference of almost 60% was found in favor of the former[170].

- *Underground Storage*

Although it was identified by Guimarães Duque, as early as 1950, as a very promising technology[171], until recently the underground dam was little known to the backcountry population. Over the last two decades, this type of dam has begun to spread across the Northeast.

The underground dam - built on an alluvial terrace perpendicular to the streambed - is intended to block subsurface runoff from the alluvial aquifer (see Figure 39 below). The use of underground dams in the semiarid region is justified by the climate and hydrological regimes of the region. Almost all rivers in the Semiarid are temporary and remain dry for most of the year. However, after a short-term flood (a few days), subsurface runoff continues for several weeks or even several months, depending on the size of the catchment area, until it runs out during the dry season. Under these conditions, the implementation of underground dams makes it possible to block the flow and, consequently, raise the piezometric level of the groundwater. Thus, the farmer can then use this water in two ways: through shallow wells/wells and through the plants grown there. Thus, as water is withdrawn from the ground of the underground dam (via waterfall, plants or evaporation), runoff continues, and the alluvial aquifer is continuously fed back by water flowing from the basin upstream of the dam. The system behaves like a sponge from which water is slowly drawn downstream. Under ideal soil conditions, with a sufficiently large catchment area and, of course, a satisfactory amount of rainfall, this system should allow drought to pass through soil water for plants and well water for other types of consumption.[172]

The underground dam is any structure that aims to block the flow of rainwater from the surface into the ground by constructing an impermeable wall installed transversely to the direction of water flow. This wall can be composed of compacted clay, masonry, concrete or plastic tarp, depending on the producer's local conditions and the availability of materials in the region. However, the 200-micron polyethylene plastic tarpaulin has been widely used, because, with its use, construction is faster and more economical.

The rainwater accumulation results in the elevation of the water table, which is close to the root system of the plants, favoring their access to soil with adequate moisture. In some situations, in years with above-average rainfall in the region, the excess water passes through the drainage, functioning as an ebb. The underground dam allows the accumulated water in the ground to supply the well built in the dam (Figure 39). This is because of the elevation of the water table. This water can be used for various purposes, especially in the driest time of the year, allowing small irrigation of fruit and vegetables. Often this water is also used for human and animal consumption.[173]

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[169] ASA-BRASIL. **Programa Uma Terra e Duas Águas (P1+2). Síntese dos Estudos de Caso do Território de Atuação do Coletivo Regional das Organizações da Agricultura Familiar do Cariri, Curimataú e Seridó Paraibanos**. Recife, PE: ASA-Brasil**:** 26 p. 2016, apud PÉREZ-MARTIN, A. M. et al. Agroecological and Social Transformations for Coexistence with Semiaridity in Brazil. **Sustainability,** v. 9, n. 6 (990), 2017. Available at: https://doi.org/10.3390/su9060990.

[170] ALENCAR, M. D. O.; JUSTO, W. R.; ALVES, D. F. Os efeitos do Programa "Uma Terra e Duas Águas" (P1+2) sobre a qualidade de vida do pequeno produtor rural do Semiárido nordestino. **Revista Econômica do Nordeste,** v. 49, n. 1, p. 165 - 180, 2017.

[171] GUIMARÃES DUQUE, J. **Solo e água no Polígono das Secas**. 5a. edition. Mossoró: Fundação Guimarães Duque, 1980.

[172] GRIMAUD, J. **As barragens subterrâneas. Estudo de caso num município do Sertão pernambucano.** Unpublished work**:** 12 p. 2002.

[173] MELO, R. F. D. et al. **Barragem Subterrânea: Tecnologia para Armazenamento de Água e Produção de Alimentos**. Circular Técnica, 104. Petrolina, PE: Embrapa Semiárido, 2013. Available at: www.cpatsa.embrapa.br.

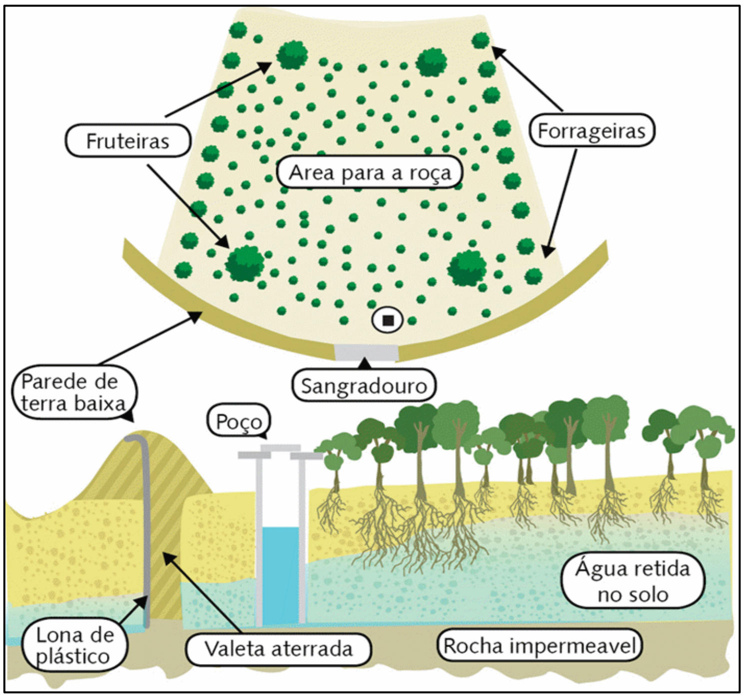

Figure 42 Schematic drawing of the underground dam operation [174]

The costs of underground dams are extremely variable, depending on the size (length and depth of the bus), as well as the way the work is done and even the form of funding. A survey conducted in Mirandiba (PE) in 2000 found out costs ranging from US$ 500 to US$ 1,000 that roughly corresponded to the average price of a small clay pit, which takes 20 to 70 machine working hours. The cheapest dams were, of course, the smallest, the deepest, and the one without a bucket. The most expensive were the dams that required a large volume of excavation (over 40 meters long and over 3 meters deep). A second survey, which was based on a Pernambuco Government's BS construction policy that ran from 2010 to 2015, reached higher values per dam built, ranging from US$ 1,500 to US$ 3,800.00.[175]

The most significant effect of the underground dam is the possibility of economic use. In the upstream alluvial soil patch, various crops can be cultivated as moisture is available to plants all year round. In the case of an area of the Cangati River micro basin (Ceará), in the first underground dam built, elephant grass was cultivated. In 'normal' rainy years, this grass stays green all year round and is available for feeding. In other cases, beneficiary families have been able to harvest food such as beans, corn, cassava and various fruit trees. But despite all these advantages, it is important to remember that the benefit of the underground dam for farming families is directly dependent on the amount of rainfall of a given rain cycle. Thus, during the last major drought, many of these dams did not produce for several years.

[174] SOUSA, T. et al. Barragem subterrânea: Tecnologia sustentável de captação, armazenamento de água e convívio com o Semiárido. **Revista Terceiro Incluído,** v. 4, n. 1, p. 97 -103. Available at: https://doi.org/10.5216/teri.v4i1.33949, 2014.
[175] COSTA, W. D.; COSTA, W. D. J. **Barragens subterrâneas e barragens de assoreamento. Conceitos e construção**. Recife, PE: Editora UFPE, 2015. Available at: [http://www.creape.org.br/portal/wp-content/uploads/2016/11/Caderno%203%20Barragens%20Subterr%C3%A2neas%20e%20de%20Assoreamento.pdf.](http://www.creape.org.br/portal/wp-content/uploads/2016/11/Caderno%203%20Barragens%20Subterr%C3%A2neas%20e%20de%20Assoreamento.pdf)

Figure 43 Waterproof tarpaulin installation of an underground dam under construction [176]

- Gray water reuse system

Among the challenges towards the culture of coexistence with the Semiarid, water is increasingly emerging as a limiting factor, due to the condition of semi-dryness, coupled with local anthropic interference (such as pollution of springs, rivers and groundwater, erosion and deforestation) and globally (as the causes of climate change), making water a scarce natural resource for the growing need for human activities.[177]

Thus, in the Northeastern Semiarid, the availability of water is always a matter of intense concern. However, it is quite common in rural backcountry to see that gray waters[178] are being wasted. In the backyards in the interior of the Semiarid, it is observed that these waters are released into the open, even in homes that have some treatment for a part of domestic effluents, such as the septic tank. Thus, untreated gray water contaminates the soil and water and causes disease to the animals that ingest it.[179]

This scenario points to the need to adopt measures for the proper use and reuse of water and to control pollution of water resources - in particular by gray waters - as a way of ensuring water current and future availability. Treated gray water should be considered as a water resource to be used for various purposes. Water reuse is a practice to be encouraged in multiple human activities, especially in agriculture, as a way of recycling nutrients and water, reducing negative environmental impacts on water bodies and soil by effluent discharge, among others.[180]

In this context, the reuse of water offered by the Family Biowater System - SBF - fills a fundamental gap, as it is low cost and takes advantage of local capacities for its implementation, management and maintenance. It provides a unit for the treatment of gray water and subsequent use in the production of high nutritional value food for families and backyard animals. It also propitiates learning agroecological principles in practice, especially soil management, water management, agrobiodiversity and nutrient cycling, which are applicable to other areas of family-run agroecosystems.[181]

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[176] MELO, R. F. D. et al. **Barragem Subterrânea: Tecnologia para Armazenamento de Água e Produção de Alimentos**. Circular Técnica, 104. Petrolina, PE: Embrapa Semiárido. Available at: www.cpatsa.embrapa.br 2013.
[177] SANTIAGO, F. et al. **Manual de implantação e manejo do sistema de Bioágua Familiar. Reuso de água cinza doméstica para a produção de alimentos na agricultura familiar do semiárido brasileiro**. Caraúbas, RN: ATOS, 2015. 190 p. Available at: https://bioaguafamiliar.files.wordpress.com/2015/09/manual_bioagua_familiar_2015.pdf.
[178] Graywater is defined as all sewage generated in a dwelling except that from the sanitary basin. It therefore includes effluents from the shower, washbasin, kitchen sink, tank and / or washing machine (BORGES, L. Z. Caracterização da água cinza para promoção da sustentabilidade dos recursos hídricos. 2003. 103 p. Dissertação – Mestrado em Engenharia. Universidade Federal do Paraná. Curitiba, 2003).
[179] DOS SANTOS FILHA, M. E. C.; ARAÚJO, M. T. L. **Aspecto para implantação de sistemas de reuso de águas cinzas em comunidades rurais no Estado do Ceará – estudo de caso: Projeto São José III**. VI Simposio de Economia Rural; Políticas Públicas e Geração de Renda no Nordeste Rural. Fortaleza**:** 15 p., 2018. Available at: https://simpoer.fortal.br/wp-content/uploads/2018/10/PSJ-Reuso-de-%C3%A1guas-cinzas.pdf.
[180] SANTIAGO, F. et al. **Bioágua Familiar. Reuso de água cinza para produção de alimentos no Semiárido**. Recife: Projeto Dom Helder Camara-SDT-MDA, 2012. 19 p.
[181] SANTIAGO, F. et al. **Manual de implantação e manejo do sistema de Bioágua Familiar. Reuso de água cinza doméstica para a produção de alimentos na agricultura familiar do semiárido brasileiro**. Caraúbas, RN: ATOS, 2015. 190 p. Available at: https://bioaguafamiliar.files.wordpress.com/2015/09/manual_bioagua_familiar_2015.pdf.

The Family Biowater System (FBS) is newly created. It was from 2009 onwards that the Sertão - PDHC Project (FIDA - GEF - MDA) established a partnership with three farming families, an NGO and the Federal University of Semiarid (UFERSA) to develop an appropriate graywater treatment system to the specific conditions of the northeastern semiarid family farmers. After more than three years of work, this system has been validated and has been called 'family biowater'. Although other graywater treatment systems are available and are being implemented in several states in the region, the Project will prioritize working with this proven system of family biowater.

The technology for reusing water from Family Biowater is a process of filtering through mechanisms of physical and biological impediment of the waste present in gray water, and organic matter is biodegraded by a population of microorganisms and earthworms (*Eisenia foetida*). The removal of the main pollutants found in these waters occurs with the digestion and absorption of the organic matter retained in the water by the worms. Reuse water is used in a closed irrigation system for the production of vegetables, fruits, medicinal plants and other types of food.

Household gray water production varies with family size, water supply and other factors. The SBF proposes that this treated water to be reused in agricultural production. This system consists of the following components: i) plumbing that carries the gray water from the house through the other components; ii) 'grease box' (which serves to remove thicker impurities); iii) biological filter (including earthworms); iv) reuse tank (to store filtered water); v) earthworm (where the worms used in the filter are created); vi) irrigation system; vii) fenced area to protect the flower beds and nurseries where crops are grown.

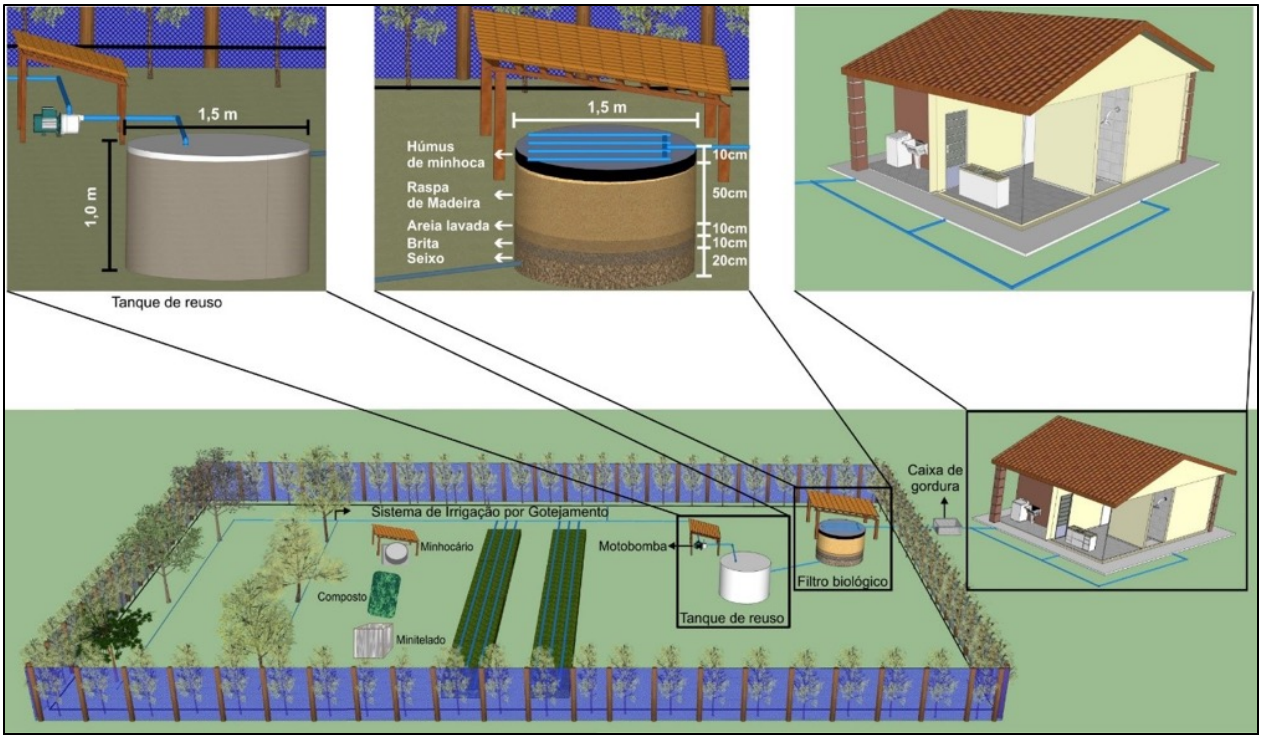

Figure 44 Sketch showing the different components of the Family Biowater System [182]

Data collected during the years of experimentation with the FBS showed that a country house with 4 to 5 people 'produces' approximately 500 liters of 'graywater' per day. The proposed biological filter in the system was designed to treat this quantity. The treated water is used to irrigate an agroforestry yard, with crop beds, and various types of trees. The total area planned for this 'yard' is approximately 300 m^2. The irrigation system must be a drip.

[182] SANTIAGO, F. et al. **Bioágua Familiar. Reuso de água cinza para produção de alimentos no Semiárido**. Recife: Projeto Dom Helder Camara-SDT-MDA, 2012. 19 p.

The FBS Implementation and Management Manual estimated the cost of a complete system at approximately $ 2,600.[183]

Figure 45 Biological filters from Family Biowater System, with plumbing bringing gray water from the house. In this case, the graywater 'production' is significant, justifying the double filter [184]

- Green septic tank – Simple system for blackwater treatment

The rural Northeast, and thus the semiarid region, suffers from a chronic sanitation deficit. It is estimated that only about 10% of rural households in the Northeast have access to adequate sanitation[185].
Lack of proper treatment of domestic sewage - especially blackwater –[186] creates considerable health problems for the population concerned. Given this situation, it is evident the need to identify alternatives that are socially, economically and ecologically sustainable, to address the problem of proper disposal of domestic sewage (especially blackwater - as we will see below) in rural areas. Thus, it is urgent to find appropriate solutions to the reality of rural communities and settlements, which contemplate the particularity of the countryside, ensuring the health of the population and the environment.[187]

There are basically two variants of sewage systems: the collective system (which means removing sewage from the served areas) and the individual type system (which represents a solution on-site, individual or for a few households).[188] The green septic tank fits into the individual system category, usually serving single-family homes.[189] It is also associated with the latest ecologically focused solutions, which, in addition to presenting a solution to health threats, are also concerned with the reuse of the nutrients and water contained in these effluents.[190]

The green septic tank, also called a bio septic bed, consists of the construction of a waterproofed trench of varying dimensions, featuring an internal pyramidal chamber structure made of ceramic bricks (8-hole), where

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[183] SANTIAGO, F. et al. **Manual de implantação e manejo do sistema de Bioágua Familiar. Reuso de água cinza doméstica para a produção de alimentos na agricultura familiar do semiárido brasileiro**. Caraúbas, RN: ATOS, 2015. 190 p. Available at: https://bioaguafamiliar.files.wordpress.com/2015/09/manual_bioagua_familiar_2015.pdf.
[184] This photo was taken by a member of the Project design team.
[185] Data available at: http://www.funasa.gov.br:8080/web/guest/panorama-do-saneamento-rural-no-brasil.
[186] In the composition of domestic sewage, it is possible to differentiate between blackwater and graywater. Blackwaters are those excreted from toilets, containing urine and feces, and need specific treatment to reduce pathogens. Graywaters are those from sinks, showers and laundries, which can be reused (OLIVEIRA, G. D. D. et al. Tratamento domiciliar de águas negras: tanque de evapotranspiração. **Revista Petra,** v. 4, n. 2, pp. 194 - 214, 2018). The family biowater system, object of the previous section, is suitable for graywaters.
[187] ARAÚJO, J. C. **Biorremediação vegetal do esgoto domiciliar em comunidades rurais do semiárido: "Água limpa, saúde e terra fértil"**. Departamento de Engenharia Agrícola – UFC, 2012. Available at: https://www.passeidireto.com/arquivo/24120781/biorremediacao-vegetal-do-esgoto-domiciliar-em-comunidade-rurais-do-semiarido.
[188] VON SPERLING, M. **Introdução à qualidade das águas e ao tratamento de esgoto**. Belo Horizonte, MG: DESA / UFMG, 2005.
[189] OLIVEIRA NETTO, A. P. et al. Biorremediação vegetal do esgoto domiciliar: o caso da fossa verde em comunidades rurais do Alto Sertão alagoano. **Revista Produção e Desenvolvimento,** v. 1, n. 3, p. 103 - 113, 2015.
[190] SOUZA, L. S.; SATIRO, A.; PRADO, C. Tratamento de água negra domiciliar através de bananeiras por Tanque de Evapotranspiração. **Atas de Saúde Ambiental,** v. 6, n. Jan-Dez 2018, p. 235 - 248, 2018.

the holes are sloped into approximately 30º and open to the space filled with filter material[191] (see Figure 43 below).

The edges of the pit or tank should exceed ground level by at least 10 cm to limit rainwater infiltration. The dimensions of this ditch depend mainly on the volume of blackwater to be treated. This, in turn, depends mostly on the number of people living in residence. It is recommended that the pit or ditch be from 1.20 to 1.50 m deep, 2 m wide, and, for the length, 1 m for each person living in residence.[192]

The sewage is directed into the chamber and then flows out of this structure, filled with porous filtering materials such as debris or coconut shell. The last layer of the surface is composed of earthy material, where plants such as banana, *taioba* or others are grown (see Figures 43 and 44 below). The effluent treatment in the pit takes place in an upward flow allowing organic solids to be in maximum contact as the support material, which is one of the key points for biomass retention. The sewage is discharged at the base of the foundation, resulting in the formation of microbial sludge that extends along with the support material.[193]

Anaerobic digestion, which occurs in the chamber, decomposes organic matter from household waste in conjunction with the action of aerobic microorganisms in the root zone of plants. The water is evapotranspiration and used consumptively by the vegetation. This means that the system does not generate effluents to be infiltrated into the soil or sent to another after treatment.[194] It should be remembered here that, when properly sized, this system removes polluting elements from the environment, and there is no danger of them coming back to cause damage. Thus, the main advantage of this alternative system is that it provides adequate disposal of domestic wastewater, which is often deposited in the open, facilitating the proliferation of insects and rodents and spreading pathogenic vectors, thus harmful to the environment and health of the population.[195]

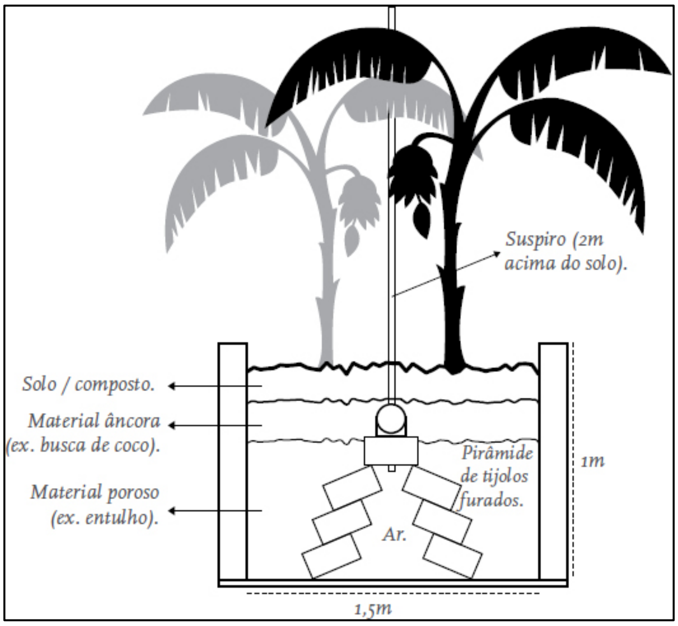

Figure 46 Green septic tank (or Bioseptic bed) sketches [196;197]

[191] In some green septic tank models this chamber is formed by an alignment of used tires replacing the pyramid chamber. (GALBIATI, A. F. **Tratamento domiciliar de águas negras através de tanque de evapotranspiração**.(Dissertação de Mestrado). Centro de Ciências Exatas e Tecnologia, Universidade Federal de Mato Grosso do Sul, Campo Grande, MS, 2009).

[192] FIGUEIREDO, I. C. S.; SANTOS, B. S. C.; TONETTI, A. L. **Tratamento de esgoto na zona rural: fossa verde e círculo de bananeiras**. Campinas, SP: Biblioteca/Unicamp, 2018. 28 p.

[193] GALBIATI, A. F. **Tratamento domiciliar de águas negras através de tanque de evapotranspiração**.(Dissertação de Mestrado). Centro de Ciências Exatas e Tecnologia, Universidade Federal de Mato Grosso do Sul, Campo Grande, MS, 2009

[194] COELHO, C. F.; REINHARDT, H.; ARAÚJO, J. C. Fossa verde como componente de saneamento rural para a região semiárida do Brasil. **Engenharia Sanitária Ambiental,** v. 23, n. 4, p. 801 - 810, 2018.

[195] ARAÚJO, J. C. **Biorremediação vegetal do esgoto domiciliar em comunidades rurais do semiárido: "Água limpa, saúde e terra fértil"**. Departamento de Engenharia Agrícola – UFC, 2012. Available at: https://www.passeidireto.com/arquivo/24120781/biorremediacao-vegetal-do-esgoto-domiciliar-em-comunidade-rurais-do-semiarido.

[196] See website: http://institutoecoacao.blogspot.com/2013/10/veja-como-construir-uma-fossa-ecologica.html.

[197] WIEGAND, M. C. **Fossa Verde: tecnologia de saneamento rural**: Sem data. Available at: http://aprece.org.br/wp-content/uploads/2017/08/aprece-associacao-dos-municipios-do-estado-do-ceara_aprece_fossa-verde.pdf.

This process falls into the category of plant bioremediation and emerges as an alternative for household wastewater treatment, in which the waters and nutritional compounds from sewage are reused by plants. This proposal is already being implemented in the Semiarid region. This is the case, for example, of the 25 de Maio Settlement, in the municipality of Madalena, in Ceara's Central Sertão, where a group from the Federal University of Ceará implemented and accompanied 70 of these units for three years. This experience was inspired by a previous one, held in the city of Icapuí, also in Ceará.

The follow-up carried out by the university allowed the crops produced in the green pits (banana, tomato, pepper, etc.) to be submitted to microbiological analysis and the results indicated that they are of satisfactory sanitary quality, therefore, fully fit for human consumption. In addition, this same initiative showed that the cost of building this alternative system is reduced compared to the conventional septic tank, of around US$ 300 per unit, and its operation and maintenance are simple and consistent with the reality of rural populations.[198]

Figure 47 Step by step construction of green septic modules in the Paus Broncos community, Settlement May 25th, Ceará.[199]

4.3 Detailed description of Project framework and activities

4.3.1 Project's objectives

Climate stressors (see section 2.4) aggravate the cycle of deterioration caused by improper practices, which translates into a decline in productivity, which in turn fuels social and environmental degradation processes, inducing impoverishment of family farmers and ecosystem services.

[198] COELHO, C. F.; REINHARDT, H.; ARAÚJO, J. C. Fossa verde como componente de saneamento rural para a região semiárida do Brasil. **Engenharia Sanitária Ambiental,** v. 23, n. 4, p. 801 - 810, 2018.
[199] ARAÚJO, J. C. **Biorremediação vegetal do esgoto domiciliar em comunidades rurais do semiárido: "Água limpa, saúde e terra fértil"**. Departamento de Engenharia Agrícola – UFC, 2012.Available at: https://www.passeidireto.com/arquivo/24120781/biorremediacao-vegetal-do-esgoto-domiciliar-em-comunidade-rurais-do-semiarido

The Planting Resilience in Rural Semiarid Communities Project will work to change the paradigm, postulating that it is possible to transform the productive systems of family farmers in the Semiarid, increasing production while improving their ability to meet the challenges posed by the climate change.
Thus, the Project will have as its primary objective to strengthen the resilience of poor and extremely poor rural families in the Brazilian semiarid region, through the establishment of more sustainable and productive agricultural systems that promote greater vegetal coverage of the area and perform their other ecosystem functions correctly, which in turn will increase and stabilize household income and food security, encouraging young generations to remain active in rural activities.

In order to mitigate the risks and bottlenecks faced by semiarid farming families in their primary production activities (agriculture, animal husbandry, extractivism), the Project will work with two strands that will seek at the same time to strengthen productive capacity and most resilient. The first strand will focus on implementing more productive and resilient systems in the face of climate change challenges (CRPS). The second will seek to develop the capacity of households to collect and store water, which should also allow them to expand their productive capacity. The third component will scale-up component 1 and 2 thought the region and to other drylands through south-south cooperation.

4.3.2 The intervention area and target audience

The targeting strategy will prioritize areas with higher climate, socioeconomic and environmental vulnerability. The selection criteria will be applied in the following sequence:

Selection of the States. The Project will work in the Northeastern semiarid region. Approximately three Northeastern states will be selected, and preference will be awarded to states with past IFAD projects. Eligible states will present projects to the Executing Entity (EE), BNDES, including information on governance arrangements, targets, as well as compliance with applicable legislation. The selection process will be based on client qualification, verifying borrowing capacity and implementation arrangements, as well as project analysis with predefined criteria (presented in PIM Annex 21).

Project area. Once the states are chosen, the Project intervention area must be defined. The municipalities will be ranked, within each of the selected States, through an analysis considering the following criteria:

(i) rural poverty incidence;
(ii) climate vulnerability index and historical exposure to drought;
(iii) food and nutritional security index;
(iv) water quality and availability.

Territorial contiguity will also be considered when drawing up the final list, since the proximity between municipalities and communities facilitates the exchange of experiences between farmers in the processes of experimentation, in addition to enabling greater efficiency in the performance of operations by the States.

Rural Advisory Services providers will be selected per area, with one extension advisor serving an average of four communities (in total about 140 families) for 3 years (for Component 1 activities) or 2 years (for Component 2 activities).

Selection of beneficiary groups. Within the selected target municipalities, the project will focus on families and communities with the highest climatic, socioeconomic and environmental vulnerability. The project will work with family farmers who have agricultural establishments or live in agrarian reform settlements,[200] and who are at greatest risk of being pushed into conditions of extreme food insecurity due to climate change. The following selection criteria will be applied:

(i) the environmental precariousness of properties/farms (signs of deforestation, erosion and soil degradation);
(ii) food and nutritional insecurity (malnutrition and chronic-degenerative diseases);
(iii) tangible effects of drought and level of access to quality water.

[200] Law number 11.326/2004, defines family farmers based on four criteria: (i) they must have an area of up to 4 fiscal modules; (ii) must have a minimum family income deriving from rural economic activities developed in his/her property; (iii) must predominantly use their own family labor force in rural economic activities; (iv) must manage their venture with their family. The family agriculture segment is integrated by agrarian reform settlers, *quilombola* communities, indigenous peoples, artisans, fisherman, among others.

The process of selecting communities and families will be defined by each State, following minimum qualifying principles set forth in the Project Implementation Manual (PIM). There will be an effort to ensure the inclusion of the most marginalized and priority groups (women, youth, traditional communities, afro-descendent and indigenous peoples) in numerical terms and to adopt a flexible and responsive approach to their particular demands and needs.

Participation will not be mandatory. Thus, public awareness campaigns and stakeholder engagement (Annex 7 of the Funding Proposal) will be necessary. For indigenous communities, the project will also follow the FPIC plan (as per Annex 6 of the Funding Proposal).

The national Unified Registry (*Cadastro Único)*[201] – the main instrument for the selection and inclusion of low-income families in federal government programs – will be the primary tool used to identify families living in social vulnerability. Some complementary sources of information will also be accessed for the selection of municipalities, communities and families:

(i) MAPAINSAN was a study developed by the MDS in 2014 with the objective of identifying families and individuals that are in situations of food and nutritional insecurity and the National System of Food and Nutrition Surveillance – SISVAN data;

(ii) Database of the National Commission to Combat Desertification and Mitigate the Effects of Drought (CNCD) and subsidies of the Warning System Tools for early detection of Drought and Desertification, designed to predict droughts in the semiarid regions in Brazil nowadays;

(iii) the municipal Human Development Index (HDI), a measure comprised of three indicators of human development dimensions: longevity, education and income;

(iv) the IVS (Social Vulnerability Index), designed from indicators of the Human Development Atlas in Brazil.

The inclusion of socioeconomic variables in the prioritization process reflects the fact that the Project assumes there is a direct relationship between the sources of vulnerability to climate change and poverty: the poorest members of the population are considered to have the lowest ability to invest in diversifying their livelihoods so as to reduce their exposure to climate change impacts, and least access to social and financial safety nets. These characteristics make them the most vulnerable to climate change. For this reason, the Project provides maximum concessionality in that part of the GCF support.

4.3.3 PCRP General Project Structure

The implementation of the PCR Project will be carried out through two main components - Component I - Climate Change Resilient Productive Systems and Component II - Water Access. This will be designed through the Territorial Resilience Investment Plans (TRIPs). Complementary cross-cutting activities in capacity and awareness building, knowledge management, south-south cooperation, public policy dialogue, monitoring and evaluation - grouped in Component III - will complement to reach the project's objective.

[201] Are allowed to register: (i) families with monthly income of up to half a minimum wage per person; (ii) families with income higher than three minimum wages, provided that register is linked to the inclusion in social programs from the three governmental levels.

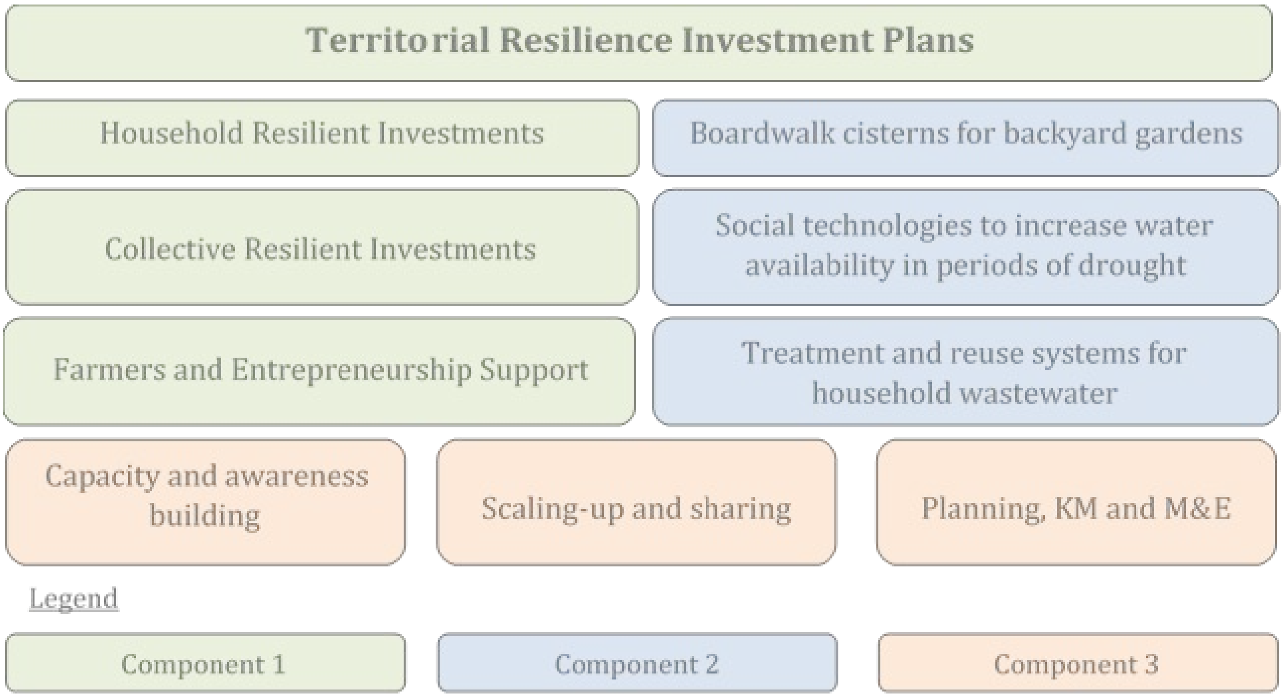

Figure 48 Project's General Structure

4.3.4 Project Intervention Strategy

The Project Planting Climate Resilience will be carried out through two main components of direct action - Component 1 - Climate Resilient Production Systems and Component 2 - Water Access. It should be emphasized here that the achievement of the main objectives of the Program, in terms of achieving higher production capacity, guaranteeing more food security and income, will be achieved through the joint action of capacity building and productive investment initiatives, materialized in the two components mentioned above. Complementary cross-cutting activities in Social Communication, Knowledge Management, and Public Policy Dialogue - which make up Component 3 - will complement the Project's drive.

The Project's gender approach, which will seek to ensure greater opportunities for women, should ensure that women are served in all three lines or scopes. The strengthening of rural youth, in the same way as the traditional, indigenous and quilombola communities will be other transversal themes and should be prioritized and present in all the actions of the Project. More elements about the Project's work with these audiences will be presented shortly after.

- *General implementation strategy*

The concrete implementation of the Project in the field will start with an awareness-raising action of the potential beneficiary public, as well as of the other social actors involved with the themes of sustainability, resilience, rural development and overcoming poverty, in order to inform them about Program´s objectives and modalities of intervention. As their performance should provide a strong articulation with local and territorial spaces of participation, these should be important permanent channels for the dissemination of information and procedures related to the Program. The Municipal Councils for Sustainable Rural Development (MCSRD) and other Municipal Committees, as well as Territorial Colleges appear as appropriate spaces to favor Program participation in local development processes.

In practice, the approach to families will be developed through community work. This approach requires performing three sequential and interconnected tasks:

i) Select the communities and associations with which the Program will work;
ii) Mobilize selected families and elaborate, in a participatory manner, the Territorial Resilience Investment Plans (TRIPs) to be implemented with the communities and families - which will involve: investments for the implantation of water collection and storage infrastructure and CRPS and other activities necessary to implement the Program proposals in communities and with families;

iii) Implement these Plans and monitor their operation.

The importance of Territorial Resilience Investment Plans (TRIPs) in the overall implementation strategy should be highlighted here. These Plans constitute the central planning tool for all activities proposed in Components 1 and 2. They include investments, resources, training, technical advice and other initiatives to achieve the intended goals.[202] Each TRIP will cover an average of four territorially contiguous communities. Beneficiaries will receive non-repayable funds but will contribute at least 10% of the total value of IP, in cash or in kind.

The first task should be carried out by the State Project teams, in interaction with relevant social actors, with emphasis on local and territorial spaces for debate and planning of sustainable rural development actions. The other tasks will be the responsibility of the Technical Advisory teams to be hired (for more details on the Technical Advisory provided for in the Project, see APPENDIX II).

In addition to this work in rural communities, the Project activities will provide a number of opportunities that should strengthen the institutional capacity of various types of public and private entities, both at the state and territorial level, to implement more resilient productive systems more generally stimulating sustainable rural development.

Finally, the Planting Climate Resilience Project was not designed to work in isolation. As a result, the action strategy will, whenever possible, seek to establish partnerships to strengthen the complementarity with other state and federal projects, programs and public policies. At the same time, it will also seek to develop partnerships with the private sector (for capacity building, providing technical advice, access to markets, etc.) whenever possible.

- *Detailed methodological roadmap*

The choice of the communities for the implementation of Components 1 and 2, which will be guided by the criteria for selection of the Program's public, will be made by the State Project teams (PMUs) in consultation with the collegiate bodies that deal with the theme of rural development and poverty alleviation in the Program's municipalities and territories as described in the section above.

Once beneficiaries are selected, the first step of this roadmap will be to raise awareness and mobilize beneficiaries, with a special effort to engage in dialogue with women and youth. This will involve holding community meetings to detail the Program's work proposal and encourage the broadest possible participation in the roadmap activities. This phase will be of great importance in the 'selection' of beneficiaries, as no one can be required to participate in the Program. In the case of indigenous communities, the Program shall also follow specific procedures defined by IFAD as per the SECAP - Annex 6 of the Funding Proposal.

The next step will be dedicated to making a *participatory diagnosis (baseline)*[203], which will focus on the core themes of the Project and determine the best entry strategy, given the characteristics and needs of each beneficiary family. This baseline study will make it possible to identify problems, potentialities and priorities, thus delineating the best opportunities to be explored in the following steps. In the case of indigenous and traditional communities, the Project will seek its Free and Prior Informed Consent (FPIC) before any action is taken in indigenous areas or that may directly affect indigenous communities (the explanation of the consultation process leading to the FPIC provided in the Indigenous Peoples Planning Framework in Annex 6 mentioned). The plan developed with indigenous communities will ensure that investments are tailored to the specificities of the indigenous group concerned and culturally appropriate to traditional forms of social and productive organization.

The third part of the roadmap is devoted to the preparation, together with the beneficiaries themselves, of a *Territorial Resilience Investment Plan (TRIP)* which, according to the specific needs of each case, will include

[202] TA teams will design TRIPs with full involvement of beneficiaries, based on the Manual for Designing Productive Investment and Business Plans (a methodological tool developed by IFAD with the support of the knowledge management SEMEAR International Program). Once completed, the TRIPs will be submitted for approval by the Project, following procedures that are defined in the Project Implementation Manual (PIM).
[203] It could be a diagnosis along the lines of what is a Rapid Participatory Diagnosis (RPD) that is already used in Brazil and many other countries (VERDEJO, M. E. Diagnóstico rural participativo: guia prático DRP. Brasília: MDA / Secretaria de Agricultura Familiar, 2007).

definition of material investments, organize exchanges, training and other initiatives that are required to deploy Climate Resilient Production Systems (CRPS) and the water infrastructure in Component 2 (Access to Production Water) that complement investments under Component 1 (CRPS).

We will mention here that TRIPs should be tailored to the specificities of each group/community as well as to each entry strategy. Program actions will build on lessons learned from the six current IFAD projects in the Northeast. TRIPs will be developed with the full involvement of beneficiaries, based on the Manual for the Preparation of Productive Business Plans and Business Plans, a methodology developed by IFAD, supported by the SEMEAR Program.

The TRIP should include the registration in the Rural Environmental Registry (CAR) for each beneficiary, identifying the Legal Reserve (RL) as well as the Permanent Protection Areas (APPs). RL and PPAs will be a priority for implementation of CRSP to optimize the resilience of ecosystem services under conditions of climate change (being critical areas for water protection and aquifer recharge). CAR / CEFIR allows monitoring compliance with the Forest Code by directing incentives or disincentives to rural properties and planning forest conservation across the landscape. The design of the TRIPs will also consider existing credit lines, for example through the Banco do Nordeste do Brasil (BNB) or Banco do Brasil (BB), and will seek to strengthen the access of the beneficiary population to these credits, avoiding substitution of these forms of financing.

Once the TRIP is finalized, the fourth step of the roadmap is its submission for review and approval of the Project. Each state may create a body (Council or Committee) that will evaluate the Plans prepared and presented to the Project to ensure their quality in the various pertinent dimensions (alignment with Project objectives, feasibility, feasibility, etc.). This body may request additional information or recommend improvements, approve, or even reject an inappropriate proposal.

As these TRIPs will necessarily be managed by the association that brings together the beneficiary families (except schools), the fifth methodological moment refers to the execution of specific activities to strengthen the community organization. Although the association's leaders should be involved in the previous and subsequent methodological moments, it is understood that particular actions are needed to improve the functioning of these organizations from gender and generational approaches. In particular, it is time to implement practices that promote their capacity building in management, including the entire process of TRIP implementation, including accountability.

With the approval of the TRIP, the next step (sixth), is the monitoring of the implementation of the TRIP with the beneficiary communities, schools, groups and families. This monitoring should actively contribute to the satisfactory implementation of investments. TA's working method should focus as much as possible on horizontal processes of information circulation and knowledge generation, creating conditions for a 'farmer-to-farmer' rural extension, involving larger family farmers in these networks.

The seventh moment of the roadmap is supporting beneficiaries in the marketing their products. CRPS is expected to allow for an increase in self-consumption production and sales. Different market alternatives in place will be discussed with families and communities. This should lead to specific marketing initiatives, such as providing guidance and support for their access to institutional purchasing programs (PAA and PNAE), local fairs and other existing trade channels, including the possibility of selling to buyers of the private sector such as restaurants, diners, etc.

In order to engage the work and results obtained with 'internal' (families and technical teams involved in the Program) and 'external' (the local population in general, as well as public managers, and other social actors) audiences, the methodological roadmap foresees a stage dedicated to communication (Component 3). This work is based on the systematization of experiences of beneficiary families/communities. From these systematizations, communication materials are produced so that more detailed information on water management and CRPS can be socialized. Communication and knowledge management happens throughout the project and it is fundamental to strengthen youth and women leadership in these actions.

Finally, in the last methodological step, evaluation activities (and, where appropriate, replanning) of the work performed should be organized. A Climate Resilience Index will be applied to measure changes in resilience of the beneficiaries.

The work to be carried out by the Project will be carried out by the Technical Advisory teams (see APPENDIX II), with the supervision of the state teams (PMUs) and the coordination of the Central PMU.

- *Specific elements for an approach that ensures gender mainstreaming*

The approach adopted in the Project to work on gender issues has two aspects, namely:

(i) One strand of the selected approach should primarily focus on particular actions and operational mechanisms that address the specific needs of women as subjects engaged in the productive and reproductive spheres of social life. The project will always seek the valorization of women and the respect of their rights so that the obstacles they face in daily life are overcome to enable their full participation in technical and political spaces.

In practice, this can take many forms. For example, training processes should be flexible enough to address women's specific operational needs and consider the importance of socializing housework and care. This may require events to be held at appropriate times and locations and may require the organization of extra activities for children.

In order to guarantee women's economic autonomy, it will be essential to strengthen their self-organization and to privilege the formation of 'women's groups' through a series of educational activities, such as exchanges, workshops and territorial meetings. The pedagogical approach adopted should be inspired by a 'feminist pedagogy' and will have as its main objective to foster a broad process of Environmental Education focusing on contextualized education.

It will also be necessary to prioritize the construction of spaces and activities that are often on the fringes of projects and programs, such as backyards, precisely because they are not conceived as 'productive' or 'economically profitable'. Therefore, in setting up Territorial Resilience Investment Plans (TRIP), TA teams should pay close attention to the importance of spaces that promote sustainable production modes, such as 'productive backyards'.

Another aspect that should be highly valued in interventions with women, at the family and community levels, is the incorporation of technologies, the processes of adding value and the acquisition of management knowledge and skills.

Finally, within the processes developing women's social organization, it will be necessary to take into account the need to ensure their access to the set of public policies that enable the recognition and expansion of their productive activities.

(ii) Another extremely valuable aspect concerns the implementation of initiatives that can ensure gender mainstreaming in the structures and instances of the Project itself.

Thus, several activities (training, exchange, etc.) should be carried out for allowing the technical team(s) to incorporate this theme and perspective of "social inequalities" (of gender, but also of race and ethnicity) in their 'understanding of reality' and interventions.

- *Elements for a rural youth approach*

The Project's option for an approach to sustainable modes of production, based on an agroecological bias, opens up a wide range of possibilities that favor the engagement of rural youth. Thus, qualification courses that address multiple activities and diversified production systems will be offered to young people in the communities within the Project's coverage area, so that they participate in the activities linked to the Resilience Innovation Investment Plan (RIIP). Also, it is expected that young people will gradually become involved in community organizations (Associations) through the planned actions, assuming full membership and leadership positions.

Another strategy that will be valued in this Project involves the use of media resources to encourage young people's interest in the full range of agricultural and non-agricultural activities offered in the countryside.

- *Approaches for working with ´traditional communities'.*

The Project will also work with various types of 'traditional communities', such as quilombola and '*fundo de pasto*' communities. It may also come to work with some indigenous communities. As traditional communities (quilombolas and indigenous) are more vulnerable to situations of extreme poverty and manifest greater fragility in their organizational processes, this project will prioritize reinforcing the productive inclusion and local development of such communities. Actions in support of production and economic autonomy must be in line with the guidelines of Decree No. 6040, which establishes the National Policy for Sustainable Development of Traditional Peoples and Communities.[204]

The particularities of the methodological approach to technical assistance for traditional communities should be incorporated into the content and methodology of the technical capacity building meetings that will take place throughout the Project, with a strong emphasis on ways of relating to the environment and the renewal of sustainable environmental practices. The production of materials that guide the implementation process of TRIPs in the context of traditional communities should be a priority of the Project's Social Communication and Knowledge Management team, so that technicians have subsidies to support their more technical interventions, mainly in the productive and environmental spheres.

4.3.5 COMPONENT I – Climate Resilient Productive Systems (CPRS)

This component's main objectives are to implement CRPS, empower beneficiaries to sustainably manage these systems and to promote women and youth leadership. Investment strategies will be designed to meet the diverse demands of family farmers given various land area sizes, climate-resilience adaptation requirements, demands of target beneficiaries and productive objectives.

Through the implementation of CRPS and relevant cross-cutting activities, the project will deliver ***Output 1.1. Increase climate resilience for family farmers and traditional communities while mitigating carbon emissions by applying CRPS.***

Activity 1.1.1 Selection of Project Areas and development of Territorial Resilience Investment Plans (TRIPs). The project will select its implementation area and develop Territorial Resilience Investment Plans (TRIPs) which will act as a "master plan" to guide collective and individual investments in all three components.

Sub-activity 1.1.1.1. **Develop a baseline study to select project area**
Step 1. Selection of states. Eligible semiarid north-eastern states will present projects to the Executing Entity (EE) – BNDES – including information on governance arrangements, targets, and compliance with applicable legislation. The selection process will be based on client qualification, verification of borrowing capacity and implementation arrangements, as well as project analysis with predefined criteria (presented in Annex 21). Approximately three NEB states will be selected; preference will be awarded to states with prior IFAD projects.
Step 2. Define project area in each selected state. The municipalities within states will be ranked through an analysis based on the following criteria: (i) rural poverty incidence; (ii) climate vulnerability index and historical exposure to drought; (iii) food and nutritional security index; and (iv) water quality / availability. Technical Assistance (TA) will be selected per area, with one extensionist serving an average of four

[204] In Decree No. 6,040 of February 7, 2007, which establishes the National Policy for Sustainable Development of Traditional Peoples and Communities, traditional peoples and communities, including indigenous peoples, quilombolas, fishermen, extractivists, riverine populations, among others, are "culturally differentiated groups that recognize themselves as such, which have their own forms of social organization, occupy and use territories and natural resources as a condition for their cultural, social, religious, ancestral and economic reproduction and use knowledge, innovations and practices generated and transmitted by tradition." (CONSEA. **Terra: direitos patrimoniais e territoriais. Documento elaborado pelas CP 5 e CP 6 do CONSEA para plenária de 29 de outubro de 2008**. Brasília: CONSEA. 2008. Available at: http://www4.planalto.gov.br/consea/eventos/plenarias/documentos/2008/direitos-patrimoniais-e-territoriais-sobre-a-terra-10).

communities (total of about 140 families) over a three-year period for Component 1 activities and two-year period for Component 2 activities.
Step 3. **Select beneficiary groups.** Each state will define the beneficiary groups, focusing on those with the greatest climatic, socioeconomic and environmental vulnerability. A baseline survey will be conducted to collect information on agricultural production, herds, local climate, water availability, gender issues, nutrition, among others of the target population. Priority will be awarded to marginalized groups, youth, and women. Participation is not mandatory, so public awareness campaigns (see output 6) and stakeholder engagement (Annex 7) are necessary. For indigenous communities, the project will also follow Indigenous People's Planning Framework (IPPF) plan as presented in Annex 6.

Sub-activity 1.1.1.2. **Develop TRIPs**. TRIPs are the planning tool for all activities proposed under Components 1 and 2. They include investments, resources, capacity building, and other initiatives to achieve the objectives. Each TRIP will cover an average of four territorially contiguous communities. The beneficiaries will receive non-reimbursable funds, but shall contribute with at least 10% of the total TRIP value, in kind or in cash. Technical assistance (TA) teams will design TRIPs with full involvement of beneficiaries based on the Manual for Designing Productive Investment and Business Plans. Once completed, the TRIPs will be submitted to the project for approval.

Activity 1.1.2. Implement CRPS in family farms and backyard gardens

CRPS will be implemented in Family farms and in backyard gardens. Investments will receive TA for development, implementation, and initial monitoring.

Sub-Activity 1.1.2.1. Implement CRPS in family farms

Objective: Reduce vulnerability of production to droughts and increase income, developing a progressive culture of multiple sustainable uses of productive areas with the implementation of Climate Resilient Productive Systems (CRPSs).
Selection criteria: Target beneficiary families that already have water for production.
Investments: Resources to implement the CRPS.[205]
Area: 31,000 plots with an average of 1/2 hectare each (total 15,500 hectares)

All productive investments of this axis, which will be included in the participatory prepared TRIPs (see the previous section) will have the following characteristics:

- Supported production activities will follow the six principles and practices of CRPS (see section 4.2.3 and APPENDIX I). This will not only increase resilience but also contribute to increased production and efficiency as well as reduce carbon emissions.
- Funds will be non-refundable.
- Investment resources will be disbursed to groups that are formally organized and constituted as regular legal entities (community associations), and may subsequently be distributed to individual members following approved TRIPs.
- TRIPs should directly involve 50% women and 50% youth.

All funded productive investment will receive Technical Assistance for three years for the development, implementation and monitoring.

Sub-Activity 1.1.2.2. Implement backyard gardens using CRPS

Objective: Develop irrigated, diverse and productive backyards in conjunction with activities in Component 2, using CRPS principles to reduce families' food insecurity from droughts and value and strengthen the role of women in production.
Selection criteria: Target audience families that don't have water for production. These same beneficiaries that will receive water access investments in Component 2.

[205] Such as seeds, seedlings, organic fertilizers, equipment rental or purchase, irrigation systems, tools, fences, etc. as mentioned before, these material investments will have Technical Assistance provided by the Project.

Investments: Resources to implement CRPS.[206]
Area: 36,000 gardens with an average size of 1/5 hectare each (total of 7,500 hectares).

All productive investments of this axis, which will be included in the participatory prepared TRIPs (see the previous section) and will be managed by community associations, will have the following characteristics:

- Supported production activities will follow the six principles and practices of resilient climate agriculture in the Semiarid. This will not only increase resilience but also contribute to increased production and efficiency.
- Funds will be non-refundable. However, beneficiaries must contribute with at least 10% to the funding amount of TRIPs.
- Investment resources will be disbursed to groups that are formally organized and constituted as regular legal entities (community associations), and may subsequently be distributed to individual members in accordance with approved TRIPs.
- TRIPs should directly involve 50% women and 50% youth as protagonists of planned actions.
- All financed productive investment will receive Technical Assistance for two years for the development, implementation and initial monitoring of TRIPs operation.

Activity 1.1.3 – Implement Collective Resilient Investments

The funds for collective investments are also non-reimbursable and will follow the same co-funding and TA as individual investment in output 2.

Sub-Activity 1.1.3.1. Implement Collective Areas Sustainable Management (CASM)

In several communities of the semiarid region, there are areas of collective possession and use of the *Caatinga*.[207] With the increasing population and land use in the Semiarid these communities are degrading and depleting the *Caatinga* by timber extraction for firewood and overgrazing.

Beneficiary communities will be chosen according to the targeting methodology described by the methodological roadmap presented above. The content of the TRIPs will have its specificities, because these communities have the challenge of managing its *Caatinga* common areas.

Objective: The main objective is to improve the ecosystem services provided by the *Caatinga*, such as microclimatic regulation, carbon sequestration and fixation, pest and disease control, water provision, waste decomposition, natural pollination of crops and other plants, and provision of raw materials (such as timber, oilseeds and fruits). The system will stabilize and, if possible, increase the forage supply. The enhanced ecosystem services help ensure that the community is the main stakeholder in the conservation and recovery of the ecosystem services.

New options for income generation are needed, especially for women and youth, and the increase of forage for the herd, so that the animals gain more weight and compensate for possible loss of income due to the herd's reduction. It is possible to develop a slow and progressive culture of multiple and sustainable uses of the Caatinga and reduce extensive grazing, while increasing income, encouraging family succession, together with the conservation and recovery of the ecosystem services.

Specific Objectives:

- Recover degraded areas using CRPS
- Decrease timber demand by implementing eco-efficient stoves and biodigestors;
- Increase supply and efficient use of water for production;
- Structure community seedbanks and nurseries to increase genetic diversity and potential products;
- Promote low-impact productive activities in collective areas (e.g. beekeeping).

[206] Such as seeds, seedlings, organic fertilizers, equipment rental or purchase, irrigation systems, tools, fences, etc. as mentioned before, these material investments will have Technical Assistance provided by the Project.
[207] Pasture Fund traditional communities always fall into this category. There are also settlements that have collective *Caatinga* areas (which may go beyond the Legal Reserve and APP areas).

The common practice in communities in the NEB semiarid is extensive pasture where animals have unrestricted access to all areas throughout the year. Thus, sustainable management and land reclamation require profound cultural change, which will need to translate into changes in management practices. Courses, workshops, practices, seminars, exchanges and community volunteering combined with traditional knowledge of these populations and the technical expertise will be implemented to achieve the Project's objectives.

As in the previous cases, TA team should carry out the necessary activities for elaborating a Territorial Resilience Investment Plans (TRIP) that is appropriate to the reality of the community, which will have sustainable management of collective areas of *Caatinga* as the main theme. Thus, the promotion of exchange visits will be important as an element of awareness and a concrete reference for the construction of the TRIP. These initiatives will promote dialogue with communities that are already working with new modalities of CRPS. Training events should also be held, as well as several TRIP workshops.

<u>Selection criteria:</u> communities that have a common use area of around 500 hectares or more.

<u>Investments</u>: Tools and materials for implementing CRPS, nurseries, seedbanks, eco-efficient stoves and biodigesters.

<u>Area</u>: 60 CASM with an average size of 600 ha each (total of 36,000 hectares).

TRIP should also provide for the material investments that will be required to implement sustainable management of these collective *Caatinga* areas. Investment possibilities include:

- <u>Seedlings and seeds</u>. Wherever possible, due to distances and transportation costs, seedling production and seed purchase for these initiatives can be undertaken by nurseries in schools (see the following section).
- <u>Nurseries</u>: Where there are already sufficiently large seedling nurseries that are close to the target areas for revegetation, planting material can be purchased ready for use; otherwise seed will be used to increase the stock of community nurseries to be established with Program support or, in some cases, for direct sowing.
- <u>Seed banks</u>: or through the local collection, in which case local people will be paid to collect the seed, under the supervision of Program technicians, to ensure the quality of the source trees.
- Fences to ensure herd management and pasture rotation.
- Equipment and Tools.
- <u>Eco-efficient stoves</u> (see section 4.2.3 - Eco-efficient stoves). After installing these stoves, communities will be advised to use this equipment. It is not sufficient to deliver the stove, but necessary to teach people how to use it and with what type of fuel.
- <u>Biodigesters</u> (see section 4.2.3 - item Biodigesters).
- Equipment and tools for the development of beekeeping and meliponiculture activities. Beekeeping, both of native species and Apis (Africanized), is an activity that does not require a high initial investment and is accessible to many family farmers. It is based on the rich diversity of native plants of the Caatinga biome and is therefore considered a sustainable and agroecological activity. This is, of course, entirely consistent with the idea of resilient production systems, as beekeeping allows harvesting 'product' from the *Caatinga* while conserving it. The Project will be able to finance beehives, honey extraction tools, clothing suitable for working with bees, etc. The necessary training will also be carried out.
- Extractivism from *Caatinga* fruits (e.g. umbú, caatinga passion fruit, licuri oil, etc.).
- Other investments needed to ensure the smooth running of this activity.

Sub-Activity 1.1.3.2 - Implement CRPS in Schools

Rural schools are where young people, children of farming families, acquire knowledge on various subjects, including rural life and agricultural production systems. The Project will seek to enable these educational institutions to work on CRPS, rational use of water for production, renewable energies, and other climate resilient practices.

In the visits made to different rural schools during the program design mission, it was evident that few institutions work with CRPS, having no place to exercise, teach and learn about the theme. That is why the Program has instituted a subcomponent of investments for rural schools.

Public Schools (municipal or state) and Agricultural Family Schools (EFAs), located in priority municipalities or within a certain distance of the selected communities, will be identified and invited to submit proposals, with the support of technical assistance teams. To be chosen, these schools must:
• Have a permanent supply of water in sufficient amounts to meet agroecological practices needs;
• Have a compatible area for the implementation of climate resilient agricultural practices.

The format of the proposals will be defined in the Project Implementation Manual (PIM). This format should be simple and appropriate to learning and beneficiaries' empowerment. The School Investment Plan should have the participation of school managers and teachers in its development and execution processes. The Project will also implement activities with the cooks who prepare school meals to orient them to the use native fruits and vegetables in their recipes, most of which will come from climate resilient production systems. Such action will enhance food and nutritional security of the children attending such schools, and make cooks (most of them women) aware of the importance of adapting their recipes and changing their eating habits.

Objective: Enable rural educational institutions for youth to experiment and teach CRPS, rational use of water for production, renewable energies, and other resilience practices to students. Target the cooks who prepare school meals, encouraging them to use native fruits and vegetables, reinforcing children's food and nutritional security.
Selection criteria: rural schools within a range of the target areas (section 4.3.2). Preference will be awarded to Family Agriculture Schools (EFAs).
The following activities will be eligible for investments in schools:

- CRPS teaching and experimentation;
- Development and maintenance of nurseries and seedbanks;
- Promotion of entrepreneurship in CRPS; and
- Training cooks and students on the nutritional value of native fruits and vegetables to diversify and enrich diets

Area: 1,000 schools (100 families per school), with 1/10 hectare each (total of 100 ha and 100,000 families.
Investments: Resources to implement CRPSs, such as seeds, seedlings, organic fertilizers, equipment rental or purchase, irrigation systems, tools, fences, nurseries, training materials, computers, etc.

Sub-Activity 1.1.3.3 - Test productive models of Bio saline agriculture

As stated above (see section 4.2.3 - Technical Analysis of the Project's Proposed Alternatives), in the Semiarid, brackish or salty groundwater is common. This happens most often in regions where the substrate is crystalline (which, as seen in section 2.4.2, represents approximately 80% of the semiarid area). The result of this is that around 25% percentage of the wells dug in the Semiarid have brackish or saltwater, unfit for human consumption. It is common in several regions of the Semiarid, more than 40% of the wells have very salty water (> 1,500 mg/l TDS - Total Dissolved Salts). We have also seen that the desalination process produces a 'concentrate' or 'tailings', and the increase in 'tailings' salinity, when compared with that of the source well water, can vary from 20 to 41%.

In this context, the Project will finance the implementation of biosaline pilot production units from the 'concentrate' produced by 24 Freshwater Project desalination plants that have been installed and are operating.

The objective of the activities supported by the Project will be to set up small production units, which should include small areas to be irrigated with the concentrate. In general, the available concentrate only allows for the irrigation of small and collective use areas. In contrast, the availability of water enables intensive production. The productive areas installed by the Project will be oriented to animal consumption and to the production of forage or vegetative material of forage species that have a tolerance to salinity (forage, palm, gliricidia, leucena, sugar cane, forage watermelon). The crop production obtained from biosaline irrigation should enable an increase in the forage potential of the beneficiary families' properties. The salinization of the cultivated soil will be avoided through the use of appropriate practices and technologies: this topic will be specifically monitored by the Fresh Water Project team and EMBRAPA.

For further details on this Biosaline production, see section 4.2.3 - Technical analysis of the alternatives to be worked on by the Project - Biosaline production.

Objective: Develop pilot testing testing of productive activities (agriculture, animal breeding) using effluent from the desalination process, which is currently is not used and accumulate in evaporation tanks.
Selection criteria: communities benefitted from collective desalinization systems
Undertakings: Fish breeding and irrigation of halophyte plants in small areas[208].
Investment: Fish, tanks, irrigation equipment, resources to implement the CRPS[209], soil laboratory tests, etc.
Number of biosaline production systems: 24 biosaline systems, each irrigating 1 hectare and benefiting 50 families (total 1,200 families and 24 hectares).

Activity 1.1.4 – Build a Farmers Network and Promote local entrepreneurship for products and services that support family farming

To facilitate the replication of CRPS, support will be provided: i) TA teams will build a territory-based intervention strategy identifying properties demonstrating exemplary experiences of CRPS and water access technologies and building a network to exchange these good practices; and ii) Small grants and business management support to microenterprises that innovate and produce specific tools and equipment to facilitate the implementation of CRPS.

Improving crop performance, animal breeding efficiency, dealing with a problem, or harnessing a potential, frequently requires new ideas, information and knowledge. Exchange visits can meet information needs and enhance knowledge sharing.

This involves organizing a group of farmers to visit another farmer or group (community, settlement, association, etc.). Thus, in this type of event, the main source of ideas and information for the group needed is their peers. In exchange visits, it is essential to emphasize the notion that peers are an excellent source of information. At the same time, although usually the visit is done to a 'more advanced' group or family regarding, in general, the visitors also discuss and comment on what is being observed. In this sense, the event is a real 'exchange' and not a one-way process. The exchange visit among farmers can often be more effective than courses or lectures given by technicians on the same topic due to the language similarity and experience of real-life situations. For instance, if a settlement is having sanitary problems in milk production, in general, it is more interesting to organize a visit to a group of farmers who have overcome the problem, instead of calling a researcher to talk about the theme.

Sub-Activity 1.1.4.1 - Build a Farmers Network
Farmers who already implement at least one aspect of CRPS will be invited to participate in the project as farmer-trainers. These farmer-trainers should be selected on their farming expertise as well as skills and interest in sharing information. Their selection will not be limited by the criteria of the target group or the size of the property. They can have several roles in the project; from integrating the technical advisory teams, allowing visits to their farms as demonstration plots, or participating in local farmer networks, training and workshops. The Project must be proactive in ensuring that women, as well as men, become farmer-trainers. The farmer-centered extension systems that empower farmers as change agents to improve livelihoods in their communities will be described in detail in Component I.

A good starting point is to discuss with local authorities and farmers to find out about their interest in testing the approach. The next step is to select farmer-trainers. Frequently, extension services and communities (i.e. producer organizations or local authorities) select farmer-trainers together. A common procedure is for extension services to agree on criteria with community representatives, and then the representatives use the criteria to choose the farmer extensionists. Criteria vary but often include having a good reputation, interest and skill in sharing information, climate resilient farming skills, and being a full-time resident in the community

To facilitate the replication of CRPS, TA teams will build a territory-based intervention strategy of CRPS network building. To do this, they will identify farms/properties that have developed attractive/ advanced experiences of CRPS and water access technologies. Frequently, these more advanced cases refer to the farmer-trainers mentioned above. These cases will be essential assets for disseminating information and for bolstering knowledge management on the subject. The following tools will be used:

[208] Hoffman and Shannon, 1985.
[209] Such as seeds, seedlings, organic fertilizers, etc.

Task 1.1.4.1.1 Train Farmers
TA teams will need to be trained in CRPS principles and practices, water access technologies and gender-sensitive approaches (see Annex 8), appropriate for indigenous and traditional communities (Annex 6) and that attract youth.

In addition, farmers who already implement aspects of CRPS will be invited to be farmer-trainers. Their selection will not be limited by the criteria of target group or property size. They can have several roles in the project; from integrating TA teams, allowing visits to their farms as demonstration plots, or participating in local farmer network, trainings and workshops. The Project will ensure both women and men become farmer-trainers.

Task 1.1.4.1.2 Hold exchange visits
Exchange visits are an important source of practical information and knowledge sharing. They involve organizing a group of farmers to visit another farmer or group (community, settlement, association, etc.). Thus, in this type of event, the main source of ideas and information for the group needed is their peers. In exchange visits, it is essential to emphasize the notion that peers are an excellent source of information. Although usually the visit is done to a 'more advanced' group, it is not a one-way process, because visitors discuss and comment what is being observed. These initiatives are often more effective than courses or lectures on the same topics due to language similarity and experience of real-life situations. For instance, if a settlement is having sanitary problems in milk production, in general, it is more interesting to organize a visit to a group of farmers who have overcome the problem, instead of calling a researcher to talk about the theme.

Although exchange events are communication spaces among peers, this does not mean that the TA present needs to stay silence. Sometimes, a question about a subject that has not been well explained can be fundamental.

Farmers from 5000 medium-sized farms (at least 5 hectares) located in the project's region will be invited to participate in the exchange visits. There will be an active participation of Young Communicators will have an active role participating in these exchanges (see activity 6.1).

Messaging apps are widely used in Brazil and can be applied to bridge communication gaps in farming communities. TA can create and manage online social-media groups to share experiences on specific topics and solve problems promptly. These groups can further the sharing of the knowledge learned in the exchange visits.

Sub-Activity 1.1.4.2 Promote local entrepreneurship for products and services that support family farming

Most small-scale products and tools available to farmers are directed towards traditional large-scale monoculture, creating a vicious cycle that makes farmers turn to non-resilient production practices. Specialized small-scale equipment and mechanization can make farmers more productive and able to add value to their production.

The few scattered farmers who dare challenge the model must develop or adapt their own tools. During visits to Bahia and Pernambuco, the design team witnessed several examples of these innovations: forage palm chopper and feeder, long-arm pruning shears, wood chipper, and low-tech water reuse facility, among others. This thriving creativity and potential demand face high barriers to their widespread use. Microentrepreneurs in this sector are mostly small and lack the management capacity for commercial financing, making efforts to scale up or even start their businesses nearly impossible. Their innovations usually never go beyond their plot.

With greater access to capital – especially capital with management assistance and sustainability conditions tied to it – microentrepreneurs with businesses that have a direct impact on climate resilient agricultural production can scale up their operations and influence family farmers beyond the project's direct beneficiaries to improve their practices. A dynamic business environment can also attract youth.

The project will support investment in small-scale mechanization of microenterprises[210] that provide services or products for improving family farmers' CRPS thereby enhancing rural entrepreneurship. Small grants may support microenterprises that innovate and produce specific tools and equipment, nurseries, composting services, apps to manage production, organic fertilizers, pest control, and market platform, etc. These enterprises will also receive business management support. The GCF grant will cover the incremental costs associated with higher-than-average screening, evaluation and technical assistance costs of the fund's investments. Additional funds could possibly be raised as co-financing from financial institutions to amplify the number of beneficiaries.

This initiative would be the first institutional effort to invest in product and service providers, specifically for climate-resilient small-scale agriculture practiced by the beneficiaries of the project. The success of the project will have an important demonstration effect with respect to the feasibility of such projects to other regions of the NEB semiarid.

Expected results of **Component 1** include:

- 575 TRIPs designed and approved;
- 31,000 families benefiting from Family Farms Investments and TA;
- 36,000 families benefiting from backyard gardens investments and TA;
- 1,000 schools teaching CRPS;
- 1,800 families from 60 communities benefiting from CASM;
- 540 eco-efficient stoves installed;
- 540 biodigesters built;
- 540 income-generating and resilient production-based activities in collective areas;
- 1,200 families benefiting from 24 biosaline productive systems;
- 5,000 medium-sized (at least 5-hectare) productive units participating in farmers networks;
- 550 TA and farmer trainers trained;
- 24,000 farmers participate in exchange events / workshops;
- 84,124 hectares under sustainable management;
- 11 $MtCO_{2e}$ emissions reduced; and
- 70 micro enterprises supported to supply small-scale equipment for CRPS.

4.3.6 COMPONENT II –Water Access

Compared to other semiarid regions of the world, where it rains between 80 to 250 mm per year, the Brazilian semiarid is the wettest on the planet. In the latter, the average rainfall is between 300 and 800 mm. annual. Rainfall concentrated in a few months of the year and distributed unevenly throughout the semiarid.

As is natural in the semiarid regions, this rainfall is lower than the evaporation rate, which in the Brazilian semiarid region can reach up to 3,000 mm per year. This causes a challenging water deficit for those living on agriculture and livestock in the region. This challenge has been addressed by farming families by storing rainwater in diverse social technologies. Accumulated water is for human consumption as well as for agriculture and livestock use.

The purpose of this component is to disseminate practices of efficient water capture, harvesting, storing and use to decrease vulnerability of livestock and crops to rainfall irregularity and prolonged droughts. All investments in this component will be channeled through TRIPs (see sections 4.3.3 and 4.3.4) for beneficiary groups (to be defined as per section 4.3.2). Component 2 beneficiaries are the same families that will implement the backyard garden (described in activity 2.2 of component 1) but do not have water for production. Using the extra stored water for irrigating small plots of land will enable the diversification of production, mainly with fruits and vegetables, for family consumption and to sell surplusses.

The resource allocated to this component will fund widely proven use of social technologies and water access and treatment practices, complementing and reinforcing Component I Climate Change Resilient Productive Systems (CRPS). articulates around the following four axes:

- Rainwater harvesting and storage;
- Groundwater storage;

[210] According to Brazilian Law, microenterprise is defined as a company with a annual gross revenue lower than R$ 360.000,00.

• Reuse of domestic waters (gray and dark);

We identified a set of technologies, which are already widely known (called Social Technologies - STs), which already have MDS Operating Instructions (OIs). In addition to detailing the construction and use characteristics, the existence of IOs explains that public and private technical advisory entities already have a good knowledge of the implementation and enhancement of these infrastructures. This is a critical factor in the planning of the Project execution that should allow a quick implementation. However, the Project will also work on proposals that are not yet 'standardized' through normative instructions, such as green septic tanks.

Investments made in order to guarantee access to water will encourage the maintenance of small irrigated areas, in which vegetables, fruits or fodder can be cultivated. It will also allow irrigation of nursery for seedlings production (family or collective) to increase the productive potential of beneficiary families, strengthening their adaptive capacity to climate change. Irrigated areas can be more intensively used and have the following comparative advantages in relation to productive systems conducted without water supply (predominant in the Brazilian semiarid):

- They are enclosed areas to avoid the presence of free-range animals during part of the year.
- They are small areas (with less than half a hectare) when compared to the total surface of properties.
- They receive a larger and more regular amount of fertilizers (compounds, manures), and irrigation allows a relevant valuing of this fertilization (risk reduction).
- Irrigated areas mainly destined for forage production with perennial or multi-cycle species[211] can reach high productivity of green matter per hectare per year, guaranteeing fresh food to the herd and decreasing the pressure on native vegetation particularly during the dry season.
- The intensification of production allowed by the use of water promotes an increase in the diversity of created and cultivated species.
- Access to water allows farmers to produce in a regular manner throughout the year providing revenue and green/fresh food (not only for the family but also for the herd). This is a significant differentiation particularly during the dry season when other productive activities are limited.
- The production intensification in these areas tends to mobilize familiar labor force, women and youth, in particular, throughout the year. This kind of infrastructure is generally built close to housing.
- Part of the production of these areas is for family feeding, bringing diversification and improvements in daily nutrition (that often includes cultivating medicinal plants) and increases in food and nutritional security. This aspect is strengthened by the production, which will be carried out following Agroecology principles.
- Cultivated areas, even if limited, generally allow part of the production to be commercialized directly, usually in the neighborhood and in local food markets, contributing to income generation and diversification.

They also favor the introduction of new practices and are, thus, learning spaces.
The TA provided to beneficiaries will address issues of efficient water management, good irrigation practices, and techniques for limiting evapotranspiration, and precautions to avoid soil salinization. All pumping systems will use renewable energy (photovoltaic or wind). The installation and good use of these technologies will require a training program. The techniques used in all these cases include principles and practices laid out in CRPS (see ANNEX I), such as wind-breaks, soil cover (dry or green), the association of complementary crops, etc.

All water infrastructure methodologies selected in the PCRP are widely disseminated in NEB and are extremely simple to build, known in Brazil as “social technologies”. Construction of the water infrastructure technologies listed below is usually carried out by trained community masons, beneficiary families, and their neighbors with oversight from TA teams. In addition to creating an activity for local workers, it also ensures future maintenance of the cisterns without relying on outside services. Technical training and training in water management will be systematically provided in association with the construction process.

[211] Such as forage cactuses (‘*palma forrageira*’), gliricídia, sugar cane and sorghum.

Through the use of water technologies, the project will deliver *Output 2.1 Improve water access to family farmers and traditional communities to reduce the impact of severe droughts by investing in small-scale technologies for harvesting, reuse, treatment and storage.*

TRIPs should include water access technologies. Before starting the activities, it will be necessary to hold a set of training events. The first of these is for the training of masons who will make the construction/implementation of water infrastructure. Training events should also be held for beneficiary families on water infrastructure management and water management for production. Exchange visits will also be encouraged to meet other families who are already working on agroecological production from water catchment and storage.

The construction will be organized by the TA teams and carried out by local artisans (masons, etc.) and families.

Activity 2.1.1 - Build boardwalk cisterns[212]

Objective: To provide access to water for the production of food, seedling and/or animal water consumption.Investment: Materials for the construction of cisterns; irrigation equipment; tools and materials for implementing CRPS. Construction of a plate tank with a storage capacity of 52 m^3, coupled with a 200 m^2 concrete water-catchment area (the boardwalk or *calçadão).*Application: Irrigation of small plots (such as backyard gardens, school vegetable gardens, etc.) to support short cycled crops (mainly vegetables) during the dry season. The role of women in this production is fundamental. Impacts on family food security and nutrition are significant.
Total: 20,000 cisterns.

Sub-activity 2.1.2.1 Build small farm ponds [213]

Farm ponds are excavated reservoirs with narrow, deep vertical walls. They allow the storage of at least 500 m^3 of water and should be between 3 and 5 meters deep, to reduce evaporation and keep the accumulated water longer. It collects surface run-off water, often with the help of conduits or ditches. Requires compacted soils to decrease infiltration. To reduce evaporation and seepage losses, when the distance allows it, water from the barrier can be pumped to a production tank. In the construction process, a backhoe should be used to reach the beginning of the rock layer.

Objective: To provide access to water for food production and animal water nutrition.
Investment: Small-width deeply excavated reservoirs that store at least 500 m^3 of rainwater to reduce evaporation and retain water for longer periods.
Application: Requires clay soils to avoid infiltration. It usually is capable of storing a large quantity of water that, if well managed, can last several months without replenishment. It has the potential to irrigate a larger system (up to 1 ha.), making the cultivation of some short-cycle crops possible. This can be managed so as to help install a CRPS (see Component 1).

Total: 500 farm ponds.

Sub-activity 2.1.2.2 Construct small groundwater storage basins[214]

The program will finance the construction of underground dams. This Social Technology (ST) is a cross-sectional blocking system for riverbanks, streams and temporary streams, accomplished by attaching a flexible plastic blanket to an excavated ditch until it meets the crystalline or waterproof thickening, which is a rocky layer characteristic of a large part of the Brazilian semiarid soils. Its function is to retain rainwater that seeps over into the soil intervals, providing the formation or elevation of the water table. Upstream and near the dam

[212] This refers to large cement-plate cisterns, with a concrete catchment area, that is known in Brazil as 'cisterna calçadão' (or 'boardwalk cistern' in a very literal translation). See Law number 12.873, dated October 24, 2013. Decree number ~~8.038 of July 4, 2013~~ 9606, of December 10th, 2018 and Operational Instruction SESAN no. 11, of September 6th, 2017.
[213] Instruction regulated by Law 12,873 of 24 October 2013, Decree number 8,038, of 4 July 2013 and Ordinance number 130, of 14 November 2013.
[214] This kind of water storage infrastructure is known as a 'barragem subterrânea' (underground dam, in a literal translation).

should be built a waterfall well, lined with concrete rings, bricks, stones or plates, to better use the water stored in the underground dam.

Investment: Construction of small underground dams through a transversal blocking system along temporary streams and river banks, with flexible plastic sheeting lining a trench (from the surface to rock or impermeable layer).

Application: Capable of irrigating larger areas and storing a significant quantity of water for several months.

Area: 500 small underground dams.

Activity 2.2.1 - Implement treatment and reuse systems for household wastewater

For rural families, untreated water represents risks to the environment, soil, and human health. Only 27% of the NEB population (mostly in urban areas) has access to sewage collection and treatment.[215] The treatment systems selected use simple and affordable technology based on cycling water and nutrients for food production. These technologies adapt forms of rural sanitation to the household level and contribute significantly to the sanitary improvement of environmental and living conditions of beneficiary families.

Sub-activity 2.2.1.1 Implement systems for greywater reuse

Investment: Construction of a treatment system which consists of filtering greywater residues through physical and biological mechanisms, in which organic matter is biodegraded by microorganisms and earthworms.

Application: Irrigate small plots, such as backyard gardens and nurseries. It avoids pollution Area: 10,000 greywater treatment systems irrigating 1/5-hectare plots (2000 hectares total).

Sub-activity 2.2.1.2 Implement green septic tanks

Investment: Construction of evapotranspiration tank (or green septic tank). Anaerobic digestion, which occurs in septic bed, consumes organic matter from household waste in the root zone of the plants.
Application: Can irrigate trees (usually banana trees, which are part of the treatment systems) and non-edible plants.
Area: 5,000 blackwater treatment systems irrigating 0.05-hectare plots (250 hectares total).

Expected results of **Component 2 include**:

- 20,000 cisterns with walkway;
- 500 trench barriers;
- 500 small underground dams;
- 10,000 greywater reuse systems;
- 5,000 blackwater treatment systems.

4.3.7 COMPONENT III – Knowledge Management and Scaling-up

Component 3 supports and expands on the activities in Components 1 and 2. The activities described below will be explored in the project so that information flows serve both to consolidate learning among families who will experience new approaches in CRPS and water access as well as to scale to a regional and international level the adaptation and mitigation measures that the project will propel. Cross-cutting activities supporting Components 1 and 2 that require central coordination are described below. Strategies developed will drive upscaling and deliver ***Output 3.1 CRPS and small-scale water harvesting system disseminated in the NEB semiarid and abroad to increase climate resilience of vulnerable communities.***

[215] Instituto Trata Brasil, see: http://www.tratabrasil.org.br/saneamento/principais-estatisticas/no-brasil/esgoto

Activity 3.1.1. Raise awareness and build capacities of women, youth and traditional communities

This activity combines several strategies: (a) highlight the leading role of youth and women as 'knowledge managers and generators and 'local talents'; (b) consolidate laboratories for learning, exchange and replication of sustainable practices within communities through diverse written and audiovisual mechanisms; (c) facilitate dynamic M&E of socio-environmental impacts, which will be registered in materials that allow effective influence in spaces dedicated to public policymaking.

Sub-Activity 3.1.1.1 - Develop a young communicators network

A total of 450 young people will be selected to participate in a media resource empowerment program, focusing on successful experiences in accessing water resources and CRPS. Besides being responsible for registering activities and facilitating the production of audiovisual and written materials, Young Communicators (YCs) will act as “social mobilizers”, fulfilling a crucial role in social organization processes.

Another important initiative in which YCs will take part, together with the farmers’ network (see activity 4.1), is the construction of a participatory monitoring model with audiovisual resources.

Local and regional exchanges between young communicators will be promoted. YC will work closely with TA teams and community-based partner organizations. Each will receive a scholarship through a "learning grant" and have access to equipment (mobile phones and notebooks).

Sub-Activity 3.1.1.2 - Strengthen capacity for women, youth and traditional communities

All educational activities (workshops, courses and exchanges) will follow a “learning by doing” approach that explores experimentation of alternative technologies and information exchange among community members. Given that women, youth and traditional communities tend to be on the margin of community-based organizing efforts, the Project will prioritize capacity-building opportunities directed especially towards these groups.

(a) **Rural women**: The Project strengthens capacities of rural women as part of an encompassing Environmental Education program, which explores the connections between feminism, women’s rights, the Semiarid region biomes, agroecology and food and nutritional security.

(b) **Youth**: In addition to YC networks, youth will be involved in short-term professional courses, with a focus on the diversity of production systems and CRPS. Then they will be incorporated into TA teams and serve as liaisons with families.

(c) **Traditional communities**: Implementation of sensitivity training for TA professionals on issues of race and ethnicity, with focus on methodological approaches and instruments that consider the relationship these communities have with natural resources and their land management techniques. The second line of action involves conducting case studies of traditional communities.

Activity 3.1.2. Drive scaling-up, unlock policy barriers and experiment with CRPS and resilience participatory monitoring model

Sub-Activity 3.1.2.1 - Promote South-south Cooperation (SSC)

Another aspect of this Project involves developing capacities by sharing knowledge, skills, resources and technologies among countries through the construction of a more horizontal relationship of solidarity than the classic "North-South" cooperation. These Project activities will be coordinated by the Central Project Management Unit (CPMU). At the start of implementation , possible exchange sites inside and outside Brazil and the systematization methods to be prioritized will be identified. In addition to TA team members, farmers will be invited to participate. The Project will invest in the construction of a database cataloguing the practices and technologies for proper management of natural resources that have been identified in these different contexts.

Sub-Activity 3.1.2.2 - Facilitate discussions to unlock policy barriers

Several policies that are constraining family farmer's CRPS were identified during project design. The most notable include:

a) lack of an Environmental Reserve Quota (CRA inPortuguese) market, and
b) norms and regulations preventing family farmers from accessing markets.

As recommended by the World Bank,[216] establishing the CRA market could provide additional incentives for family farmers to increase the area covered with the Climate Resilient Agriculture Systems laid out in the project. A CRA credit produced on a beneficiary's property could be used to offset a legal reserve (RL) debt on another property within the same biome, preferably, the same state. The RL debts represent obligations acquired by ay given farmer that can be efficiently offset by environmental improvements produced by smallholder farmers with CRPS, thereby generating a transfer payment from the RL offender to the smallholders. Implementing a State CRA could create a market for forested lands, adding monetary value to a preserved *Caatinga*. Given the high costs of *Caatinga* restoration/reforestation, the exchange of CRAs could become an effective way to facilitate Forest Code compliance, meeting NDC targets and avoiding deforestation of surplus native vegetation.

Concerning norms and regulations for marketing family farming agricultural produce, the Committee on World Food Security and FAO (2016) recommend governments employ public policy to support family farmers in issues such as pricing policies, public procurement, food safety and standards, and appropriate credit and infrastructure. Family farmers in Brazil are affected by the top-down imposition of food safety standards designed to respond to large-scale, mechanized and standardized commodity-based food production for large distribution channels. As a consequence of these entry barriers, family farmers revert to informal markets with lower demand and prices.

The project will facilitate discussions in fora geared towards marketing and market access for family agriculture. The proposal is to take advantage of existing organizational structures, reinforce them and create new ones when necessary. These working groups should involve a broad set of stakeholders (e.g., project beneficiaries, NGOs, the private and public sectors) and develop a roadmap to implement the CRA markets and improve the regulatory conditions for family farmers' access to markets. In addition, it will commission research on targeted policy and regulatory issues.

To qualify inputs produced in these forums, aimed at influencing public policymaking, materials (publications and videos) will be produced that present results of the actions undertaken, in accordance with the progress indicators used in the M&E system. These publications, that present concrete social, environmental and economic outcomes of transitioning to a model of family farmer CRPS, can influence public opinion, thereby contributing to the 'scaling up' process.

Sub-Activity 3.1.2.3 - Experiment with CRPS and resilience participatory monitoring model

Since the transition to CRPS is gradual and its social, economic and environmental impacts are not immediately perceived, there is a need to build a monitoring methodology that demonstrates and gives visibility to transformations promoted during implementation.

Therefore, the proposal is to develop a specific monitoring methodology, guided by some indicators, that can be used to monitor CRPSs in each territory, so that a picture may be drawn that clearly captures the changes in the flows of inputs and resources, in addition to the effects on the environment and social relations in these time frames. The Central Management Unit (UCGP) will coordinate this action at the regional level, being responsible for conducting workshops to train Young Communicators and other members of the TA teams in methods of participatory systematization and monitoring that are suitable for CRPS. Audiovisual media instruments, such as video and photographs, will be of great value in recording the evolution of CRPS, by allowing clear visualization of the socio-environmental transformations that will occur during the intervention period.

[216] WORLD-BANK. **Brazil's INDC Restoration and Reforestation Target.** Washington, DC: World Bank 2017.

An independent closing evaluation and mid-term review is part of the project. Activities will be developed at national and state level as follows:

Sub-activity 3.1.3.1. PMEL at National level, undertakings include: building-up an information platform based on systematizations and innovation experiences, 12 GIS evaluations (4 at start-up, 4 at midterm and 4 at completion), contracting yearly M&E, IT and Communications services, preparing the Project Completion Report, carrying out M&E meetings and planning workshops (one per year) and elaborating 4 Studies, Systematizations and other Knowledge Management products (2 at mid-term and 2 at completion).

Sub-activity 3.1.3.2. PMEL at State level, undertakings include: 12 Studies, systematizations and other Knowledge Management products (4 per State), 21 planning workshops, 21 M&E meetings and 21 Territorial Committee Meetings (1 per year per State). It also involves elaborating the baseline study, mid-term review and impact evaluation including the PRO-WEAI and MDDW Study. Finally, the M&E system at the State level includes 3 more State-specific studies.

Systematizations will be published and subsidize political advocacy processes, reaching external stakeholders, such as public managers and institutions working on related topics.

Activity 3.1.3. Plan, Monitor, Evaluate and Learn (PMEL)

More details in Annex 11

Expected results of **Component 3:**

- 54 workshops for young social communicators;
- 100 systematizing workshops;
- 9 state exchanges;
- 36 regional exchanges;
- 414 youth benefited with scholarships and communication equipment;
- 70 newsletters and informative reports produced;
- 300 training workshops for women about sustainable technologies;
- 360 territorial meeting for women;
- 12 exchange programs for women;
- 27 training workshops of gender experts;
- 243 training workshops for youth;
- 4 national learning routes;
- 3 international learning routes - LAC and Africa;
- 8 thematic studies;

5. ECONOMICAL AND FINANCIAL ANALYSIS AND SUSTAINABILITY

5.1 Introduction to EFA analysis

The current chapter summarizes the main assumptions, hypothesis and results of the Project´s economic and financial analysis (EFA). The profitability indicators were calculated taking into account the outcomes, phasing and expected beneficiaries for each type of activity. Benefits were calculated for a 20-year period lifetime cycle as the project involves agroforestry and natural resource management activities with both short and long term results, requiring an extended period of analysis.

The economic and financial analysis consists of comparing the resources required for the project´s implementation (represented by the project costs) with the expected impacts calculated as the benefits of each promoted activity. It is conducted from the point of view of each beneficiary (financial analysis), but also aggregating and calculating the benefits for the Brazilian economy.

The financial analysis allows understanding, based on behavioral hypothesis and parameters, if potential beneficiaries will be motivated to take risks and make the investments required by the Project. It implies the simulation of the incentives and benefits at the individual level (or even in groups), but also to make sure that the beneficiaries will have the means to take on the project´s proposal, with a realistic approach by making assumptions on the delays in adopting technologies and on drop-out rates for entrepreneurship initiatives.

The economic analysis considers all the costs and benefits of the Project. It allows evaluating the global efficiency in resource management for the government and society as a whole. The analysis is based on the aggregation of the results derived from farm models using economic prices and adding externalities (that will be represented, in this case, by the environmental benefits from avoiding CO2 emissions).

Both in the financial and economic analysis, each initiative will be considered profitable if the additional benefits of the project's cash flows (over a 20 year period) surpass investment and recurrent costs at a cut-off rate. As a result, profitability indicators will be the Net Present Value (NPV, economic and financial), the Internal Rate of Return (IRR, economic and financial) and the Benefit-Costs ratio (B/C, both economic and financial). A sensitivity analysis will test the vulnerability and robustness of the obtained results for changes in key economic variables.

The first part of the chapter summarizes the sources of the project´s benefits (both measurable and not measurable) as well as the main assumptions and hypotheses made. Thereafter, the financial analysis is presented, which analyzes the proposed models and the corresponding expected benefits. In the end, aggregated benefits (with externalities included) will determine the overall economic profitability and the sensibility of the results in the face of adverse shocks and climatic events.

Estimates and calculations were made using information obtained in field visits, and consultations with experts. Other references were also used, including current agroforestry experiences records and M&E tables. Nevertheless, as far as the proposed activities are not still disseminated among beneficiaries, the models still represent a theoretical construction, that will need to be demonstrated in the field.

5.2 Market analysis

Market options can be found at the community level, local fairs or markets and intermediaries or at the regional or international level for niche products or commodities. Most of the increase in production will be consumed locally, and the presence of imported and non-regional food signals that the local markets have the capacity to absorb increased production. In this context, technical advisory services will provide support in orienting the production towards demand, linking farmers to buyers, local processing units (fruit, milk, honey, meat) and other markets by developing local and regional networks and facilitating the farmers' participation in trade fairs, as well as in federal or subnational level programs supporting purchases from family farmers (like PAA and PNAE).

Eggs, milk, fruits and vegetables, forage and meat (goat and beef), and diverse types of tree products are the proposed products to be marketed. The extent of the additional production for the market has been estimated in the production models in the economic and financial analysis, versus the business as usual scenario. In general, these models indicate that the proposed production systems are viable. The Project will be implemented under a demand-driven approach.

Nine models are proposed in this chapter, based on the most frequent products, simulating the Project´s proposal and impacts at the individual level. However, the aggregation in production estimates may not provide an accurate source of information to compare with an implicit demand for those products. Besides, a differentiation process can be found with higher prices in the market for eggs, chicken, honey and vegetables from family farming, because they have qualities recognized and valued by consumers both at the local and regional levels. Competitors are processed products from the agribusiness production, that can be cheaper but are not preferred if local production is available (for health and flavor reasons mostly).

The following sections present the market potential for family farming in the Northeast, in selected value-chains.

5.2.1 Goats and sheeps

The Northeast accounts for more than 90% and 56% of the total national herd of the goat and sheep, respectively. The two activities are typical in the Northeastern Semiarid, with predominantly extensive breeding systems for meat production. The main destination of the meat is local consumption. Family farming predominates in the number of goat farms (228 thousand, or 91.6% of the total) and in the number of products sold (1 million heads, or 77.1% of the total). Even though non-family enterprises are a small minority in quantity in the region (8.4%), their revenues from goats and sheep reach 22.9% of total sales. It is important to point out that, when considering the semiarid region as a whole, goats and sheep are, by far, the main production of family farms of the region.

5.2.2 Poultry farming – egg production

Egg production in Brazil reached 44.2 billion units and exports in the same period were 5,834 thousand tons[217]. Even if production is mainly destined for the local market (which currently has the highest per capita consumption in history), new international markets (such as South Africa) have opened up in the last years, which may generate new production challenges. According to the IBGE Egg Production Survey for 2017 and the *Banco do Nordeste Diário Econômico* Bulletin (May 2017)[218], the Northeast accounted for 14.3% of egg production in the country in 2016, with 442.44 million dozens. In the region, "(...) the states of Pernambuco and Ceará, concentrate approximately 65% of the regional production, with 152.40 million and 134.90 million dozen eggs in 2016, respectively." According to Guanziroli et al.[219], based on IBGE (2006), family farmers in the region recorded a gross value of poultry and egg production (29.7%). The highest participation of family establishments in the Gross Value of Production of birds and eggs was recorded in the States of Maranhão, Alagoas and Piauí.

5.2.3 Cassava (or manioc)

Cassava root production is made almost entirely by family farming and has experienced a 47.6% drop in the Northeast region in the last 10 years and generated the need to purchase cassava and its derivatives from other regions for the domestic market. However, the area has market potential since it is the destination of 12.9% of manioc starch production of other regions. In addition, there are small factories that are the family enterprises, considered as a possible up-grade in the value chain of cooperatives or associations of family farmers who seek to add value. Both family enterprises and large industrial plants can diversify production (with flour, scrap, biscuit, etc.)

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[217] ABPA. **Relatório Anual 2017**. São Paulo: ABPA. Available at: http://abpa-br.com.br/storage/files/3678c_final_abpa_relatorio_anual_2016_portugues_web_reduzido.pdf 2017.
[218] Available at: https://www.bnb.gov.br/documents/1342439/1603204/196_18_05_2017.pdf/578f9de7-a572-04d2-3777-372cc5d4fb00.
[219] GUANZIROLI, C.; DI SABBATO, A.; VIDAL, M. D. F. **Agricultura Familiar no Nordeste: uma análise comparativa entre dois censos agropecuários**. Fortaleza, CE: Banco do Nordeste do Brasil, 2011. 172 p.

In the last ten years, Brazil was the second-largest producer of cassava starch with a production of more than 360 thousand tons a year, on average, and in 2017, 261 thousand tons of starch were processed in the country due to the low root supply[220]. However, it has small participation in the world transactions with annual imports that still surpass the exports.

5.2.4 Honey

Although Brazil is among the top ten exporters of honey in the world, it is also one of the lowest consumers (0,09kg per capita[221]), and more than 60% of total production was destined for export in 2016. The Northeast, which produces 26% of the country's honey, mostly by family farmers. Northeastern honey is considered of superior quality due to the region's low humidity (which inhibits diseases in bees) and its lower use of pesticides when compared to other regions. In the Northeast, the states with the best results are Bahia and Piauí. In the northeast, beekeeping is an eminently family farming activity and often serves as an additional source of income. Almost all producers, family or not, relate to cooperatives in one way or another, thus necessarily going through similar commercial channels.

5.2.5 Opuntia forage cactus

Brazil is the world's largest producer of forage *Opuntia and Nopalea*[222] cactuses. It is a strategic food resource for the arid and semiarid regions of the Brazilian Northeast since it is a crop that presents a unique physiological aspect, supporting long periods of drought. It is estimated that there are around 500 thousand hectares of forage cactuses in the Northeast, distributed in the states of Pernambuco, Paraíba, Alagoas, Rio Grande do Norte and Bahia. More recently, these forage cactuses are also being planted in Piauí and Ceará.

In Brazil, the *Opuntia* and *Nopalea* cactuses are used almost exclusively for fodder, since species without thorns have been selected.

5.2.6 Sisal

The leaves of sisal produce a highly resistant fiber that is used to create handicrafts, brooms, bags, hats, strings, mats and rugs. It can be used as well in the production of cellulose for the production of kraft paper (high strength) and other types of thin paper (for cigarette, filter, dielectric paper, sanitary napkin, diaper, etc.). In addition to these applications, it is possible to use sisal fiber in different economic branches or sectors: the automobile sector, furniture, home appliances, geotextile (for use in protection of slopes, in agriculture and road cladding), in the polypropylene blend, as a substitute for fiberglass (in the composition of plastic objects) and civil construction[223].

The by-products of sisal, which today are practically considered waste, can have numerous uses. Mention should be made of the possibility of using mucilage as a food supplement for cattle and goats; as an organic fertilizer and juice, which is rich in ecogenin, a drug used as a medicine and can be used as a bioinsecticide for the control of caterpillars of nematodes and ticks, in the shape of soap and healing paste. The substrate resulting from the processing of sisal can also be used for the cultivation of edible mushrooms. Sisal has an important place in the exports of states such as Bahia.

The main importers of Brazilian sisal are the United States (manufactured fiber, mainly in the form of carpets), China, Mexico and Portugal, among others. There are also smaller-scale buyers such as the Netherlands, Spain, Germany, Hong Kong, France, Singapore, Chile and Belgium. The Brazilian fiber faces some problems to enter the world market because of the quality, which is much lower than the African one, which has a market value far superior. Even so, there are good prospects for the sisal sector. Despite the strong presence of

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220 FELIPE, F. I. **Conjuntura e perspectivas para o mercado de mandioca e derivados**. São Paulo: CEPEA - Esalq/Usp, 2017. Available at: http://www.agricultura.gov.br/assuntos/camaras-setoriais-tematicas/documentos/camaras-setoriais/mandioca/2017/40a-ro/apresentacao_camara_setorial_agosto.pdf.

221 FAO. **The State of Agricultural Commodity Markets 2018. Agricultural trade, climate change and food security.** Rome: FAO, 2018. Available at: http://www.fao.org/3/I9542EN/i9542en.pdf.

222 SANTOS, D. C.; FARIAS, I.; LIRA, M. A.; SANTOS, M. V. F.; ARRUDA, G. P.; COELHO, R. S. B.; DIAS, F. M.; MELO, J. N. **Manejo e utilização da palma forrageira (Opuntia e Nopalea) em Pernambuco**. Recife: IPA, 2006. 48p. (IPA. Documentos, 30).

223 ALVES, M. O; SANTIAGO G. E; MOREIRA LIMA, A. R. **Diagnóstico Socioeconómico do Setor Sisaleiro do Nordeste Brasileiro**, Fortaleza. Serie Documentos do ETENE. Banco do Nordeste, 2015.

synthetic fibers in the market, the requirement for natural fibers is still present. The sisal fiber can be exported as prepared sisal, cables, ropes and twine, yarn and rugs.

The new applications related to uses in the automotive industry. Another possibility of using sisal fiber is in the furniture and construction industry. The main competitors are the other plant fibers, so there is a challenge for the Sisal Sector to improve quality and reduce inefficiencies among the value chain.

5.2.7 Market constraints

Once the increase in production occurs, access to the market could be a challenge for small producers. Some identified problems in the selected value chains are:

(a) weak bargaining power and higher transaction costs due to the problems in supply capacity, scale and timeliness,
(b) inefficiencies due to inadequate technologies for processing,
(c) low access to marketing services and packaging,
(d) higher post-harvest losses due to improper transportation and storage facilities.
(e) higher exposure to climate change

Those issues weaken family farmers' capacity to comply with minimum standards and requirements to reach value-added or niche markets.

For the fruit and forage tree products, there are additional problems concerning the development of the value chain itself. There is a lack of information on proper technologies, prices, buyers and standards. However, it means that there is still room for family farming to participate in shaping those channels obtaining a better bargaining power and position in the value chain. This could elevate the level of risk involved, but the gains could be higher as well.

To counter these risks, the Project, through TA, will strengthen farmer groups to market their products jointly and link them with existing storage and processing units, such as cooperatives and other private sector companies. The TA provided will also support farmers in identifying demand and possible additional outlets.

5.3 Financial analysis

5.3.1 Parameters and assumptions

The financial analysis considers the costs and benefits for adopting the project´s proposal from the individual perspective over the period of 20 years (including the program duration of 8 years).

Models.
Nine models were developed to simulate impacts for each type of intervention on each targeted group of beneficiaries. For Component I, eight models are proposed. Benefits and savings from Biodigesters and Efficient Stoves are considered separately. For these models, benefits are based on promoting Agroforestry practices and technologies in order to increase resilience and productivity for each forage production ecosystem, improving income generation and reducing the environmental pressure. All measurable benefits arise from addressing several problems such as: (i) decrease in incomes as a result of increased costs of forage purchases when a climate change event occurs; (ii) decreased productivity due to the high pressure on native grazing; (iii) expansion of degraded lands and unsustainable practices in collective areas.

For Component II, there are three models to illustrate the range of activities that could be developed by the targeted beneficiaries. In this case, both quantitative and qualitative benefits are expected from the Project's intervention relying on two axes: (a) Increased access to water for production by implementing tested social technologies; (b) the transition in agricultural practices to a new productive and resilient model with impact on food security and climate change mitigation.

Direct outcomes are expected to come from an increase in the land area that will be recovered under the new approach, as well as increased productivity, sales and incomes for the family farms involved.

Qualitative benefits rely on (i) social-capital enhancement and improved cohesion to increase empowerment of targeted groups, (ii) improvements in food security, nutrition and health by increasing self-consumption of more in-farm natural fruits and vegetables.

As mentioned before, the analysis made in this chapter stem from farm models, that will be presented in sections to follow. Yet, even if the models used in this EFA assume the existence and importance of certain types of activities and try to recognize some possible effects and impacts, the Project acts over an uncertain and diverse reality of family farmers, so none of these main activities in the models should be considered mandatory in order to apply for proposals during implementation. On the contrary, the identified support 'mix' of investments that were included in the models could guide a possible list or menu of flexible Agroforestry packages for each type of environment, context and family that is benefited (given the categorization that was used in this exercise).

Models, sectors and products for the '*with* and *without* project' situations have been selected by applying the following criteria for the Northeast Semiarid: representativeness (for the '*without* project' situation) and climate change adaptation impacts, scaling-up potential and pro-poor, pro-more-gender-equality and pro-youth propensity for the proposal (for the '*with* project' situation).

Aggregation.
All of the models are supposed to be progressively involved in the project´s proposal from year 1 to 8. That´s why 100% of benefits will be considered after year 8. However, the 75% success rate is applied while aggregating in order to illustrate the case better when beneficiaries get lower impacts or dismiss the project´s proposal during the first 4 years.

Resilience.
In forage production models there is a simulation of a climate change event that shocks the productivity every 5 years (60% of losses), low down the breakeven (5%), and has increased impacts without climate change adaptation measures. In the 'w*ith Project*' simulation, adaptation measures would allow cushioning the blow (15%), recover the breakeven and turn over the increase in impacts. All the assumptions are very realistic in order to avoid overestimation of the project´s benefits.

Time span.
The financial analysis prepared for the Planting Climate Resilience Project considers the costs and benefits for adopting the project´s proposal from the individual perspective over the period of 20 years (including the program duration of 8 years).

Prices.
Prices in Brazil are determined by the market. References have been taken from local producers, suppliers and retailers, verified with the official and private open information platforms for selected products.

Interest and financial discount rates.
The average local Interest rate for domestic credit in the past 5 years is shown in the table below. The financial discount rate is considered at 10%.

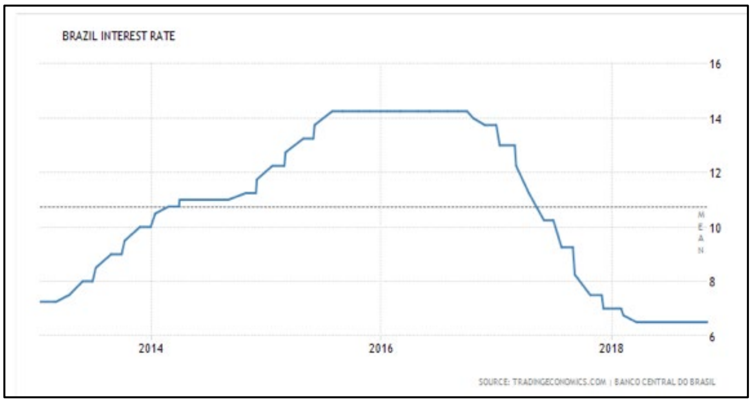

Figure 49 Average local interest rate (%) 2013-18.

5.3.2 Project's proposed models

Component I

The eight proposed models for this Component intend to simulate the impact of Agroforestry Investment Plans, Natural Resource Management Investment Plans (with Income Generating Activities) and Micro-enterprises to develop agroforestry input suppliers (adapted machinery, nurseries, for example). In the first case, it considers promoting agroforestry activities in degraded or monoculture lands to reduce both the degradation of grasslands and purchases of externally-produced forage when a climate event occurs. For the Natural Resource Management Investment Plans, bee-keeping is considered as a proposed income-generating activity to reduce over-exploitation of natural resources, and eco-efficient stoves and biodigesters are income saving innovations

The adoption of Agroforestry practices and technologies is considered an opportunity for farmers to address climate change challenges. All the models proposed are designed to try to increase resilience. The table below illustrates each model's in-farm dynamic when adopting Agroforestry technologies and practices

Table 7 Component I models

Model	Main features	Purpose	Main activity	Typical innovative system	Targeted families
2a	Agroforestry on rain-fed land	Production of forage & fruit	Goat and sheep breeding - Meat	0.5 ha. for forage production with agroforestry. Herd size: 80 animals	10,300
2b	Agroforestry in rain-fed land	Production of forage & fruit	Poultry	0.5 ha. for forage production with agroforestry, for 200 laying hens	10,300
3a	Agroforestry diversification of *Opuntia* monoculture plots	Production of forage & fruit	Goat and sheep breeding – Meat	0,5 ha for Forage production and agroforestry. Herd size: 80 animals	10,300
3 b(*)	Agroforestry diversification of *Opuntia* monoculture plots	Production of forage & fruit	Dairy cattle – milk	0,5 ha for agroforestry diversification for 20 dairy cows	5,000
4	Microentrepreneur business development	Develop production of agroforestry inputs (tools, seedlings, etc.)			70
5	Reduce pressure on collective/protected areas	Sustainable management of *Caatinga* areas	Bee-keeping	The typical group of farming families with access to protected or collective areas	540
6a			Eco-stoves		540
6b			Biodigesters		540

(*) All models will have access to investments (with Territorial Resilience Investment Plans - TRIPs) and TA, except for model 3b, that will participate in the Project via Farmer Networks.

Component II

In this case, the proposed models are based on the need for water access in communities as an entry point, to promote the paradigm shift under the agroforestry approach. After providing training and capacity building for the implementation of water infrastructures, the component will provide support for an agroforestry investment plan with the first round of funding. This is meant to be an element to enhance motivation that will be complemented with hand-holding in the initial phases of the newly installed garden, by means of 2-year close technical assistance services under learning by doing approach. All participants should be able to benefit from a minimum agroforestry package. Three models of this type of support are simulated: i) a typical farmer of 0.5 ha with a fruit and vegetables 0.3750 ha.-plot irrigated with one of the possible types of micro-dams, ii) an average farmer of 0.5 ha with a fruit and vegetables 0.3750 ha.-plot irrigated with a cistern, and iii) a model for the development of a fruit and vegetables 0.1250 ha.-plot, to be irrigated with water from a gray water (or sewage) reuse infrastructure.

It should be considered that some of the models require only a part-time occupation (from 2 to 6 months, depending on the activity). It means that the annual income per year represents only a small part of total family incomes (and sometimes even personal incomes). Also, drop-out rates are challenging to estimate, but an intensive hand-holding, a rigorous selection and the family approach demonstrate that there is a possibility to keep up all the well-sustained investment plan initiatives.

Table 8 Component II models

Model	Main features	Purpose	Main activity	Typical innovative system	Targeted families
1a,b	Irrigated agroforestry backyard gardens	Vegetable beds, fruit trees	Vegetable and fruit production	0.5 ha. Garden with 0.375 ha. of irrigated area with water from micro-dams or cisterns / 21 veg. beds + trees.	21,000
1c	Small Irrigated agroforestry gardens	Vegetable beds, fruit trees	Vegetable and fruit production	0.125 ha. of irrigated area, with water from reuse infrastructures / 7 vegetable beds + fruit trees.	15,000

More details on the proposed models are presented in APPENDIX III – Production model details

5.3.3 Financial analysis of proposed models

Overall, the financial analysis shows positive Net Present Values (NPV), Financial Internal Rate of Returns going beyond the cutoff rate and Benefit-Costs ratio higher than 1. These results suggest that all models should be considered profitable, with FIRR (Financial Internal Rates of Return) ranging from 10% to 39. % depending on the supported activity. Net present values (NPV), at the 10% discount rate, vary from R$ 2,322 to R$ 219,941. The following tables summarize these profitability indicators for all the financial models.

Table 9 Profitability indicators per model (A) – in R$ (Reais)

	Model 2a - Agroforestry on rain-fed land, goats and sheep	**Model 2b -** Agroforestry on rain-fed land, poultry	**Model 3a -** Agroforestry diversification of Opuntia monoculture: goats & sheep	**Model 3b -** Agroforestry diversification of Opuntia monoculture: dairy	**Model 4 -** Microentrepreneur business development	**Model 5 –** Reduce pressure on collective/protected areas. Bee-keeping	**Model 1a –** Irrigated agroforestry backyard gardens: micro-dams	**Model 1b –** Irrigated agroforestry backyard gardens: cisterns	**Model 1c –** Small Irrigated agroforestry gardens: water reuse infrastructure
Without Project									
Costs	5,158	5,650	4,068	138,847					
Sales	6,534	7,497	6,534	174,924					
Margins	***1,376***	***1,847***	***2,466***	***36,077***	***34,452***	***1,080***	***2,171***	***2,171***	***724***
With Project									
Costs	*5,568*	*7,256*	*5,568*	*132,811*	*502,452*	*1,329*	6,549	6,549	2,828
Sales	*8,168*	*8,127*	*12,128*	*186,804*	*600,000*	*5,346*	15,032	15,032	5,011
Margins	***2,599***	***871***	***6,559***	***53,993***	***97,548***	***4,017***	*8,483*	*8,483*	*2,183*
IRR	14%	11%	19%	25%	*10%*	*35%*	39.0%	28.7%	19.0%
NPV	7,268	2,322	11,224	40,018	*39,521*	*219,941*	33,958	27,054	5,734
B/C Ratio	1.27	1.43	1.29	1.55	*1.16*	*2.89*	2.2	2.18	1.96

Model – FIRR – NPV – B/C Ratio

Table 10 Profitability indicators per model (B)

Model	**FIRR**	**NPV**	**B/C Ratio**
	%	R$	Nº
Model 1a- Veg. Beds and Fruit trees 1- Grey Water Reuse	19.0%	5,734	1.96
Model 1b- Veg. Beds and Fruit trees 2- Other Water infrastructure	39.0%	33,958	2.21
Model 1c- Veg. Beds and Fruit trees 3- Cisterns	28.7%	27,054	2.18
Model 2a- Forage production and Agroforestry diversification in native lands 1	14.0%	7,268	1.27
Model 2b- Forage production and Agroforestry diversification in native lands 2	11.3%	2,322	1.43
Model 3a- Forage production and Agroforestry diversification in palm monoculture lands 1	18.8%	11,224	1.29
Model 3b- Forage production and Agroforestry diversification in palm monoculture lands 2	25.3%	40,018	1.55
Model 4- Micro-entrepreneur Business development	10.0%	39,521	1.16
Model 5- Bee-keeping	35.1%	219,941	2.89

The impact on income is simulated by comparing each model family revenue with several representative scenarios of a typical 2-person income house-hold. The increases in incomes are shown, per model, in the table below.

Table 11 Income impact per model – in R$ (Reais)/ Year

	Model 1a – Irrigated agroforestry backyard gardens: micro-dams	**Model 1b –** Irrigated agroforestry backyard gardens: cisterns	**Model 1c –** Small Irrigated agroforestry gardens: water reuse infrastructure	**Model 2a -** Agroforestry on rain-fed land, goats and sheep	**Model 2b -** Agroforestry on rain-fed land, poultry	**Model 3a -** Agroforestry diversification of Opuntia monoculture : goats & sheep	**Model 3b -** Agroforestry diversification of Opuntia monoculture: dairy	**Model 4 -** Microentrepreneur business development	**Model 5 –** Reduce pressure on collective/protected areas. Bee-keeping
Without Project									
Family incomes without Project	2,171	2,171	724	*1,376*	*1,847*	*4,176*	*63,563*	*34,452*	*1,080*
With Project									
Family income with Project	7,618	9,213	6,358	*7,154*	*8,706*	9,919	*74,093*	*78,038*	*4,927*
% increase	251%	324%	779 %	*420%*	*371%*	*138 %*	*17 %*	*127 %*	*356%*

For more details, see ANNEX 3.

5.4 Economic analysis and sensitivity

Economic analysis. The economic analysis (with economic prices to calculate total economic costs) uses the aggregated economic model´s benefits (by beneficiaries) over a period of 20 years and at a shadow discount rate of 10%[224].

Figure 50 Brazil Government Bond 10Yr (2013-2018)

To incorporate the results to the economic analysis, all prices have been calculated applying conversion factors for imported tradable goods, exported goods and labor. No market distortions are supposed to affect non-tradable goods.

Externalities/additional economic benefits. Two different types of additional economic benefits were included: a) the family savings due to the implementation of efficient stoves, biodigesters and other proven social technologies; and b) environmental externalities calculated using the Ex-Acte tool software to estimate the project´s mitigation impact of avoiding CO2 emissions.

Results. The overall EIRR (Economic Internal Rate of Return) is estimated at 19.77% while the NPV reaches U$S 152 million.

Table 12 Economic results

Indicator	Results
NPV@10%	R$ 684,020,261
NPV@10%	USD 152,000,000
EIRR (%)	19.77%
B/C Ratio	3.18

Sensitivity Analysis: A sensitivity analysis was carried out assuming different risk scenarios. These include an increase in project costs (10%, 20% and 50%), a reduction in project benefits (10%, 20% and 50%), delay in project benefits (1 and 2 years) and the occurrence of climate change extreme events (every 2, 3 and 4 years).

The project is assumed to be profitable and resilient as it supports most of the tested scenarios as an increase in costs up to 30% or a reduction in benefits of 30%. Profitability remains positive even in the case of a mixed increment in costs up to 20% and a reduction in benefits of up to 20%. In these cases, the NPV remains in the positive range. The project wouldn´t be profitable in the case of a mixed cost increase of 20% and a benefit reduction of up to 30%. Besides, nine sources of benefits equally contributing to the total project´s benefits have been identified. This serves to demonstrate that the project is well-diversified and not highly exposed to price or sectorial risks

[224] Taking into account 10 year bond yields for the country (between 9 and 10%).

5.5 Concessionality: justification for GCF funding request

Existing Brazilian funding. An IMF working paper estimated the total market capitalization of the invested global multi-asset market portfolio in Brazil at BRL 7.12 trillion[225]. Government bonds represented the largest asset class (37.04 percent), followed by equities (26.85 percent), bank funding (13.92 percent), corporate bonds (10.58 percent), and real-estate (5.10 percent). The total market capitalization of the three other asset categories is relatively small. IMF also provided the historical composition of the Brazilian market portfolio going back to 2005. Despite its wide range of instruments, the financial market is not directly channeled to climate change finance for the targeted region in Brazil.

After consultations in the country, it has been identified that BNDES offers specific conditions for support for the environment for different target groups and different financial terms: a) Non-reimbursable funds concerning Social Fund and Amazon Fund with R$ 200 million that targeted 20% of agroforestry systems; and b) Reimbursable Funds concerning Climatic Fund and FINEI Environment with R$10 million for private sector enterprises. None of those funds involves the Brazilian states as executing partners or the Northeast Semiarid as the targeted area.

Climate change finance gap. The current project requires GCF funding in order to leverage the investment for Climate Change for mitigation and adaptation to the Northeast Semiarid region, almost inexistent in the present scenario. The Brazil Country Program for the GCF, prepared in March 2018, estimates a resource requirement for mitigation and adaptation objectives that are well above the current investment level with domestic or international sources of financing. An indicative amount of resource mobilization required to promote the actions provided in the NDC is estimated to a range of R$ 890 to R$ 950 billion, corresponding to total investments of approximately 1% of the annual GDP at face value. Nowadays, climate change finance in Brazil is mainly concentrated in the Fundo Amazonia that is one of the most significant and important world initiatives to fight deforestation. It is expected to cover at around R$ 3 billion that is only 0.3% of the climate change financing required amounts. Other international programs are addressed to different purposes or regions.

Key barriers and Justification. The key barriers identified for investments in climate change-related projects that justify the proposed blend of GCF funding in the targeted region are the following:

- **The rising level of public indebtedness and fiscal imbalances at the national and sub-national levels.** General government gross debt rose from 56.3 percent of GDP at the end of 2014 to 69.5 percent by end-2016 and is expected to rise further and peak in 2023 at above 90 percent of GDP. At the subnational level, the fiscal situation is also hampering the sustainability: a decline in revenues mixed with an increase in spending but aggravated by the fact that the states have limited own sources of revenues and a lower capacity to access borrowing, as well as reduced transfers from the Union. While lending by other International Financial Institutions has been addressed to the States in recent years, the new project will deal directly with the Federal Government of Brazil. BNDES will guarantee consistency between the Federal Government and support for the States, expected public expenditures and anticipated level of indebtedness. Tighter conditions for public spending and limited access to borrowing require a consistent strategy for access to funding for the States.

- **Weak investment capacity and deteriorated the local credit market.** Investment decreased from 18.1% in 2015 to 15.5% of GDP in 2017 while credit issued in local currency fell by 3.6 percent in 2015 and by 9.2 percent in 2016 due to the economic recession. The rise in credit risks for the Brazilian economy was reflected in higher interest rates increasing the credit cost while the quality of the financial assets and loans decreased as a consequence of various corporate sector scandals. Brazilian net interest margins of the financial intermediation are amongst the highest in the list of 15 peer emerging market economies[226] , mainly due to high operating costs, loan losses and bank concentration.

[225] TESSARI, C.; MEYER-CIRKEL, A. **Brazilian Market Portfolio**. IMF Working Paper WP/16/51. Washington: International Monetary Fund 2017.
[226] IMF. **Brazil. IMF Country Report 18/253**. Washington: IMF, 2018. Available at: https://www.imf.org/en/Publications/CR/Issues/2018/08/03/Brazil-2018-Article-IV-Consultation-Press-Release-Staff-Report-and-Statement-by-the-46154

- **High perceived risks for both climate change and highly vulnerable groups funding in the targeted region.** The share of resources that commercial banks and institutional investors have been allocating to project financing, either in loans or bonds, has remained very limited and mainly concentrated on refinancing projects that are already operational, thus with a lower risk profile. Regarding commercial Banks, the implementation of the Basel III regulations is expected to reduce even more their ability to invest in high-risk assets. As a consequence, Climate Change financing addressed to highly vulnerable groups in rural areas is not offered in the Northeast Semiarid. There is a high perceived risk of this type of investment for both the public and private sectors. BNDES, with its social and financial perspective, will play a key role in promoting and supporting this instrument that is expected to mobilize other public and private investments for this purpose in the region.

- **Lack of Long-term investment drivers and high intermediation costs.** While the Brazilian basic interest rate (SELIC) is still attractive for investors, the Brazilian Treasury Bonds act as a short-term inducement for banks and pension funds investments. As a consequence, they are discouraged from investing in long-term development projects or long-term assets. The project´s tenor will allow unlocking the climate change financing under a broader long-term perspective. Besides, commercial banks charge very high mark-ups, making real interest rates of commercial loans in Brazil among the highest in the world, above 20% for corporate loans, making the Brazilian financial market less liquid and more difficult to access. Expected market volatility related to economic and political uncertainties, shifts the local investments towards the shorter end of the maturity spectrum, making it difficult to find a reference for a long-run interest rate with a duration compatible with projects-based investment reference for long-run interest rates with a length compatible with projects-based investment. The Brazilian interest rate curve presents that particularity: long-term rates do not have sufficient liquidity, and short-term rates are very high.

- **High-interest rates and spread.** Under the current financial scenario of interest rates, BNDES, States, and the private sector are not willing to take loans to invest in climate change mitigation and adaptation. Besides, the targeted groups can´t have access to finance with formal banks, and climate change doesn´t seem to be the first priority in terms of investments for them. With the current Project and its GCF concessionality, a blended rate will be offered, making a more attractive financial instrument that will be provided to States. As a consequence, it is expected to leverage both public (at the national and sub-national level) and private investments. The GCF grant element with the loan concessionality would allow BNDES to offer a favorable particular credit line enabling the States and the family farmers to invest in climate change purposes.

Financial structure justification and profitability indicators (focused on GCF funding)

The main current funding for climate change and highly vulnerable groups is driven by BNDES through the Amazon Fund and Climatic Fund. However, as mentioned before, it is focused on the Amazonia and '*Mata Atlántica'* regions leaving the Northeast Semiarid with no access to funding.

Without GCF financing, under the current conditions, the project would not be profitable for the country or for the States. With the Planting Resilience Project, both the States and the Union will be benefiting from concessional lending terms, which would lead to a viable investment project, taking into account also a GCF grant element.

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The full concessionality of the GCF financing will allow the project to provide support for the poorest of the poor families to transition to a climate-resilient production system. Within this group, the project will be able to target women, youth and traditional communities (indigenous, quilombola and *fundo de pasto*), which are the groups that are most vulnerable to climate-related risk, endure extreme poverty conditions, lack access to the labor market, and have no permanent income sources.

GCF grant of US$ 34 million will be focused on activities to implement CRPS (Component I) and the Knowledge Management and Scaling-up activities (Component III).[227] The project addresses a key constraint to adaptation and emission reduction in agricultural production in Semiarid Brazil: the lack of information and technical advisory services for promoting climate-resilient agriculture practices. The Project's knowledge management component will promote identification, systematization and public awareness of CRPS. Proposed exchanges will enable lessons learned sharing among farmers.

With the GCF funding, the Project unlocks the potential for replication and scaling up to other developing countries facing similar challenges, thus facilitating a paradigm shift. By fostering South-South Cooperation (SSC), the project gains in effectiveness and scale, enhancing its contributions to the implementation of the 2030 Agenda goals and for living no one behind.

GCF loan of US$ 65 million will be the main funding providing support for CRPS Investment Plans in Component I for individual family farmers, schools and collective areas.[228] It will also partially support Component II's water technologies needed to shift towards a CRPS.[229] The loan element is aligned with priorities for indebtedness and eligibility criteria established by the national government (COFIEX of the Ministry of Economy). GCF loan interest rate is lower compared to domestic IRs and provides grace period and tenor's benefits. Without the GCF concessional loan, the cost of funding would be significantly higher and would undermine the Project's economic viability. With GCF support, the project leaves locked-in development paths and uses an innovative approach in the designing of climate-resilient production systems. This will only be possible bringing together stakeholders and knowledge from various sectors, as well as merging IFAD, GoB through BNDES and GCF financing.

The key barriers identified to investment and the indebtedness of the recipient that justifies the current blend of GCF funding in the targeted region are:

- A rising level of public indebtedness and fiscal imbalances at the national and sub-national levels;
- Weak investment and deteriorated the local credit market;
- Lack of long-term investment drivers and high intermediation costs; and
- High-interest rates and spread practiced in Brazil.

[227] (i) Component 1: for individual family farms - US$ 28.58 million (100% of total cost), (ii) for backyard gardens - US$ 1.95 million (10.6% of total cost) ii) Component 3: Knowledge management - US$ 3.97 million (39% of total component´s costs).
[228] Component 1 (i) individual - US$ 13.7 million (GCF covers 75% of the total cost), (ii) Schools -US$ 3.68 million (100% of the total cost); and (iii) Natural Resource Management in Collective Plans - US$ 5.16 million (100% of the total cost).
[229] Component 2: (i) Cisterns - US$ 28.49 million (40% of total cost); and (ii) Re-use of grey and blackwater systems (US$ 13.97 million) (70% of total cost).

5.6 Benchmarks

Latin America is a relatively scarcely populated continent; thus, costs per beneficiary tend to be higher than other developing regions. Table 12 below compares the PCRP with other GCF rural development projects in the region. Considering only GCF's finance portion, the efficiency is 99 U$D/beneficiary. Even considering the entire cost, PCRP lies within the higher effectiveness range of rural adaptation projects in the region.

Table 13 Project Benchmarks

Items	**Planting Climate Resilience – Brazil**	**PROEZA Paraguay**	**CFAVCP-Cambodia**	**FIRA-México**	**DBSA CFF - South Africa and SACD Region**	**RECLIMA-El Salvador**
	Base	**1**	**2**	**3**	**4**	**5**
Date of approval		March 2018	March 2018	March 2018	November 2018	Sept. 2018
Direct Beneficiaries	1,000,000	87,210	390,000	802,980	22,732	225,000
Annual Emissions	580,455 t CO2 eq	262,267 tCO_2eq	35,000 tCO_2eq			210,842 tCO_2eq
EIRR	19.77%		16.13%	-	-	
NPV	U$S 152 Million		U$S 133.543	-	-	
Effectiveness of GCF Adaptation Inv. (U$D GCF/Beneficiary	US$ 99.5/ beneficiary	US$ 288 / beneficiary	US$ 102 / beneficiary	US$ 27 / beneficiary	US$ 2,446 / beneficiary	US$ 159 / beneficiary
Effective-cost (cost per tCO2 reduced for GCF funding)	US$ 9 / tCO2eq	US$ 96 / tCO2eq	US$ 19 / tCO2eq	US$ 30.82 / tCO2eq	US$ 1.87 / tCO2eq	US$ 169 / tCO2eq
Total Cost (U$S Million)	217,83	90.3	141.39	27	170,55	127.7
GCF funding (U$S Million)	65 Million loan 34,5 Million grant	25.1 Million grant	10 Million loan 30 Million grant	22 million loan	55 Million loan 0.61 Million grant	35,8 Million grant

5.7 Macroeconomic and financial market overviews

5.7.1 Macroeconomic overview

After years of economic expansion mainly driven by expansionary policies, a shift in external conditions led to a progressive decline in economic growth followed by a severe recession in 2015-16, causing a significant slowdown in economic activity mainly due to domestic political uncertainty, fiscal disequilibria and the lack of confidence. During the following years, investments showed a decline of around 30 percent. Even if a mild recovery is currently underway[230] (supported by accommodative monetary and fiscal policies), there are still pressing challenges to recover the level of investment that would unleash the Brazilian potential.

The main current difficulties are based on: i) a structural fiscal imbalance at the national and subnational level; ii) rising public debt (General government gross debt rose from 56.3 percent of GDP at the end of 2014 to 69.5 percent by end-2016 and is expected to rise further and peak in 2023 at above 90 percent of GDP) and iii) low level of investment (it decreased from 18.1 in 2015 to 15.5 of GDP in 2017).

[230] IMF Executive Board. Article IV Consultation with Brazil (August, 2018)

At the subnational level, the fiscal situation is also hampering the sustainability: a decline in revenues mixed with an increase in spending but aggravated by the fact that the states have limited own sources of revenues and a lower capacity to access borrowing, as the transfers from the Union reduced. Lending by International Financial Institutions has been addressed to the States in recent years.

Concerning the credit markets, Real credit fell by 3.6 percent in 2015 and by 9.2 percent in 2016 due to the recession. The rise in credit risks for the Brazilian economy was reflected in higher interest rates increasing the credit cost while the quality of the financial assets and loans decreased as a consequence of various corporate sector scandals. Brazilian net interest margins of the financial intermediation are between the highest among 15 peer emerging market economies[231] , mainly due to high operating costs, loan losses and bank concentration.

In the 2017-2018 period, the fiscal deficit has declined to 1.7 percent of GDP in 2017 as a result of under-execution of spending and inflation dropped to record lows (2.9% in 2017) after a tight monetary policy. The economy grew 1% in 2017 and is expected to keep that path in the next years. The deficit in the current account was reduced between 2014 and 2017 as imports contracted, cushioning the impact of the recession, but it is expected to rebound in the mid-term as investments recover its strength.

An important cornerstone of the macroeconomic strategy was relying on the flexible exchange rate regime. It acted as a shock absorber while inflation was controlled by the Central Bank, regulations and the economic context. Also, the banking system was resilient to the crisis[232] as the main banking indicators remained adequate while rollover risks were dissipated as there was a low foreign-currency exposure and a comparatively small share of foreign-held government debt. However, Brazil is still vulnerable to a tightening of global financial conditions and possible trade disruptions[233], and the public debt is rising while national and subnational public expenditures are being reduced to keep up the fiscal accommodation.

5.7.2 Brazil's capital markets

Based on the information available at the end of 2015, an IMF working paper estimated the total market capitalization of the invested global multi-asset market portfolio at BRL 7.12 trillion[234]. Government bonds represented the largest asset class (37.04%), followed by equities (26.85%), bank funding (13.92%), corporate bonds (10.58%), and real-estate (5.10%). The total market capitalization of the three other asset categories is relatively small. IMF also provided the historical composition of the Brazilian market portfolio going back to 2005.

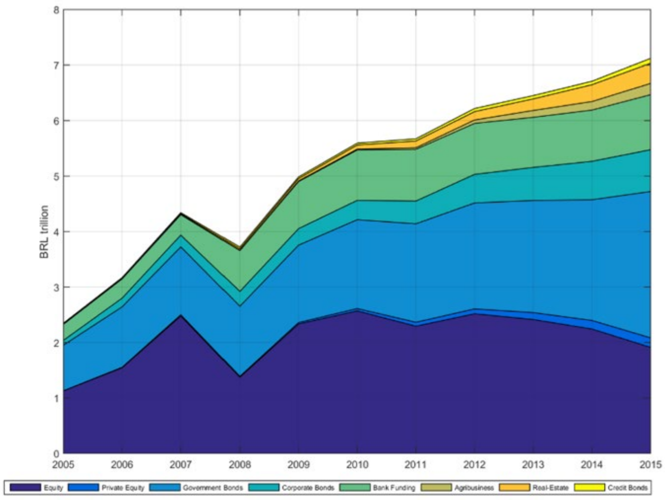

Figure 51 Estimated market values in the Brazilian market portfolio, 2005-2015

[231] IMF. **Brazil. IMF Country Report 18/253**. Washington: IMF, 2018.
Available at: https://www.imf.org/en/Publications/CR/Issues/2018/08/03/Brazil-2018-Article-IV-Consultation-Press-Release-Staff-Report-and-Statement-by-the-46154.

[232] As stated in the IMF´s **Brazil: Financial System Stability Assessment** report in 2018. Retrieved at: https://www.imf.org/en/Publications/CR/Issues/2018/11/30/Brazil-Financial-System-Stability-Assessment-46411).

[233] IMF, 2018, as reference in footnote above.

[234] TESSARI, C.; MEYER-CIRKEL, A. **Brazilian Market Portfolio**. IMF Working Paper WP/16/51. Washington: International Monetary Fund, 2017.

Government Bonds: With a total amount of BRL 2.6 trillion in outstanding securities, the Brazilian domestic government bond market has expanded rapidly since the mid-1990s and has become one of the most liquid and sophisticated among emerging markets. The domestic federal public debt (DFPD) is composed of a wide range of securities, including floating rate, fixed-rate, inflation-linked, and dollar-indexed instruments. The Financial Treasury Bill (*LFT - Letra Financeira do Tesouro*), whose floating rate remuneration is based on the Selic rate, is the most significant government security in terms of outstanding amounts. The National Treasury Bill (*LTN – Letra do Tesouro Nacional*), zero-coupon fixed-rate security, has expanded sharply in recent years and is now the second most important type of outstanding marketable liability. The National Treasury Notes Series-F (*NTN-F - Notas do Tesouro Nacional série F*), which is a standard coupon-bearing fixed-rate security, has also expanded in recent years. The other NTN securities are indexed to various other indices. The NTN-B and NTN-C, inflation-indexed bonds, have increased their share of total marketable debt in recent years. Overall, the securities discussed in this table represent 99 percent of the total domestic commercial debt of the federal government. Debt issuance by states and municipalities is modest.

Table 14 Brazilian Government Bonds

Security	Description	Indices	Type of Interest	Interest	Terms	Maturity Rule
LFT (Letra Financeira do Tesouro)	Floating rate bills	Selic Interest Rate	Floating	None	26 months (average term)	Third month of each quarter
LTN (Letra do Tesouro Nacional)	Short-term, zero-coupon fixed rate bills		Fixed	None	6, 12, 24, and 36 months	First day of January, April, July and October
NTN-F (Notas do Tesouro Nacional série F)	Long-term fixed rate coupon bonds		Fixed	Semi-annually, with adjustment of the term in the first flowing period, when applicable	5 and 10 years	First day of January
NTN-B (Notas do Tesouro Nacional série B)	Inflation-linked coupon bonds	IPCA Price Index	Inflation-Linked	Semi-annually, with adjustment of the term in the first flowing period, when applicable	3, 5, 10, 20, 30, and 40 years	
NTN-C (Notas do Tesouro Nacional série C)	Inflation-linked coupon bonds	IGP-M Price Index	Inflation-Linked	Semi-annually, with adjustment of the term in the first flowing period, when applicable		No longer issued

Comments: Number of Days: Business days of the security/252

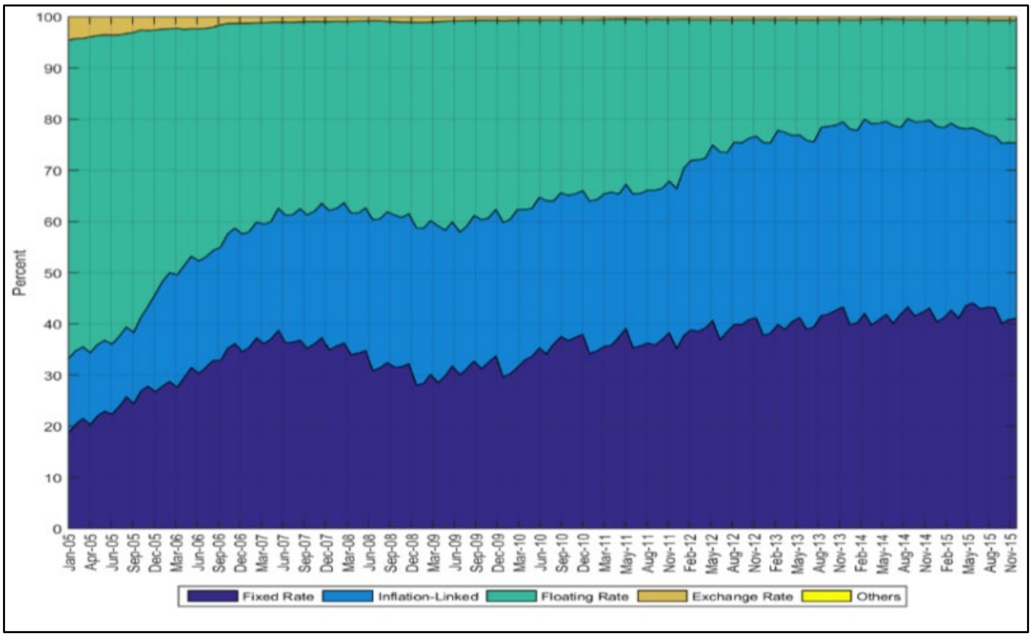

Figure 52 Profile of Government Bonds (2006 – 2015)

Equity: Brazil has one of the largest stock market capitalizations in Latin America. By the end of 2015, total equity market capitalization was BRL 1.9 trillion (US$ 490 billion), representing 37.8 percent of GDP, with a diversified investor base including individuals, institutional investors, financial institutions, private and public companies, and foreign investors.

Brazil's equity market grew rapidly in terms of market capitalization until 2007, when the equity market capitalization was BRL 2.48 trillion, representing 102.18 percent of the GDP. With the global financial crisis in 2008, Brazil lost equity market capitalization by about 45 percent. Its highest value over the past 10 years was BRL 2.57 trillion in 2010. Since 2012, Brazil has seen its total equity market capitalization drop by about 24 percent, from BRL 2.52 trillion to the current BRL 1.91 trillion.

Despite Brazil's large market capitalization, turnover ratio, and a number of listed domestic companies, the country was considered to rank poorly in terms of transparency and corporate governance just a few years ago. In 2000, with the hope of encouraging corporations to adopt higher standards for corporate governance, Brazil's main stock exchange — BM&FBOVESPA, also known as São Paulo Stock Exchange adopted transparency, and minority shareholder protection, as pre-requisites for listing.

Bank Funding: The main fundraising instruments for banks in Brazil are, traditionally, demand deposits, term deposits, and savings. Over the past decade, the large and growing bank funding market has become more diversified with the introduction of the Financial Bill (*LF – Letra Financeira*) in 2010 and the Time Deposit with Special Guarantee (*DPGE – Depósito a Prazo com Garantia Especial*), in 2009. With the expansion of the menu of available financial instruments in recent years, the importance of funding through LFs has increased, although the Bank Certificates of Deposits (*CDBs – Certificados de Depósito Bancário*) still represent the primary source of funds in this segment. The increase in the share of LFs and DPGEs partly reflects characteristics of these instruments, such as tax exemption and protection by the Credit Guarantee Fund (*FGC – Fundo Garantidor de Crédito*). Since 2012, state-owned banks have expanded rapidly and now make up half the banking system. They rely on subsidized financing for direct lending, which accounts for over half of total credit. The authorities plan to reduce the reliance on state subsidies gradually as part of fiscal adjustment but need to weigh the effects on corporate balance sheets and asset quality. Corporate debt constitutes almost one-third of bank assets and banks' exposure to problem loans of large corporates is high. Banking system soundness indicators remain adequate, but the deteriorating economic situation and the impact of the ongoing scandals on the corporate sector may affect asset quality adversely. Credit risks have risen in the current recession with a slight deterioration of the quality of loans.

Corporate Bonds (Debentures): Companies do not need to issue stocks to raise financial resources. Instead, they may find it more advantageous to issue either debentures or commercial papers. These securities represent cheaper sources of financing when compared to bank credit, with more flexible maturities. Some of the most profitable bonds/debentures in 2016 include: (i) EDP @ IPCA + 8.26%, CPS @ CDI + 2.5%, Vale @ IPCA + 6.62% and sovereign bonds @ IPCA + 6% to 7.2%.

Credit Bonds: Although the credit bonds market is still small in Brazil, it has grown significantly in recent years. By the end of 2015, the amount outstanding in this market was BRL 89 billion, from BRL 6 billion in 2005. The Bank Credit Note (*CCB – Cédula de Crédito Bancário*) has been the main instrument. The amount of CCBs increased from BRL 3 billion in 2005 to BRL 38 billion in 2005. Meanwhile, the amount of Export Credit Notes (*NCEs – Notas de Crédito à Exportação*) increased from BRL 1 billion in 2005 to BRL 38 billion in 2015.

5.7.3 Barriers to long-term investments

Indeed, the government securities market in Brazil is widely developed and, as the basic interest rate in Brazil (SELIC) exceeds similar rates prevailing in the rest of the world, these assets are highly attractive to domestic and foreign investors. As a result, banks and pension funds invest massively in Brazilian Treasuries and have negligible participation in financing long-term assets or infrastructure. Because Brazil has not developed a secondary market for private or corporate bonds, savers have concentrated resources in government debt, which offers a profitable and much more liquid secondary market. In addition, commercial banks charge very high mark-ups, turning real interest rates of commercial loans in Brazil among the highest in the world, above 20% for corporate loans. As a consequence, there is no market reference for long-run interest rates with a duration compatible with projects-based investment. The Brazilian interest rate curve is characterized by a high level of short-term rates and upward sloping format—long-term rates do not have sufficient liquidity, and short-term rates are very high.

The new government of Brazil is committed to addressing these issues and has engaged in a severe macro-fiscal adjustment, which includes reforms able to decrease and stabilize the growth of the public debt to eventually reducing short-term interest rates. Meanwhile, the share of resources that commercial banks and institutional investors have been allocating to project financing, either in loans or bonds, has remained very limited and mainly concentrated on refinancing projects that are already operational, thus with a lower risk profile. Regarding commercial Banks, the implementation of the Basel III regulations is expected to reduce even more their ability to invest in high-risk assets. Another issue is the market's ability to accept long-term bonds. Despite the need for adequate financing of investments with long maturation period, debentures issued since 2000 have maturities under six years on average. After the 2008 economic crisis, the average maturity fell even more, from six to four years.

5.7.4 BNDES financial instruments for climate finance

Between the main financial instruments, BNDES offers specific conditions for support for the environment for different target groups and different financial terms: a) Non-reimbursable funds concerning Social Fund and Amazon Fund with R$ 200 million that targeted a 20% of agroforestry systems; and b) Reimbursable Funds concerning Climatic Fund and FINEI Environment with R$10 million for enterprises.

The Amazon Fund is one of the biggest and most important world initiatives to fight deforestation and a key part of Brazil's commitment to eradicate illegal deforestation by 2030. In its eight years of operation, the Amazon Fund has earmarked around R$ 1.4 billion for 89 projects from different segments and areas of the Legal Amazon region. All funds are non-reimbursable and destined for projects to prevent, monitor and fight deforestation and to promote conservation and sustainable use in the Legal Amazon region. Managed by the Brazilian Development Bank (BNDES), the Amazon Fund has funds from three sources. The Norwegian government contributed the largest share, around 97.4% of the total (approximately R$ 2.77 billion). The German government contributed 2.1% (about R$ 60.69 million), and Petrobras contributed 0.5% (R$ 14.7 million).

The Brazilian Ministry of the Environment plays a strategic role in the participatory management of the Amazon Fund. It chairs the three-way Steering Committee (COFA) which comprises the federal government, state governments, and civil society. COFA is responsible for establishing guidelines and criteria for investing funds, as well as regularly approving information on the Amazon Fund. COFA also oversees the alignment of initiatives supported by the Amazon Fund, in accordance with the guidelines of the Plan for Prevention and Control of Deforestation in the Legal Amazon Region (PPCDAm) and the National REDD + Strategy (ENREDD +).

The Amazon Fund supports projects by the federal government and state and local governments, third sector organizations, universities and even an international project – Monitoring Forest Cover in the Amazon Region, of the Amazon Cooperation Treaty Organization (ACTO), which comprises eight countries (Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela). The following areas are supported by the Amazon Fund:

- Management of public forests and protected areas.
- Environmental control, monitoring and surveillance.
- Sustainable forest management.
- Economic activities developed from the sustainable use of vegetation.
- Ecological and economic zoning, land planning and regularization.
- Conservation and sustainable use of biodiversity.
- Restoration of deforested areas.

Since 2009, 89 projects have been supported by the Amazon Fund, and currently, there are 10 projects under analysis. The states with the highest number of projects are Pará (14), Mato Grosso (13), Amazonas (9) and Acre (9), but there are 31 other projects involving more than one state. Third sector organizations hold the largest number of projects (47), followed by states (21), cities (7), the federal government (7), universities (6) and international (1).

5.8 Response to GCF investment criteria

5.8.1 Impact potential

The project will contribute to five Adaptation and three Mitigation Fund Level Objectives and Results.

Adaptation (A1, A2, A4, A5 and A7)

Water is considered the limiting factor for agricultural and animal husbandry in the Semiarid. Nevertheless, the water debate should be focused not on absence but on how to preserve water during the rainy season, and how to use it efficiently during the rest of the year. Component II will work with water harvesting techniques which have been widely applied in the Semiarid region. Component I will develop and disseminate agroforestry systems. This set of technologies will be implemented to help promote a shift from the conventional 'productivist' culture in the NEB towards CRPS, so that the infiltration can occur naturally making the springs perennial and developing a biological water reserve in the soil, roots and leaves of specialized vegetation.

Studies[235,236,237] suggest that stratified systems are more resilient to extreme climatic conditions than annual crops and tree-crop monocultures, as they have several mechanisms to reduce the impact of droughts, such as buffering of humidity, reduction of air and soil temperature extremes, windbreaks and shelterbelts to slow wind speed and minimize water loss from evapotranspiration. Stratified, diversified, and densified cultivation increases the photosynthetic capacity of the land and, therefore, the volume of biomass per cultivated area, improving water circulation and promoting an improvement in the microclimate.[238] The idea is to combine different plants into a system that is able to perform photosynthesis the entire year-round, and thus regularly produce biomass and accumulate water. It is important to emphasize that with active management; the whole system re-sprouts vigorously, generating more resistance for the dry periods.

The following adaptation benefits are anticipated by the project:

- 1,000,000 people (being 40% women and 50% youth) will benefit from the adoption of diversified, climate resilient livelihood options (including fisheries, agriculture, tourism, etc.) representing 3.7% of the total population of the northeastern semiarid region of Brazil;
- 53,600 households will be food secure (including during drought periods) (assuming 80% success rate)
- 28,800 families will have water available for production (assuming 80% success rate)
- 36,000 hectares of *Caatinga* ecosystems will be protected and strengthened in response to climate variability and change
- working groups will be operational to strengthen institutional and regulatory systems for climate-responsive planning and development
- 75,000 vulnerable households will use tools, instruments, strategies and activities to respond to climate change and variability.
- 26,800 households will increase their production and earnings

Mitigation (M4, M6 and M9)

The project will contribute towards the shift to low-emission sustainable development pathways by obtaining reduced emissions from land use, deforestation, forest degradation, and through sustainable forest management, and conservation and enhancement of forest carbon stocks. CRPS principles and practices will help eliminate the slash and burn as a method of land clearing and will bring about a significant increase in biomass production and carbon sequestration.

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[235] MAMEDE, M.; ARAÚJO, F. Effects of slash and burn practices on a soil seed bank of Caatinga vegetation in Northestern Brazil. **Journal of Arid Environments**, n. 72, p. 458 - 470, 2008.

[236] BRANCA, G. et al. **Climate-Smart Agriculture: A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management**. Rome: FAO, 2011. 35 p.

[237] MICCOLIS, A. et al. **Restauração Ecológica com Sistemas Agroflorestais: como conciliar conservação com produção. Opções para Cerrado e Caatinga.** Brasília: Instituto Sociedade, População e Natureza – ISPN/Centro Internacional de Pesquisa Agorflorestal – ICRAF, 2016. 266 p.

[238] LASCO, R. D.; DELFINO, R. J. P.; ESPALDON, M. L. O. Agroforestry systems: helping smallholders adapt to climate risks while mitigating climate change. **Wiley Interdisciplinary Reviews: Climate Change,** v. 5, n. 6, p. 825 - 833, 2014.

Practices such as fodder storage, pasture rotation and reduction of free-roaming livestock will be promoted to implement the proposed CRPS. Stratified systems with trees can provide benefits to ruminant herds on farms, since trees can be a source of shade and shelter, improving productivity by reducing heat stress in tropical climates. In addition, some tree species produce leaves and pods, which are highly palatable to animals and are available during the dry season when pastures are of low nutritional quality. Fodder from native trees of the *Caatinga* improves weight gain and milk production.[239] Well managed pastures can improve the ecosystem services provided by the *Caatinga*, such as micro-climate regulation, carbon sequestration and fixation, pest and disease control, provisioning of water, the decomposition of wastes, natural pollination of crops and other plants and provisioning of raw materials (such as timber, oil seeds and fruits).

The estimated impact to be achieved by the project is the following:

- 24,800 households reporting adoption of environmentally sustainable and climate-resilient technologies and practices (assuming 80% success rate)
- Between 11,086,999 and 11,621,173 tons of carbon dioxide equivalent (t CO_2 eq) reduced or avoided (including increased removals) - forest and land use
- 268,000 Semiarid region inhabitants use climate information products/services in decision-making, in climate-sensitive sectors
- At least 40% of the families benefited by productive projects report an increase in production
- 84,124 hectares of land under improved and effective management that contributes to CO_2 emission reductions

Further expected impacts concerning other relevant economic, financial and productive indicators (example: an increase in economic and financial benefits, expected increase in household incomes), are presented above, in section 5.3.3 - Financial analysis of the proposed models.

5.8.2 Paradigm shift potential

Potential for scaling-up and dissemination

The project will promote a shift from the predominant monoculture and the top-down application of static technological packages to the promotion of farmer-led technology development and implementation of dense, stratified and diversified systems (what we call CRPS) which will enable farmers to adapt effectively to the impacts of climate change. These systems have not yet been absorbed by the mainstream technical advisory services providers, and successful examples are few and sparse, with limited exchange among them.

More efficient water management linked to the restoration of vegetation cover will produce significant synergies for carbon sequestration, crop yields and landscape organization that will already show positive impacts in the short run during the project implementation, and will provide even higher benefits and positive effects for livelihoods over time. The results in terms of adaptation for farming families, higher yields, carbon sequestration, etc. should enable a paradigm shift not only amongst farmers but also with technical advisory services. The project will scale up the CRPS directly reaching 250,000 family farmers, equivalent to one million beneficiaries in the Semiarid region.

Activities under Component 3 (Knowledge Management), including youth communicators, capacity development, farmer's network, south-south cooperation and policy mainstreaming, will focus specifically on creating conditions required for scaling-up project impacts at the regional level, resulting in the paradigm shift described above occurring in the entire semiarid. This will provide the foundation for multiplying the CRPS with the potential of scaling to an additional 1.5[240] million farming families farmers in the region (approximately 6 million beneficiaries) as well as other drylands farmers in Latin America, such as those from Gran Chaco and the Central American Dry Corridor.

[239] ARAÚJO FILHO, J. A. **Manejo pastoril sustentável da caatinga**. Recife, PE: Projeto Dom Helder Camara, 200 p., 2013.
[240] The 2007 Agricultural Census (IBGE) data show that in that year there were just over 1.5 million family farms in the Semiarid region (Cf. INSA-(IBGE). **Estabelecimentos agropecuários do semiárido brasileiro (Censo 2006)**. Campina Grande: INSA/SIGSAB, 3p., 2014. Available at: http://sigsab.insa.gov.br/static/themes/v1/lib/elfinder/Arquivos/Publica%C3%A7%C3%B5es/Estabelecimentos%20agropecu%C3%A1rios%20do%20Semi%C3%A1rido_S%C3%ADntese%20(2006).pdf). Based on this data, it is estimated that there are currently approximately 1.75 million family establishments in the region.

The BNDES will be a key stakeholder able to apply the lessons learned from this project to existing credit lines for farmers producing in other biomes in the country, thus proving the replication on a national scale. BNDES has the means to encourage successful entrepreneurs supported by the Project to expand their tools and services to family farmers beyond the semiarid, a potential market of over 4 million family farmers (16 million beneficiaries).

Potential for knowledge sharing and learning

A guiding axis of this project will be the experimentation and dissemination of methodological and technological innovations in the implementation of productive systems resilient to climate change. In this process of stimulating innovation, the Project methodology will strive for constant exchanges of knowledge and practices, inspired by the principles of popular education,[241], whether in the form of workshops, meetings, exchanges or collaborations that highlight the talents and skills of farmers at the local and regional levels.

It is important to emphasize that exchange visits between communities and territories will be fundamental strategies to spread successful experiences that can serve as reference points in the social and environmental development of local communities. These exchanges go beyond the local and regional level: the project will make an effort to strengthen ties between countries in the southern hemisphere through “learning routes” that will result in the creation of a database, an internet portal and various materials that reveal the connecting links between experiences that ensure greater resilience to climate change in different parts of Northeast Brazil, Latin America and Africa.

One aspect that will strengthen the proposed methodological approach is the use of social communication methods. The media will have a pedagogical function, helping to disseminate new information during the multiplication phase of learning, so that it can qualify and give visibility to educational actions. Since the systematization of innovations is a vital aspect of the communication process, the recording and systematization of 'good practices', especially those that are carried out by women and young people within communities, will be key elements in strengthening the learning processes cited here.

An innovative aspect of the TA system proposed under this project is the “Campesino a Campesino” (or “Farmer to Farmer”) approach. It involves the valorization of the ‘local talents’, based on the choice of some people who stand out as references in sustainable knowledge and practices and who will be validated from work carried out together with the hired technicians of the institutions and partner organizations. Rural development projects in several Latin American countries that have been characterized by the “Campesino e Campesino” methodological approach have shown to be particularly successful in stimulating simple, non-culturally invasive agroecological practices that improve upon careful observation of experiments at the empirical level. At the same time, the process of implementing thousands of CRPS of various types will be an instrument that will significantly contribute to the learning of technical advisory teams who will work with Project beneficiary families. This process should also enable the promotion of CRPS to become part of the institutional axis of rural technical advisory bodies.

[241] The principles of popular education that guide the educational and organizational processes of this Project are based on the teachings of the Brazilian educator Paulo Freire: (i) the validation of popular and native forms of knowledge, rather than theoretical and conceptual thoughts and ideas imposed “vertically”; (ii) the exchange of beliefs, concepts and practices among the participants as a foundation, to be complemented by the intervention of outside figures, affirmed as “experts”, such as technical advisory services agents; (iii) the creation of “tools” (such as audio-visual and written materials) that arise from the communities’ needs and demands and are written/created using their own terms and expressions.

Contribution to the creation of an enabling environment

The first important legacy of the Project in creating an environment that is conducive to resilient and low carbon development will be the introduction of new practices and technologies for farmers in the Northeastern Semiarid. CRPS, which incorporates practices of greater resilience and climate change adaptation, will focus on increasing production stability by adopting sustainable management of available natural resources (water resources, soil, native vegetation, genetic resources in agriculture and livestock) and balancing higher commercial production with diversification and sustainable self-consumption. Thus, the Project's actions will help to develop and disseminate various types of well-performing agricultural production systems with resilience and climate change adaptation characteristics managed by thousands of farmers.

This process will allow several public and private technical advisory and research entities to gain experience in the design and implementation of more resilient and adapted agricultural production systems (CRPS). In this regard, the Project will invest in improving the technical capacity and knowledge of government and private rural advisory agencies, farmers' organizations and farmers themselves on adaptive approaches to agro-ecosystem management. The paradigm shift driven by the Project depends on a coordinated approach, and the Project will foster an enabling environment for coordination among the various stakeholders, favoring complementarities between the public and private sectors for the implementation of CRPS.

The process triggered by the Project will enable farmers to develop their capacities to manage their agroecosystems sustainably. This means that a set of private sector social actors can play a prominent role in the development process of the semiarid region. Thus, it will be these social actors who will implement the new, more productive and resilient systems, enabling the strengthening of their livelihoods, with an adaptation to climate change. It is understood that this scenario will serve as a stimulus for these actors to continue working with these systems in the long term and that this will encourage other producers to adopt such practices after the end of the Project. The fact that there are seed banks and nurseries in operation, thanks to the Project's action, should feed the continuity of the functioning of the implanted systems and favor the dissemination of these resilient and adapted systems.

As the Program has contributed to the creation, experimentation and production of new tools and equipment that can facilitate the management and decrease the operating costs of CRPS, there will be a group of local companies that will be able to offer these instruments in the market, which should strengthen the consolidation and expansion of this type of system.

Considering the positive results obtained with the implementation of these innovations, it is expected that banks that offer credit to rural producers will finance the implementation of resilient and climate-resilient agrosilvipastoral systems within the framework of rural credit programs.

The growth in the production of herds, cultivated areas, orchards, and *Caatinga* extractivism will strengthen the various production chains that work with these products from the semiarid region. Greater ease of access to markets will provide an incentive for households to seek to expand their areas under this new management.

In addition, the Project will enhance the sustainability of its effects by creating opportunities for better coordination of public policies and government programs to support resilience and adaptation to climate change. It is expected that government institutions will continue to invest in the different initiatives catalyzed by the Project, and adaptation measures will be integrated into different plans and programs. In addition, it is expected that access will be facilitated to credit, which should ensure investments to catalyze adaptation and mitigation impacts. In this context, it should be noted that in Brazil there are, in addition to the most common policies such as agricultural credit, various policies/plans that relate directly to the issue at hand, and which should reinforce the continued and growing participation of the multiple sectors of society in the processes. of resilient development. Here are some of the key initiatives:

a) The National Plan on Climate Change - PNMC;
b) The National Climate Change Adaptation Plan (PNA) (launched in 2016);
c) The REDESER Project, which is a multi-institutional initiative led by the MMA, aimed at the installation of Degraded Areas Recovery Units (URADs).
d) There is also the ABC Plan - Low Carbon Agriculture Plan.
e) The Forest Code and the National Plan for the Recovery of Native Vegetation (PLANAVEG).

The project's design was designed to increase the complementarity of the actions of public and private actors to support the implementation of a more resilient agricultural model adapted to climate change in the Brazilian Semiarid. It will be the private sector - especially the region's farming families - that will implement the innovative systems. The hiring of TA services from private or public entities points to another dimension of complementarity. Project support for other private sector actors - such as tool and equipment manufacturers or the production and supply of seedlings and seeds - reinforces this perspective. In this model, the public sector assumes the role of facilitator, while private actors take responsibility for implementing the actions needed to improve the sustainability of their livelihoods in their various dimensions. This complementarity seeks to reinforce the deployment of a type of development capable of ensuring both prosperity and resilience at the same time.

Contribution to the regulatory framework and policies

The Project will help Brazil achieve its NDC and the targets of the Low-carbon Agriculture Program (ABC). CRPS principles are a viable option for smallholders to fulfill their legal obligations under the Brazilian Forest Code (FC). The Project will support beneficiaries to overcome the challenges they face (e.g., lack of technical support and incomplete fiduciary documentation) to fully comply with the national regulatory framework.

The project will strengthen regulatory frameworks by implementing the instruments established in the Brazilian Forest Code (Law 12651/2012). The Forest Code governs the use and protection of private lands in Brazil. It is one of the most critical pieces of legislation with the potential to drive efficient land use in Brazil and, in doing so, become an effective tool against climate change.

Under this Code, rural properties play an important role in biodiversity and natural resource conservation, as owners must maintain 20% native vegetation of their total land area in the *Caatinga* Biome. These “Legal Reserves” (LR) are intended to preserve forested areas and their ecosystems, thus contributing towards an enhanced ecological balance and avoiding deforestation emissions. In addition, rural properties have to map and leave Permanent Preservation Areas (APP in Portuguese) intact, being areas that have been designated for protection because they have been identified as critical to the preservation of essential ecosystem functions, such as the preservation of water resources, landscapes, geological stability, biodiversity, genetic flows for fauna and flora, soil protection and safeguarding the wellbeing of human populations. Examples of APPs are riparian zones, springs, hilltops, steep slopes and mangroves. Each rural landholding is thus required to have an environmental rural registry (CAR – the Portuguese acronym), which is an electronic register of georeferenced information about a rural property. The CAR integrates environmental information regarding the property (such as the LRs and APPs) to assist in monitoring and combating deforestation and degradation of native vegetation in private rural properties. The CAR is essential to access rural credit from financial institutions.

However, many properties have yet to meet these requirements: they either don’t have a CAR yet, or there is a deficit regarding the LR or a degraded APP that ceases to provide environmental services. Embrapa researchers found that family farmers face some particular barriers when it comes to the implementation of the forest code such as low education level of the farmers, lack of technical support, and incomplete fiduciary documentation[242]. The small size of these farms is also an issue, as preserved areas are not fully available for cropping and grazing. In this general context, the extension agents providing support to the farmers in this Project will work with all beneficiaries to ensure they become (are) fully compliant with the forest code. Smallholding family farmers are entitled to a slightly more flexible rule, that enables them to include certain types of production within their LR. According to research, the CRPS principles proposed by the Project are a viable option for smallholders to both fulfill their legal obligations to conserve and/or restore land within the Forest Code and maximize livelihoods and other benefits[243]. The CRPS proposed here are entirely aligned with the Low-Carbon Agriculture (ABC) program.

[242] LOPES, S. R. M.; BRIENZA JR., S. **A Regularização Ambiental e o Agricultor Familiar na Amazônia Legal a Partir da Lei Nº 12.651 de 2012**. Belém, PA: Embrapa Amazônia Oriental, 2017.
[243] MICCOLIS, A. et al. Restoration through Agroforestry: Options for Reconciling Livelihoods with Conservation in the Cerrado and Caatinga Biomes in Brazil **Experimental Agriculture**, n. 2017 - Online. Available at: https://doi:10.1017/S0014479717000138, p. 1 - 18, 2017.

The Forest Code also established another instrument that has only been implemented by one state in Brazil (Mato Grosso do Sul), the *Cotas de Reserva Ambiental* (CRA, Environmental Reserve Quotas)[244]. The CRAs[245] are a market mechanism of offsetting that can be an effective conservation tool for rewarding farmers that sequester carbon or avoid deforestation emissions[246]. This CRA market could potentially reduce the country's overall LR 'debt' by 56% [247]. Given the high costs of forest restoration, the exchange of CRAs could become a cost-effective way to facilitate compliance, meanwhile protecting forest surpluses that might otherwise be legally deforested. Balanced use of CRAs should focus on improving functional and ecological attributes of forested landscapes, e.g., habitat integrity (and thus biodiversity), carbon stocks, and water balance regulation.

The Project will fund activities designed to facilitate the development of a roadmap to implement the CRA market. Depending on these roadmaps, additional studies may also be financed by the Project to define priority areas, flexible compensation rates, ecological value, among others. In addition, all families participating will obtain the CAR, an instrument that is crucial for the implementation of the Forest Code.

The Low-carbon Agriculture (ABC) program and the Forest Code are the two most important instruments for achieving the NDC. Once state regulators and extension agents understand the possibilities and benefits of the CRPS principles implemented by the Project, they will be better equipped to oversee and support the implementation of the new Forest Code (to other non-beneficiaries of the project) and the ABC program, therefore generate consistent services and policy.

Overall contribution to climate-resilient development pathways, consistent with relevant national Climate Change Adaptation strategies and plans

The project will promote a shift from the predominant monoculture agriculture and top-down application of technological packages to the promotion of farmer-led technology development of CRPS. More efficient water management linked to the restoration of vegetation cover will produce valuable synergies for carbon sequestration, crop yields, and land management, producing huge benefits and positive impacts for livelihoods. Farming adaptation results should enable a paradigm shift not only amongst farmers but also with technical advisory services.

5.8.3 Sustainable development potential

Economic and social co-benefits

IFAD's core mission is to enable rural poor people, who are the most vulnerable to climate change, to overcome poverty themselves. The Project will enable the transition of 1,000,000 people, smallholder farmers and their families, to increase their resilience in an extreme climate environment, through improved CRPS and water access.

It will also create employment opportunities, as local economies are fostered and stimulated by its investment to promote rural entrepreneurship activities. There will be long-term macro-level indirect economic benefits derived from the project's contribution to food security and self-sufficiency. Reducing the vulnerability of farming households will also reduce the likelihood of such households needing relief assistance and/or safety-net pay-outs.

The project will ensure youth and women's participation in community decision-making, as this modus operandi is central to IFAD's operations and support to policy dialogue and south-south cooperation.

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[244] GASPARINETTI, P.; VILELA, T. **Implementando Mercados de Cotas de Reserva Ambiental (CRA): Desafios e oportunidades para as Regulamentações Estaduais**. Documento de Discussão. Available at: http://www.observatorioflorestal.org.br/content/uploads/2018/05/PORT_documento_de_discussao_CRA_CSF_Fev2018.pdf: Conservation Strategy 2018.
[245] Each Forest Reserve Credit represents one hectare (1 ha) of forest Legal Reserve, that is surplus to the amount required by law to be maintained in any given rural property.
[246] The CRA market can potentially reduce the country's overall Legal Reserve 'debt' by 56%.
[247] SOARES FILHO, B. et al. Cracking Brazil's Forest Code. **Science,** v. 344, p. 363 - 364, 2014.

All measurable benefits arise from addressing problems such as: (i) decrease in incomes resulting from increased costs of forage purchases when a climate change event occurs; (ii) decreased productivity due to the high pressure on native grazing; and (iii) expansion of degraded lands and unsustainable practices.

The following quantitative economic co-benefits can be pointed out:

- At least a 15% increase in vulnerable household´s income as a result of CRPS, thus contributing to poverty alleviation in the region.
- At least 23,000 ha of degraded or monoculture lands turned out into diversified and integrated agroforestry models.
- 36,000 vulnerable farmers are benefiting from increasing water access.
- Estimated increase in local fruit production of 78,000 tons after a 10-year period, improving the availability of fresh fruits for the local population, improving local consumption and nutrition levels.
- 70 local micro-enterprises strengthened, generating 200 local jobs for rural youth to support resilient productive family farming.
- Families in sustainably managed collective areas diversify their sources of income with other income generation activities and reduce timber extraction.
- 67,000 family farms participating in CRPS reaching an increase in biomass production of at least 50.000 kg/ha after a 10-year period.
- At least 1,080 small-holder households save between R$ 80 and R$ 104 per month in firewood / LP gas purchases for cooking, due to the implementation of efficient and ecological systems (stoves and biodigesters).
- Efficient and ecological systems (stoves and biodigesters) will also bring health benefits for these 1,080 families because they are smoke-free.
- At least 36,000 ha of collective areas benefit reducing CO2 emissions and improving families' livelihoods.

Qualitative benefits rely on (i) social-capital enhancement and improved cohesion to increase empowerment in targeted groups, (ii) improvements in food security, nutrition and health by increasing self-consumption of more in-farm natural fruits and vegetables.

Environmental co-benefits

Ecosystem restoration through CRPS offers compelling synergies between mitigation and adaptation to climate change, given that they improve the resilience of small-scale farmers through more efficient water use, soil conservation, improved microclimate, increased soil water content, control of pests and diseases, as well as improving farm productivity, beekeeping, and provide greater thermal comfort for animals, while sequestering carbon at the same time.

In addition, they help preserve the *Caatinga* ecosystem by increasing organic matter; improve pastoral management by adjusting stock rates; improve the management of native vegetation; and rationalize forest management, through selective logging, regrowth management and the redistribution of nutrients in the agro-ecosystem. It also diversifies production, increases land productivity and improves income and quality of life for farmers and their families. The system works for the protection of springs (riparian) and the reduction of water losses to provide continued access to water.

In short, the 90,000 ha of agroforestry systems funded by the Project and implemented by the family farmers will bring multiple environmental co-benefits, such as:

- ***Caatinga* restoration.** AFS can promote recovery of the original *Caatinga* ecosystem in at least two ways. 1. by integrating sustainable forest management within the same area of production; and 2. by naturally intensifying production in certain areas of the farm, which allows farmers to release key areas for restoration and conservation of the *Caatinga.*
- **Stabilization of the agricultural frontier.** Agroforestry allows a natural intensification that lengthens the time that crops can be grown on a given piece of land and increases crop productivity. Better soils

lead to better yields and higher efficiency, reducing the need for more land while providing a sustainable supply of firewood.

- **Improvements in ecosystem services.** The vertical structure of agroforestry systems supports significant levels of biodiversity and provide ecosystem services such as natural pest management, carbon sequestration, water and soil conservation, nutrient cycling, hydrological protection and crop pollination.
- **Improved water-use efficiency.** Leguminous trees in agroforestry systems have been shown to considerably enhance rain-use efficiency (the ratio of aboveground net primary production to annual rainfall).
- **Improved landscape integration.** The tree-rich matrix of agroforestry systems acts as a buffer for remnant natural forest fragments, ameliorating edge effects, improving landscape connectivity, and extending source habitat for a subset of the regional species pool.
- **Improved sustainability of land management** as a result of both ceasing fire for land preparation and integrating *Caatinga* vegetation into cropping and grazing systems that initiate the process of rebuilding soil fertility and also restoring agroecosystem functions.

Gender, traditional communities and youth-sensitive development aspects

In order to adopt a gender-sensitive rural development approach, 40% of technicians hired to perform technical assistance services in communities, including 'experimenting farmers' or 'local talents', must be women, which will facilitate greater protagonism of the female population in the planned actions. In the planned courses, meetings and exchanges, there will be an effort to maintain equity between men and women in the target audience. The proportion of 50% of women will be more easily maintained through the "*cirandas*" initiative for childcare during the planned activities.

The gender assessment revealed that women have less access than men to both tangible productive resources (land, credit, housing, and basic services) and intangible resources (education, technical assistance, political participation). The project will promote gender equality by providing access for rural women to the productive resources needed for agricultural development. The project will build women's leadership skills, foster their participation in decision-making processes, and assist women in accessing credit and technology for production and commercialization.

In practical terms, with regard to TRIPs, the Project will ensure that at least 40% of family farms can count on women and young people in their implementation cycle. It should be emphasized that building partnerships with gender reference organizations should be fostered as a way of facilitating gender mainstreaming with a feminist approach in the AT system, as these organizations can provide methodological approaches that support local and regional processes.

In order to guarantee women's economic autonomy, a fundamental guideline of the Project will be the promotion of specific training activities that ensure the incorporation of technologies based on the 'learning by doing' pedagogical approach, promote value addition and facilitate the exchange of knowledge about management aimed at the organization of housework and care. The educational approach adopted in local workshops and territorial meetings between women farmers will be inspired by 'feminist pedagogy', and its main objective is to foster a broad process of Environmental Education, seeking connections between feminism, women's rights, the *Caatinga* Biome's specificities and agroecological principles.

Although diversification is considered a primary principle of CRPS to be incorporated into the approach used by TA teams, it does not necessarily guarantee that household diets within the coverage area are more varied, as there is often a disconnect between production practices and Consumption habits. Thus, in order to improve the nutritional quality of families' diets, an action plan will be carried out with women lunch makers in the context of the PTIRs that will be developed within the EFAs and schools. The proposal is to convey information about the value of native plants and foods in local and regional culture, as well as encourage the creation of new recipes for school meals and encourage the establishment of seed banks within public facilities and local communities, targeting women who have traditionally taken care of food and socio-biodiversity practices within these environments.

Dissemination of climate information will apply gender considerations, and local governments will be trained to ensure that financial support can flow to activities that meet the needs of women.

The Project's gender focus will ensure better opportunities for women and youth in all three components. These implementation measures will:

- 400.000 women (40% of total beneficiaries) to have access to project benefits,
- Of these, 230.000 will access CRPS.

The full Gender Assessment and Project-level Gender Action Plan are provided in Annex 8 of the Funding Proposal.

As traditional communities (quilombolas, Funde Pasto and indigenous communities) are more vulnerable to situations of extreme poverty and manifest greater fragility in their organizational processes, a priority of this Project will be the reinforcement of the productive inclusion and local development of such communities. , aiming at social, environmental, cultural and economic sustainability. To this end, the Project will seek to develop specific technical advice approaches that seek to value traditional knowledge about agricultural production modes, extractivism and practices aimed at preserving biodiversity (such as the preservation of 'Creole seeds', for example). It will also seek to strengthen the processes of self-organization and articulation with relevant broader organizations, including in order to support these groups in guiding the land regularization processes in which they were eventually involved. The particularities of the methodological approach to technical assistance for traditional communities should be fully incorporated into all activities performed by TA teams working with these groups. In the case of indigenous groups, in addition to the aspects mentioned here, all Project activities with them must be framed by the FPIC Plan.

With regard to rural youth, the Project will develop two lines of action in order to create more opportunities for this segment, giving priority especially to young women, who tend to be even more excluded than young men in the processes of productive organization. The first action guideline focuses on providing opportunities for professional qualification courses, focusing on encouraging multi-activity and diversified production systems such as those based on agroecology. Such activities aim to strengthen their entrepreneurial capacity, serving as a form of preparation for the professional field, but at the same time, they should keep them linked to the universe of small-scale agricultural production.

The second guideline involves the use of media resources to encourage young people's interest in the full range of agricultural and non-agricultural activities offered by the countryside. A network of 'young communicators' will be fostered who will act at the local and regional level, assisting the audiovisual recording processes and participatory systematization of the actions developed with families, as well as contributing to the production of materials on semiarid themes that consolidate an affirmative image in relation to the rural area, its cultural traditions and the lessons learned in the field of sustainable agriculture. Potentially produced materials will be incorporated into the pedagogical projects of the rural schools, the EFAs and the field education programs in the Project coverage area, as well as serving as inputs for political impact.

5.8.4 Needs of the recipient

Vulnerability of the country and/or specific vulnerable groups

Although Climate Change Vulnerability Index (CCVI) evaluates Brazil as a medium risk country[248], the Brazilian Semiarid is the most vulnerable region in South America, exposed to an average annual temperature increase from 4° to 6° C[249]. If current trends are confirmed, the region will become arid by 2050. The targeted area has a very high incidence of prolonged and severe droughts, with the most recent drought cycle lasting approximately five years (2011-2016). Semiarid areas highly susceptible to desertification reaches nearly 200 thousand km^2 (20% of the region), involving 1,262 municipalities[250]. In the context of global warming,

[248] CAF. **Vulnerability Index to climate change in the Latin American and Caribbean Region**. Caracas. : CAF, 2014. Available at: http://scioteca.caf.com/bitstream/handle/123456789/509/caf-vulnerability-index-climate-change.pdf.
[249] IPCC (2014). Central and South America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. In: Barros VR et al. (Eds), Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, p. 1499-1566.
[250] VIEIRA, R. D. S. P. et al. Identifying areas susceptible to desertification in the Brazilian Northeast. **Solid Earth,** v. 6, p. 347 - 360, 2015.

communities' high dependency on crops raises the regional vulnerability index, which can increment to extreme or high risk levels.

The Project targets the most vulnerable groups to climate change in the country (rural women, youth and traditional communities of the Semiarid), enabling expansion and diversification of income-generating activities. Women are particularly vulnerable to reduction in food and water supplies. Traditional communities (indigenous, *fundo de pasto* and *quilombola*) are also highly exposed, notably to land tenure insecurity, because most of them lack legal titling and recognition of their communal lands.

Economic and social development level of the country and the affected population

Although Brazil is classified as an upper-middle-income economy, with 2017 per capita earning of US$ 8,580, poverty levels are alarming, and the country has one of the world's highest inequality rates.[251] From 2014 to 2017, poverty has increased by 33%, reaching 11.18% of Brazilians (23.3 million people). [252] The target area is the world's most populous dryland[253] and the local population is among the poorest in the country - 59.1% of all Brazilians in extreme poverty live in the Northeast (9.61 million people), and the region encompasses 32.7% of municipalities with very high food and nutritional vulnerability (a total of 52 cities)[254]. Family farmers of the Semiarid face pressing economic and social development challenges, such as low income, limited access to credits, food and water insecurity.

The absence of alternative sources of financing

There is a critical need to bridge existing investment gaps to assure Brazil transitions towards a climate-friendly and resilient development pathway[255].

The following key barriers were identified creating the absence of tailored funding for climate change adaptation and mitigation for highly vulnerable rural areas in the Northeast Semiarid: i) rising level of public indebtedness and fiscal imbalances at national and subnational levels, ii) weak investment and deteriorated local credit market, iii) high perceived funding risks for highly vulnerable groups in the targeted region, iv) lack of long-term investment drivers and high intermediation costs, iv) high interest rates. The current Project aims to address these barriers by mobilizing the BNDES – a very important public sector financial entity in Brazil – with a financial instrument composed by a blend of grant and loan that leverages public and private funds, enabling new investments in climate change-related projects.

The need for strengthening institutions and implementation capacity

In the Brazilian semiarid region, there are several deficiencies or weaknesses in what refers to the design/conception and also the implementation of effective actions of implantation of productive and resilient agrosilvopastoral systems, capable of promoting the adaptation of the present systems to the predicted climate changes. There are also difficulties in implementing what the Forest Code determines.

Firstly, the multiplicity of rural actors, coupled with the lack of concertation mechanisms, makes it difficult to coordinate actions. On the other hand, there are also limitations regarding the domain of climate risk issues and resilient systems, both at the level of governmental bodies responsible for designing policies of this type, and at the level of direct execution in the field, which is basically done by advisory providers. Technique In the latter case, the limitations encompass both the domain of the aforementioned problem and the use of participatory methodologies, necessary to mobilize the local population to adapt to climate change. Regarding

[251] ALVAREDO, F. et al., Eds. **World inequality report 2018**: Havard University Press, p.296, ed. 2018. Available at: https://wir2018.wid.world/download.html.
[252] Based on the statistics of the Continuous National Household Sample Survey (PNAD), from 2004 to 2014, the extreme poverty reduction surpassed 63%. (NERI, M. **Qual foi o impacto da crise sobre a pobreza e a distribuição de renda?** Rio de Janeiro: Fundação Getúlio Vargas, 2018. Available at: https://www.cps.fgv.br/cps/bd/docs/NOTA-CURTA-Pobreza-Desigualdade-a-Crise-Recente_FGV_Social_Neri.pdf.).
[253] MARENGO, J. A. Vulnerabilidade, impactos e adaptação à mudança do clima no semi-árido do Brasil, Parcerias Estratégicas, 27, 149–75, 2008. Available at: http://seer.cgee.org.br/index.php/parcerias_estrategicas/article/viewFile/329/323%20%C2%A0.
[254] IBGE (2017). Pesquisa Nacional por Amostra de Domicílios Contínua (PNAD). Available at: https://www.ibge.gov.br/estatisticas/sociais/habitacao/17270-pnad-continua.html?=&t=o-que-e.
[255] OECD. **Financing Climate Futures: The role of National Development Banks in Brazil and South Africa**. OECD Case Study - KEY FINDINGS. Paris: OECD, 2017. Available at: http://www.oecd.org/dac/environment-development/Financing-Climate-Futures-NDB-Brazil-South-Africa.pdf

the application of the Forest Code, there have been advances in the realization of the rural real estate environmental records (CAR) and also in the elaboration of the Environmental Regularization Programs (PRAs), which is elaborated when the property presents irregularities before the determinations of the Rural Code. But the difficulties are still very significant regarding the effective implementation of these PRAs.

At the institutional level, by working with various government agencies at the federal and state levels, the Project will contribute to improving the coordination processes between these agencies, providing opportunities for the design and implementation of joint actions. Thus, the Project will contribute to the improvement of planning processes, in order to improve the processes of implementation of initiatives oriented to resilient agricultural production and adaptation to climate change. In this way, the implementation of the Program should help the competent bodies to define better public policies and climate change adaptation programs. The participation of state government agencies (Secretariats of Agriculture, Agrarian Development, etc.) in the implementation of the Project will allow capacity building at this level, previously absent, for the design and implementation of such initiatives. At the same time, the Programme's action will enable the various types of TA providers, both public and private, to gain greater mastery and experience with participatory methodologies and the most productive and resilient agrosilvopastoral systems.

On the other hand, the implementation of these agrosilvopastoral systems should be a powerful instrument in the process of adapting rural properties to the norms of the Forest Code. In this way, the Program will be showing a path for the implementation of PRAs, which should continue after their completion.

The intensive work of monitoring and systematizing the processes and results obtained by the Program should feed into this process of strengthening the different organizations involved and the capacity to implement such initiatives. This institutional strengthening, at various levels, should allow the process of changes in the productive semiarid systems to consolidate and even expand after the end of the Program.

Thus, this Project will play a crucial role in strengthening local, regional and national institutions for education, research and extension, and in regulating strategies to promote climate adaptation and resilience in the agricultural sector. TA will be provided to family farmers' organizations and schools, introducing new concepts and skills linked to environmental sustainability. These initiatives will strengthen the linkages between implementing agencies and organizations in the Northeast, taking advantage of each partner's comparative advantages to maximize mitigation and adaptation benefits as well as other co-benefits (Section D3 of the funding proposal). In addition, South-South Cooperation will facilitate knowledge sharing among other developing countries.

5.8.5 Country ownership

The proposed project is included in the National Strategy for the Green Climate Fund, and it adheres to the two strategic axis and the following investment areas: Adaptation based on Ecosystems and Water Security; Resilience and Sustainability of Indigenous and Traditional Communities; Restoration, Conservation and Reforestation; Low Carbon Agriculture and Adaptation of the Productive Process. The strategy also includes water security as a key priority.

Brazil has an overarching National Policy on Climate Change, which paves the way to the implementation of measures for adaptation and mitigation by the three federative government layers: federal, state and municipal. The National Policy supports the national voluntary commitment of reducing GHG emissions by 36.1% to 38.9% in relation to the projected emissions, until 2020. Regarding specific REDD+ actions, Brazil has an obligation to stabilize emissions at 2005 levels for the *Caatinga* Biome.

In the Nationally Determined Contribution (NDC), Brazil highlights that adaptation is considered a fundamental element to tackle climate change and its effects. The social dimension is at the core of Brazil's adaptation strategy, bearing in mind the need to protect vulnerable populations from the adverse impacts of climate change and enhance resilience.

In this context, the country developed a National Adaptation Plan (NAP), which puts forward cross-sector adaptation strategies to address the wide range of risks that climate change is creating and is the means to implement the adaptation aspect of the NDC. The NAP has also established guidelines to implement adaptive measures aimed at increasing climate resilience in 11 sectors and themes.

The NDC presents the strengthening of the Low Carbon Agriculture Program (ABC) as the main strategy for sustainable agriculture development and commits to restoring 15 million ha of degraded pasturelands, enhancing 5 million ha of integrated cropland-livestock-forestry systems and restoring and reforest 12 million ha of forests by 2030. The ABC Plan is one of the sectorial plans devised under the National Policy on Climate Change. Its overall objectives are: reducing greenhouse gas emissions in agriculture; improving the efficiency in the use of natural resources; increasing the resilience of production systems and rural communities; and promoting adaptation to climate change in the sector.

Brazil has also been reviewing environmental regularization of private rural areas to reduce deforestation and promote sustainable land use practices. The Forest Code has been reviewed on 2012, and Law No. 12.651/2012 reinforces Brazil's commitment to the protection of native vegetation and the integrity of the climate system by establishing restriction for the use of areas of native vegetation on private properties: Permanent Preservation Areas (APP) and Legal Reserve (RL), as defined by the law, must be maintained by the landholders with native vegetation at a proportion of 20% for the *Caatinga* Biome. The Forest Code also included responsibilities for environmental liabilities through a mandatory registration on the Rural Environmental Registry (CAR) for all rural landholdings (Article. 29, Law No. 12.651/2012).

Beyond the revision of the Forest Code, in 2012, a series of advances in environmental policies and laws occurred in the last twenty years. Recently the National Policy for the Recovery of Native Vegetation (PROVEG) was launched with the challenge of implementing the Forest Code in a total area of at least 12 million hectares by December 31, 2030.

The additional Recovery of Native Vegetation Plan (PLANAVEG), launched through Inter-ministerial Ordinance No. 230, dated November 14, 2017 will support the continuation of the implementation of the Forest Code, providing incentives to smallholders, indigenous peoples and traditional communities, having as a basis the information from the National Rural Environmental Registry System (SICAR).

The Brazilian Biomes Environmental Monitoring Program is aligned with the objectives of the ENREDD+ and will deliver the enhancement and improvement of systems and monitoring protocols – particularly for the extra-Amazonian biomes – necessary for achieving the desired national scale combat to deforestation and forest degradation and to foster forest recover using the National Climate Change Fund.

Nevertheless, Brazil has been advancing on setting an enabling environment for the country's priorities for low-emission and climate-resilient development, and recently has had its first successful and exclusive approval of payment for US$ 96 million for reducing deforestation, degradation or emissions through other REDD+ activities such as conservation, sustainable management of forests or enhancement of carbon stocks (e.g. ecosystem restoration).

5.8.6 Efficiency and effectiveness

Financial structure justification and profitability indicators

As discussed in detail in Section 5.5, under the current scenario of climate funding in Brazil, the project would not be viable, neither for the country nor states, without GCF funding.

The proposed financial elements were selected to render the project viable.

Benchmarks

Considering the GCF finance portion only, the indicator of 'Effectiveness of GCF Adaptation Investment' stands at a cost of US$ 99.5/ beneficiary. As discussed in section 5.6, when compared to other rural development projects in Latin America, the 'Planting Climate Resilience Project' is well ranked. Even when the entire cost is taken into consideration, the PCRP Project lies within the higher effectiveness range of rural adaptation projects in the region.

Another indicator that can be considered is 'Effectiveness of GCF Mitigation Investment', measured by the cost of each tCO2 reduced. In the case of the PCRP Project, this cost is US$ 24.6 / tCO2eq, which a low cost when compared to other projects of the region.

Financial indicators

Financial analysis (see section 5.3 Financial Analysis) allows understanding, based on behavioural hypothesis and parameters, if potential beneficiaries will be motivated to take risks and make the investments required by the project. It simulates the incentives and benefits (at the individual and, sometimes, group level) to ensure beneficiaries will have the means to take on the project´s proposal. The analysis uses a realistic approach by making assumptions on the delays in adopting technologies and drop-out rates for entrepreneurship initiatives. Ten models were developed to simulate impacts for each type of intervention on each targeted group of beneficiaries. These models illustrate the range of activities that could be developed by the targeted beneficiaries.

Overall, the financial analysis per model shows positive Net Present Values (NPV), Financial Internal Rate of Returns (FIRR) going beyond the cutoff rate and Benefit-Costs ratio higher than 1, so all models are considered profitable, with FIRR rates ranging from 10% to 39% depending on the supported activity, and net present values (NPV) at the 10% discount rate varying from R$ 2.322 to R$ 219,491. For more information, see section 5.3 and Annexe III.

Profitability indicators and cost-effectiveness

The economic analysis considers all the costs and benefits of the Project (with market prices to calculate total economic costs). It allows evaluating the global efficiency in management resources for the government and society. The analysis is made by aggregating the farm models using market prices and adding externalities (that will be represented in this case by the environmental benefits from avoiding CO2 emissions). It was calculated over a period of 20 years and at a shadow discount rate of 10%[256]. To incorporate results in the economic analysis, all prices have been calculated applying conversion factors for imported tradable goods, exported goods and labor. No market distortions are supposed to affect non-tradable goods. As mentioned before (section 5.4 Economic Analysis and Sensitivity), the overall Economic Internal Rate of Return (EIRR) for the Project is 19.77%, while the NPV is worth US$ 152,004,000.

It is essential to highlight that the calculations performed to show that the cost benefit ratio of the Project as a whole – expressed by Project B / C Ratio – is 3.18. This number can be considered a very positive result.

When considering financial benefits at the household level, the average increase in incomes can be estimated at approximately 20%.

As was said before, a sensitivity analysis was carried out assuming different risk scenarios, including different increases in project costs, possible reductions in project benefits, delay in these project benefits and the occurrence of climate change extreme events (every 2, 3 and 4 years).

According to these calculations, the project is assumed to be profitable and resilient as it supports most of the tested scenarios, such as an increase in costs up to 30% or a reduce in benefits of 30%. Even in the case of a mixed increment in costs up to 20% and a reduction in benefits of up to 20%. In these cases, the NPV remains in positive range. The project would not be profitable in the case of a mixed cost increase of 20% and a benefit reduction of up to 30%. This serves to demonstrate that the project is well diversified and not highly exposed to price or sectorial risks.

[256] Taking into account 10 year bonds yields for the country (between 9 and 10%).

5.9 Sustainability, up-scaling and exit strategy

The proposed long-term strategy for rural areas of the Brazilian Semiarid builds on the extensive experiences and lessons learned from previous BNDES[257] and IFAD[258] projects targeting the strengthening of family peasant farming and promoting climate-friendly social technologies in the region. Building on this solid foundation, the project also expects its results will have sustainability beyond the project period.

The following elements, incorporated in the Project design, contribute to the sustainability, durability, and scalability of its impacts after development assistance embodied in Project activities has been finalized:

- **Institutional strengthening and capacity building.** As mentioned in several sections of this Study, capacity building of farmers and strengthening of rural organizations (community or branch associations[259], cooperatives, etc.) will be an important objective of the Project. For this reason, diverse activities of this kind will be implemented. As a result of this effort, the project will build the capacity of family farmers, and their organizations, to assess, plan, adopt and use climate resilient agriculture and water management practices.

- **Locally adapted solutions**. The selection, development and dissemination of CRPS, which are viable and offer economic benefits, will be done in partnership with famers, thus assuring that these systems will be highly adapted to local environmental conditions and also the families' needs. At the same time, the investments made with local microenterprises that produce tools, equipment and other innovations for resilient climate production will be another factor that will ensure that local solutions are valued.

- **Assuring self-reliance through climate resilient productive systems (CRPS), locally adapted solutions that are cost-effective**. CRPS shifts the way family farmers manage soil and water resources in the post-project scenario. The project concentrates on technologies that are cost-effective and easily taught and applied.

- **Adapted tools and microenterprises to foster rural entrepreneurship**. The project will provide support to microenterprises to stimulate the development of tools, equipment and services geared towards CRPS to improve labor conditions in the field.

- **Multi-stakeholder Engagement[260].** The Project was designed and will be implemented with an active community, civil society, local and national government participation. This collective building helps ensure lasting impacts. Effectively managed partnerships with selected partners at international, national and local levels will enable the Project to: i) focus on partner's complementarities and comparative advantages; ii) strengthen its capacity to address agricultural issues effectively and efficiently; iii) leverage resources to scale up successful approaches.

- **Engagement of the National Development Bank.** BNDES is a strategic partner whose commitment and experiences will add value to all the Project cycle and maximize the achievement of the Project's goals. BNDES has national influence and a capacity to mobilize resources. It also will disseminate lessons learned to other bank programs and has the potential to include many more CRPS-type projects in its lending portfolio.

- **Influencing public policy.** Advocacy to improve access to markets and establish CRA markets will guarantee that sustainable gains are maintained beyond implementation.

[257] BNDES's Social Fund is currently investing on family farming development programs in seven Northeast States and has already funded 24 thousand cisterns and 3.3 thousand social technologies for agroecological production in the region.
[258] IFAD is currently implementing 6 projects supporting the productive structuring of family farming and water access social technologies, encompassing 11 states, 9 of which located in the Northeast region.
[259] Branch associations, such as goat breeders' or bee-keepers' associations.
[260] IFAD's Strategic Framework 2011-2015 includes effective partnerships and resource mobilization as one of eight principles of engagement. (IFAD. **An executive summary of IFAD's Strategic Framework 2011-2015**. Rome: IFAD 2011. Available at: https://www.ifad.org/documents/38714170/39132730/sf_summary_e.pdf/c76021bc-a3de-4563-adcf-eddfbb9a6e16).

- **Women and youth empowerment**. These groups' leadership is promoted transversally throughout most project activities. The network of young communicators, for example, engages youth to register, experiment, and build awareness of the CRPS practices. Women leadership will be fostered by developing the capacities of local women, enabling them to become ‘knowledge managers’.

- **Knowledge building based on lessons learned from the Project’s implementation process.** A monitoring and evaluation framework (M&E) system and data base-lines are designed in such a way that M&E can operate in real time, as from the beginning of Project implementation. Under Component III, the Project will systematize and disseminate the results of the implementation of CRPS, including economic analyses of the returns of these systems. This information will be disseminated widely to the farming community, buy it will also be targeted towards decision makers and policy formulators, with the aim of stimulating commitments from different stakeholders, including government agencies that deal with resilient rural development. Dissemination will be done using a range of methods and platforms, such as capacity building sessions, learning and knowledge sharing events and workshops, as well as multiple media outlets. The exchange of lessons learned will foster development effectiveness and allows scaling up of the implementation of agroforestry systems in existing *Caatinga*.

- **Fostering South-South Cooperation.** The Project also engages in South-South Cooperation for sharing knowledge and lessons-learned with farmers of other developing countries living under similar climate stress.

- **Exit Plan.** To sustain the interventions and scaling up pathways after the end of the project, the PCRP project team will develop an exit plan in the penultimate year of implementation which will focus on building beneficiaries’ capacities to manage the investments, hand-over of data and responsibilities for maintenance of infrastructure (e.g. of databases) to relevant authorities, and compile results and lessons learned and finalization and systematisation of knowledge products.

The exit strategy relies on the success of the project itself to improve the livelihoods of project participants and to create an enabling environment at various levels that are supportive of climate resilient agricultural production.

6. MONITORING AND EVALUATION

6.1 General configuration of the Monitoring and Evaluation System

A Planning, Monitoring Evaluation and Learning System (PMEL) will be developed to allow the results-based project management. The data and information collected through the use of specific tools for the implementation of Climate Resilience Productive Systems (CRPS), will contribute not only to learning, feedback and improvement of project interventions but will also build the foundations for the material relevant to the knowledge management (KM). The PMEL will be a fundamental tool to the Central Project Management Unit (CPMU/BNDES) decision making and will be in particular useful to provide feedback to the Project Management Units (PMUs) at the state level. In addition, the systematization and dissemination of good practices and successful experiences will be important to define and design South-South cooperation schemes, advancing concrete results.

The Project Management and Accountability System (PMEL) of the activities and results will be executed at two levels (or by two instances): the first will be inserted in the central coordination team (PMEL-CPMU), and the other level that will make up the state project teams (PMEL-PMU). These two levels will be active parts in the planning and monitoring of the activities to be performed. PMEL activities will be undertaken by state-level projects, with information compiled by the central body to be established with the CPMU.

The PMEL-PMU teams should be in line with the State Secretariats involved assisting in the measurement of logical framework indicators, information regarding physical advances and results obtained. In this way, each PMEL-PMU will be able to monitor and coordinate the execution of all activities proposed for the Project in the respective State and strategically support the implementation of these actions. In addition to operational complementarity, these articulations will be vital to ensuring that the counterpart portion of the state is implemented in accordance with the proposed design.

The choice of each activity to be performed by the Project should be linked to an analytical and participatory process, involving all stakeholders, starting with the other professionals of the PMUs, state units, entities engaged in the provision of the TA service, collegiate bodies. municipal and territorial level, and the community and economic organizations with which the Program works. In this sense, the planning process will take place within the rural communities, land reform settlements and traditional communities in all municipalities that will be part of the Project. It will be up to each PMU to create mechanisms and procedures to integrate, at the local and regional level, the Project planning process with the other planning carried out by partner public and private entities in the municipalities covered by the Project.

The PMEL-CPMU team will be responsible for receiving and consolidating information from the state projects, and should, therefore, be articulated with the PMEL-PMU teams. Thus, it will be up to the CPMU to feed the Program's logical framework with the progress of the results, besides planning and conducting evaluative studies that encompass the main activities carried out in the field by the State Projects.

6.2 M&E activities and tools

6.2.1 Activities

The main PMEL activities are:

i) monitoring of Logical Framework (LF) indicators;
ii) supporting the preparation of the AOP with the responsible for components;
constantly updating the M&E IT system (own and of IFAD Brazil);
iii) supporting the teams responsible for the implementation of the Components in the preparation of the Technical Progress Reports;
iv) managing the Impact Assessment Study (Baseline and Final Assessment);
v) Elaborating quantitative records of interventions by thematic area;
vi) conducting a participatory and qualitative assessment of results;
vii) using Geographic Information System (GIS) for monitoring.
viii) Monitoring Resilience and GHGs

Therefore, there will be an effort to integrate Project monitoring strategies. This will provide the creation of internal space for the technical teams for continuous reflection, based on the systematized information, on the progress and obstacles in the achievement of the indicators put, and provide the conditions to review the action strategies in the various stages of the implementation cycle.

Regarding the institutional arrangement, it should be emphasized that the specialists of Social Communication (SC) and Knowledge Management (KM) should work in line with the teams of M&E and those of gender, race and ethnicity. Thus, there will be the production of knowledge in an integrated manner, able to subsidize new actions, and also for the dissemination of the main results obtained.

The information generated by the M&E system, which will attest to the validity of experiences in the social and environmental field from the various proven impacts, will be used by the SC & KM team in the dissemination process, serving as inputs to influence public opinion and to influence the political sphere. In this way, the materials produced under the Projects will provide a solid basis for the scaling-up process, also assisting in the elaboration of legal frameworks and public policies aimed at the sustainable management of natural resources.

6.2.2 Tools

The main MRE tools of the Project - at the general level and also at the state level - are:

The **Logical Framework** integrates three levels of indicators: impact (based on results of Impact Assessment Studies), results and process (Project advances). The last two types are designed to evaluate the results of Project actions in the field and will serve as a basis for rethinking and realigning the planned strategies and activities. The M&E system is sensitive to gender and generation; thus, whenever possible, these data will be disaggregated.

Impact Assessment will be carried out by each State Project and composed of two phases:

- **Baseline Study (BS)**, which is a start-up phase database of families' conditions in the covered area at the beginning of the Project. It will consist of a sample survey involving treatment groups (beneficiaries), and a control group (not served by the Project). The survey questionnaire will follow the model IFAD applies for its Projects in Brazil, adapted to cover all the expected impacts of the Project. In order to elaborate the sample design of the baseline study, as this is particularly important for the accomplishment of the impact assessment study, the Project should consult with renowned institutions such as the International Policy Center for Inclusive Growth (IPC-IG), a United Nations body and IFAD's partner in developing sample designs and validation of baseline databases in Brazil.
- **Final Evaluation Study** is based on a household sample survey. It shall apply the same research questions, and impact indicators of the BS, covering the same treatment and control groups visited during the previous phase. This Study shall be done during the last year of project execution and will include families that have benefited from the Project for at least three years, as well as a control group.

Quantitative systematizations of interventions by thematic area shall be carried out, to inform the Project M&E unit of the most immediate impacts on households in terms of income and food security in short to medium term. These activities need to articulate with other Project components and to include specialists of different areas - Race, Ethnicity, Gender, and Youth. The results of the learning exchange visits will also be systematized and reported. At least 3 of these thematic systematizations will happen throughout the project execution period.

Participatory qualitative evaluation of results. The CPMU will implement a participatory monitoring methodology referring particularly to CRPSs results obtained in the field, with the participation of youth communicators. M&E data will be used to communicate Project's results to the media, governments and partners. Outcomes of exchanges and learning initiatives will also be published as part of the Project Knowledge and Results Management.

Technical Progress Reports (TPR). State Projects will submit TPRs each semester, with detailed descriptions activities by component and subcomponent. TPRs will inform to what extent implemented activities promoted progress in reaching the goals set in the Project design and Annual Operational Plan.

M&E using Geographic Information System (GIS). The Project will carry out monitoring activities using the Geographic Information Systems (GIS) methodology, with the objective of demonstrating the recovery of the intervention areas (areas of productive use (SAFs) and vegetation restoration areas). The adoption of this type of methodology will serve as an essential subsidy for the calculation of carbon sequestration.

To analyse the restoration of recovered areas, the following ecological indicators will be monitored: canopy and soil cover, regenerating density, and number of regenerating species. This analysis will extrapolate the limits of the intervention areas, evaluating the spillover effect of Project actions. Vegetation recovery will be monitored every three years and studies should be preferably performed during/after the rain season. These studies will be implemented in partnerships with expert institutes, such as GEO-BNDES, the National Institute of Space Research (INPE), MapBiomas, in addition to specific consultancies.

Monitoring of resilience: Monitoring of changes in the resilience capacities of farming families is a particular feature of the monitoring of the impacts of the project. Understanding and monitoring family/household resilience is complex. There are multiple factors, linked to socioeconomic and agroecological conditions, contributing to the families' capacities to cope with climate shocks and adapt to growing tress from slowly increasing temperatures and hotter and dryer conditions. Inspired by the DFID KPI4 Methodology adapted to the IFAD and GCF project type, a resilience scorecard and index have been developed tailored to the project's theory of change (reference appendix 1). This methodology has a pragmatic approach to deal with the multifactor complexity. It only focuses at monitoring the resilience capacities the project seeks to address or is likely to influence. It does not monitor absolute resilience but changes in resilience of the beneficiaries compared to the baseline or control group families. The resilience questionnaire and scorecard may be adjusted in consultation with project stakeholders at project start-up and will be completed as part of the baseline survey and at midterm and at the end of the project. As mentioned under point (3), it should be used for knowledge generation and improved analysis of resilience dynamics by combining it with the GIS-based monitoring studies of vegetation cover and ecological quality and climate data showing if stresses or extreme weather events have occurred during the implementation of the project.

Participative and qualitative evaluations of results: Participative monitoring will use indicators to analyze several aspects (in conjunction with the "youth communicators"). The team should use M&E data to prepare communication documents on the project's main results for the media, government, and partners, including the Forum of Secretaries of Family Agriculture of the Northeast and Minas Gerais. It is the responsibility of the consulting team to present -- in a simple, visual and comprehensive manner -- the progress made in the project's main activities and results, in both the monitoring and evaluation phases. This consulting team will use the progress reports as well as the M&E system inputs, results of the baseline study, thematic systematizations, and impact assessment study to draft and disseminate material summarizing and illustrating the project's main advances to a diverse audience, in both the public and private sectors. The consulting team will prepare and organize the photographic material to be used in the content disseminated to the government and partner entities. The project's knowledge management team will also be in charge of the dialogue and exchange of experiences with other BNDES and IFAD projects in Brazil. Publication and dissemination of communication material on results of exchanges and learning pathways with farmers and technical assistance teams from other IFAD and BNDES projects will also be part of the project's knowledge and results management.

Quantitative organization of interventions by thematic area: The project should quantitatively organize activities by thematic area (e.g., productive farms, sheep / goats, transformation of waste from productive activities into production inputs, etc.). This organizing will report on the most immediate impacts on each family's well-being in terms of income and food security in the short to medium term. At least five thematic organizing efforts should be undertaken during the project execution period. By their nature, these evaluations will be part of the Learning and Knowledge Management subsystem.

GHG tracking tool (annex 11A): will provide initial estimations on GHG reductions, for verification. The information required to complete the report will be streamlined into TRIPs and will be tracked at investment level. Each PMU will present to the CPMU semiannual reports tracking investments for evaluation.

6.3 Results Framework

Please select the appropriated expected result. For cross-cutting proposals, tick both. ☒ Shift to low-emission sustainable development pathways ☒ Increased climate resilient sustainable development

E.2. Core indicator targets			
Provide specific numerical values for the GCF core indicators to be achieved by the project/programme. Methodologies for the calculations should be provided. This should be consistent with the information provided in section A.			
E.2.1. Expected tonnes of carbon dioxide equivalent (t CO_2 eq) to be reduced or avoided (mitigation and cross-cutting only)	Annual	550,140 t CO_2 eq	
	Lifetime	Between 11 086 999 tCO_2eq and 11 621 173 t CO_2 eq	
E.2.2. Estimated cost per t CO_2 eq, defined as total investment cost / expected lifetime emission reductions (mitigation and cross-cutting only)	(a) Total project financing		202,500,000 USD
	(b) Requested GCF amount		99,500,000 USD
	(c) Expected lifetime emission reductions		11 M t CO_2eq
	(d) Estimated cost per t CO_2eq (d = a / c)		18 Choose an item. **/ t CO_2eq**
	(e) Estimated GCF cost per t CO_2eq removed (e = b / c)		9 Choose an item. **/ t CO_2eq**
E.2.3. Expected volume of finance to be leveraged by the proposed project/programme as a result of the Fund's financing, disaggregated by public and private sources (mitigation and cross-cutting only)	(f) Total finance leveraged		103,000,000 USD
	(g) Public source co-financed		103,000,000 USD
	(h) Private source finance leveraged		Choose an item.
	(i) Total Leverage ratio (i = f / b)		1.04
	(j) Public source co-financing ratio (j = g / b)		1.04
	(k) Private source leverage ratio (k = h / b)		
E.2.4. Expected total number of direct and indirect beneficiaries, (disaggregated by sex)	Direct	1,000,000 40% of female	
	Indirect	1,500,000 40% of female	
E.2.5. Number of beneficiaries relative to total population (disaggregated by sex)	Direct	4.7 (Expressed as %) of NEB population	
	Indirect	7 (Expressed as %) of NEB population	

The full Results Management Framework is available in APPENDIX IV of this Feasibility Study.

7. PROJECT MANAGEMENT AND IMPLEMENTATION

7.1 Implementation Arrangements

The institutional arrangements aim at simultaneously providing cohesion for the project and guaranteeing operational independence for the participating states. They result from ample consultations with state governments, local stakeholders including civil society, and relevant national authorities, including the National Designated Authority (NDA) in the Ministry of Economy (ME), Ministry of Citizenship (MC), Ministry of Regional Development (MRD) as well as BNDES. The main legal agreements will be the funding activity agreement between the GCF and IFAD; the loan and grant agreement between IFAD and BNDES; the state level agreements between BNDES and participating state governments, and the Convênios between the states and final beneficiaries.

The Central Project Management Unit (CPMU) will be placed within BNDES to monitor implementation, compile physical and financial information, report to IFAD and be overall accountable. As sole EE entity, BNDES will have the final decision making power on all project activities including: i) use of funds; ii) State selection and project implementation area; iii) final beneficiaries; iv) eligible practices and interventions; v) TRIPs approval; vi) approval of procured TA Teams and service providers.

Each state will prepare a carta consulta (or proposal) for BNDES review and decision, which will include proposed implementation area, final beneficiaries, and interventions, among other relevant information. BNDES will review and select proposals applying eligibility and prioritization criteria as included in the PIM. If approved by BNDES, a State-level Implementing Unit (SIU), will be set up to support procurement, financial management, evaluation and monitoring at state level. Each state will implement its state level financing agreement with BNDES and comply with IFAD policies on procurement, financial management, auditing, monitoring, eligibility, and anticorruption, as well as requirements defined by BNDES in its co-financing policy. The state level financing agreement will mirror the arrangements established in the loan and grant agreement(s) and comply with its provisions. Before granting the no-objection to the subsidiary agreements, IFAD will conduct a financial management assessment of the corresponding SIU to ensure that the appropriate financial management arrangements are in place.

The SIUs will be based within the state secretaries responsible for family farming, whenever possible, states will build upon pre-existing operational structures of IFAD-supported projects. The TORs and selection of key SIU team members, as well as selection of support consultants, will require prior review by IFAD and approval by BNDES. Both the CPMU and SIUs will establish multi-stakeholder committees for guidance, composition and responsibilities are further described in table 2 below.

Figure 6. Project management structure

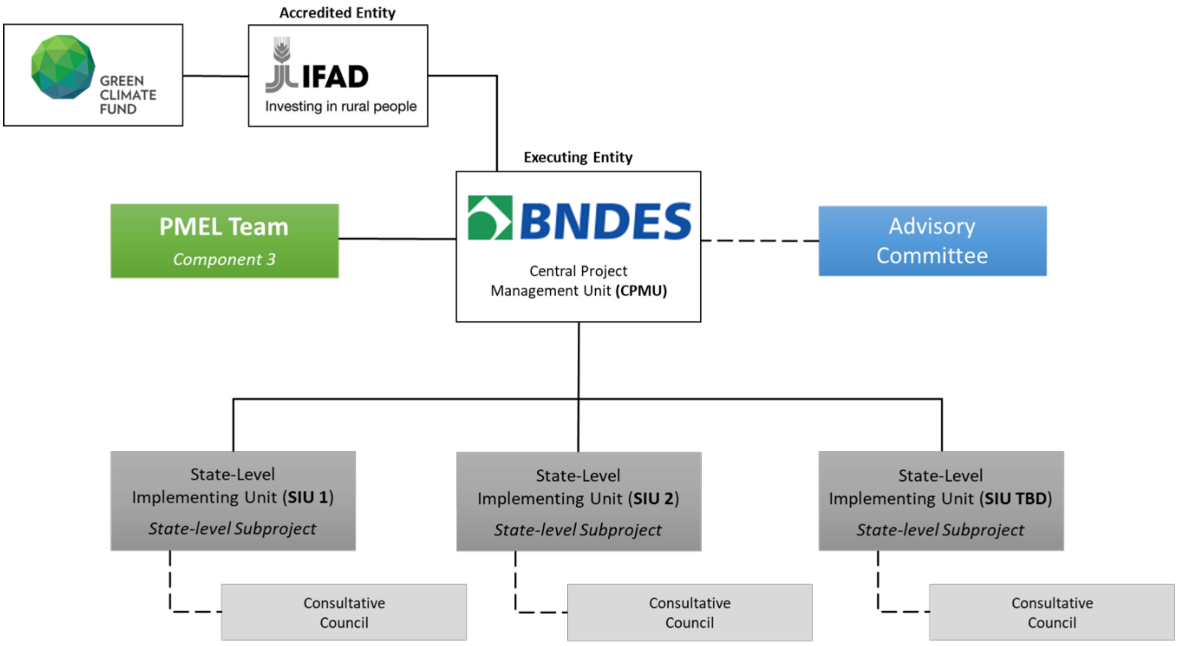

Table 15. Institutional governance

ARRANGEMENT	COMPOSITION	RESPONSIBILITIES
IFAD	IFAD team headed by Country Director	Produces the GCF´s Annual Performance Reports on the basis of the progress reports received from BNDES; Carries out the supervision (includes the findings of the field supervision missions), mid-term, implementation support and final review missions, and reports as necessary; Reports to the GCF; Conducts prior reviews and issues no-objections.
Central Project Management Unit (CPMU)	BNDES team headed by Project Coordinator	Housed in the Executing Entity, has final decision making power. Executes the overall project and coordinates state-level subproject implementation in line with the PIM; Oversees, guides and evaluates project execution; Approves the state-level sub-projects' AWPBs; Guides the PIUs on state-level subproject implementation, including AWPBs, operational issues and reporting; Submits AWPBs, including procurement plans, and physical and financial progress reports for the overall project to IFAD; Performs financial management, accounting, engages auditors and submits audit reports to IFAD, relative to the activities of the overall Project; Submits Withdrawal Applications to IFAD; Requests IFAD no-objections; Proposes changes to the project design based on implementation experience and external circumstances (including the project's logical framework and the PIM).
State-Level Implementing Units (SIUs) State-level subproject	Subproject teams headed by Subproject Manager	Implements **Components 1 and 2** at state level in line with the PIM and the guidance of CPMU; Perform financial management, procurement and contract management; and provide full access to and collaboration with the project auditors; Submit Withdrawal Applications to BNDES; Submit requests for no-objections to BNDES, for passing on to IFAD; Ensure procurement is compatible with the Project's social and environmental safeguards; Submits AWPBs, including procurement plans, and physical and financial progress reports for the subprojects to BNDES; Ensure that contractors are familiar with GCF, IFAD and BNDES policies, norms and procedures to: (i) avoid ineligible expenditure and delays in projects implementation; (ii) protect the assets of the project; Develop TOR and cost estimates, technical specifications and budgets; Conduct analysis of quotations, technical and financial proposals; Prepare price calculation maps, reports of portfolio, technical and financial evaluation; and Manages respective contracts provided for procurement and contracting plan.
PMEL Team	Planning, Monitoring, Evaluating, and Learning Team headed by PMEL Manager	Implements **Component 3** in line with the PIM and the guidance of CPMU. Perform financial management, procurement and contract management; and provide full access to and collaboration with the project auditors; Submit requests for no-objections to BNDES, for passing on to IFAD; Ensure procurement is compatible with the Project's social and environmental safeguards; Submits AWPBs, including procurement plans, and physical and financial progress reports for the subprojects to BNDES; Ensure that contractors are familiar with GCF, IFAD and BNDES policies, norms and procedures to: (i) avoid ineligible expenditure and delays in projects implementation; (ii) protect the assets of the project;

		Develop TOR and cost estimates, technical specifications and budgets; Conduct analysis of quotations, technical and financial proposals; Prepare price calculation maps, reports of portfolio, technical and financial evaluation; and Manages respective contracts provided for procurement and contracting plan.
Advisory Committee	Representatives from the NDA, federal government, civil society, participating states, BNDES	Ensure project efficiency, integration with other programs / policies, and achievement of expected results. Advises on general direction of project execution; and Promotes integration and alignment with other government projects, programs and policies.
Consultative Councils	Representatives of State Administration, beneficiaries and civil society	Ensure attainment of objectives, transparency and equity. Ensure participation of beneficiaries and civil society representatives (including indigenous peoples) in addition to representatives from state secretariats. Review the subproject´s AWPB. Assess activities and procedures of the SIU; Review technical-administrative, economic-financial and operational information related to SIUs; and Integrates and aligns with other state projects, programs and actions Evaluate and validate TRIPs for BNDES approval

7.2 Flow of Funds and Disbursement

Flow of funds and disbursement arrangements: Project operations will be in compliance with loan and grant agreement(s), IFAD General Conditions for Agricultural Development Financing and its disbursements, financial reporting and audit procedures, as well as with BNDES regulations for financing state entities. GCF grant and loan, and IFAD loans will be made available to BNDES under one financing agreement covering grant and loan instruments, and including a sovereign guarantee agreement[261]. IFAD Client Portal will be the online platform used by BNDES to submit requests for disbursements to IFAD. IFAD standard disbursement procedures will be applicable to both GCF and IFAD financing:

(1) Advance/replenishment. BNDES will open and maintain designated accounts for each financial instrument to receive GCF and IFAD funds, which will then be channelled to the SIUs operating accounts. The currency of the designated account will depend on the currency selected for the financial instruments. The operating accounts at State level will be managed by the SIUs. IFAD will establish the amount of the advance for each financing instrument on the basis of approximately 9 months of average expenditures (indicatively). Funds will then be replenished following the presentation of withdrawal applications and relevant supporting documentation of eligible expenditures.
(2) Direct payment. BNDES may also request IFAD to directly pay providers for amounts higher than the equivalent of USD 100,000.

Further details and disbursement procedures will be included in the Letter to the Borrower (LTB) and Disbursement Handbook, which will be prepared by IFAD and sent to the Borrower upon signature of the Loan and Grant Financing Agreement (s).

The financing to the states will also be under one single financing agreement covering GCF, IFAD, and BNDES financing, and including both loan and grant instruments. BNDES will have a single agreement with each selected stated covering sub-loan and sub-grant. For the states, BNDES may advance resources and make successive replenishments through the presentation of evidence of expenditures, following its institutional financing procedures, the Project Implementation Manual, and in compliance with IFAD requirements. The flow of funds arrangements between BNDES and the states will be established in the State level Agreements. The SIUoperating accounts at State level will also receive counterpart funds directly from BNDES.

The states in turn will exclusively have sub-grant agreements (in legal terms called Convênios) with community associations or organizations (final beneficiaries). The states transfer funds to legally constituted beneficiary associations and organizations bank account under a “convênio” agreement with the state. Additionally, TA teams will be contracted by the states following BNDES guidelines and final approval, through open selection

[261] GCF and IFAD loans will benefit from a sovereign guarantee by the Federal Government as approved by COFIEX Resolution No. 01/0137, of September 17, 2019 (doc. SEI 5638739).

process and competition (procurement) to implement TA work. The same procedure is applicable for all TA under components 1 and 2. In addition, in the case of Component 3, BNDES will carry out a procurement for a specialized organization to support implementation of activities.

IFAD project financial supervision and midterm review. Project supervision will be carried out directly by IFAD, independent from other national control and oversight bodies. From the financial perspective, it will consist of onsite supervisory missions, which will assess financial management arrangements, identify areas requiring improvement, fiduciary risks, and corresponding mitigating measures. Financial supervision will also be conducted through office reviews of periodic financial and annual consolidated audit reports.

There will be a midterm review of the project, which will evaluate: (i) progress in relation to achievement of results and disbursement performance; (ii) effectiveness of the institutional and financial arrangements; (iii) the financial procedures manual, suggesting revisions and updates; (iv) the results of execution and financial management of the states; and (v) achievement of AWPBs.

In an on-desk role, IFAD will conduct prior reviews of the initial bidding process for each of the planned method in each state and of those that exceed the resource margin set forth in the procurement plan. During supervisory, support and mid-term review missions, IFAD will analyse, through sampling, the subsequent tenders. Annual audits should be considered mainly to analyse sampling of biddings processes not verified by IFAD in its missions to have a greater scope of execution verification. All IFAD reviews, as well as the audits, should be guided by the IFAD procurement policy and the fight against fraud, corruption and eligibility.
To ensure the executing entity (BNDES) has sufficiently strong financial management systems and oversight to manage, control and report the project's finances adequately to ensure that resources are used economically and efficiently for the intended purpose (in line with IFAD's financial management assessment guidelines), IFAD conducted a financial management assessment (FMA) at BNDES, in particular in the financial division and public management and sustainability division, which will be responsible for project coordination.

In terms of state-related risks, BNDES will use its expertise for credit evaluation considering the states' payment and implementation capacity. BNDES will seek sovereign guarantees, as extended to GCF and IFAD loans, for the state level project operation.

Figure 7. Flow of Funds

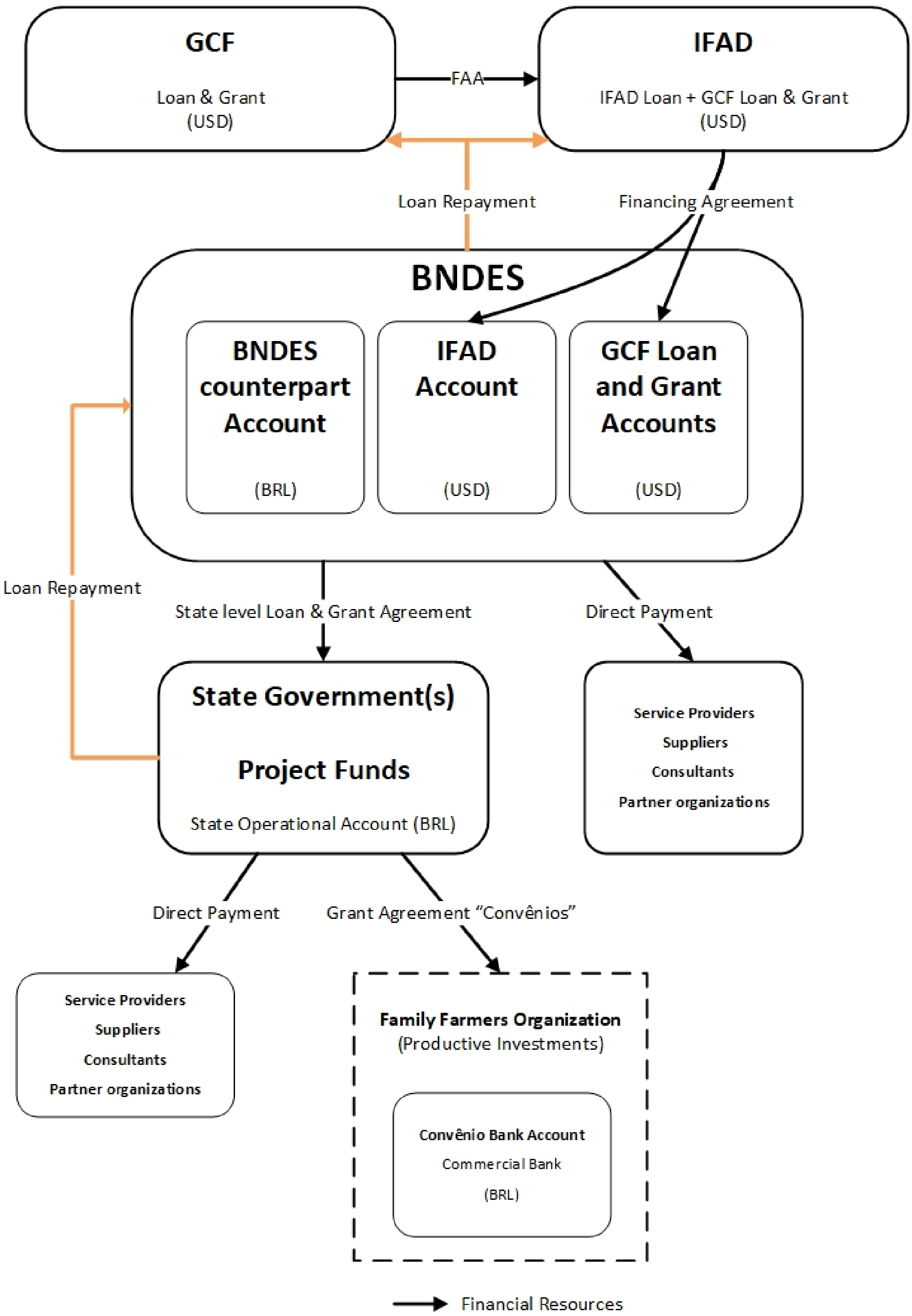

Figure 40 Funds Flow Chart

7.3 Financial Management and Procurement

7.3.1 Financial management

GCF resources will be under IFAD's fiduciary responsibility, and the agency will follow its technical, financial and monitoring standards. BNDES will have the role of Central Project Management Unit (CPMU), carrying out the Project's financial management with a qualified team of public servants and acting with a global fiduciary responsibility to execute the financial arrangements established in IFAD Guidelines.

Internal Control will be ensured by the segregation of duties, reconciliation of accounts and expenses approval by experts. The Handbook of Financial Procedures, detailing guidelines for disbursements, payments, approvals, commitments, and reporting, will orient CPMU and PMU staff. All Project budget and accounting transactions will be carried out in the Accounting Management System (AMS) of each entity. All project costs are accounted for in accordance with the Annual Work Plan and Budget (AWPB).

Accounting: BNDES uses its own financial management system for the planning, execution and follow-up of projects and activities. This system will provide information for monitoring the Annual Work Plan and Budget (AWPB), the use of resources, project accounts, counterpart contributions, contracts and agreements by categories of expenditures, project components and sources. The Project will use IFAD's Client Portal-ICP to send requests for withdrawals, accountability and monitoring of Project's financial information.

Financial Reports: Both the CPMU and the PMUs will generate financial information, identifying sources of funds and expenses by budget line, categories and components. The CPMU will periodically send interim financial reports (IFR), and Annual Financial Statements to IFAD. PMUs will report to BNDES, subsidizing the CPMU in the consolidation of information submitted to IFAD.

Internal and External Audit: The Project will be audited annually by independent external auditors in accordance with International Standards on Auditing (NIAs) and INTOSAI. Reports shall be submitted to IFAD within 6 months after the end of the fiscal year. PMUs will also have their project accounts audited annually, the report of which shall be provided to the CPMU to support the auditing of the whole Project.

7.3.2 Procurement management

Procurement management will be carried out through the PMUs with the support of experts in bidding, hiring, and accountability. State Project teams should have the technical capacity to prepare and manage contracts, as well as support the formalization, execution, and closure of agreements with beneficiaries

In all Procurement and Contracting Plans (PCP) activities, PMUs should use IFAD and BNDES Guidelines. Bidding can be awarded to a partner institution, mainly for the recruitment of staff, after analyzing its institutional capacity to follow IFAD and BNDES Bidding Guidelines, contractual arrangements and policy on fraud and corruption.

To ensure an efficient execution, IFAD will conduct an analysis of the installed capacity of each Project. IFAD will keep track of team selection to ensure that the workforce is adequate; review the preparation of each Project Implementation Manual (PIM); oversee the elaboration of Handbooks and Booklets for bidding commissions to ensure proper project execution; supervise procurement and contract management. IFAD will also provide training to improve teams' capacity at the start of implementation and when necessary.

PMUs shall be responsible for the safekeeping and provide instruction on procurement processes and ensure that beneficiaries do so and make them available for future audits or IFAD and BNDES supervision. This also applies in cases where there is a partner institution supporting project implementation.

8. CONCLUDING REMARKS

As stated earlier, in the Brazilian semiarid region, the present situation and future prospects of the rural population, as well as of the *Caatinga* biome itself, are quite gloomy.

The livelihoods of family farmers are already severely stressed due to the historical degradation of the ecological and productive functions of backcountry agroecosystems, a process resulting from several factors. Among them, we will mention their vulnerability to climate variability and the increasing demographic and productive pressure on the resource base available to these families. In this context of increasing pressure on resources (vegetation, soil, genetic resources, water), many of the newly introduced innovations aimed at intensifying production have had a negative effect on sustainability, increasing resource depletion.

This process will be severely aggravated by the regional effects of climate change - such as increased rainfall variability with a significant downward trend, more frequent and severe droughts, and rising temperatures - with a possible collapse of production systems. This situation can lead to a substantial worsening of environmental degradation, as well as a situation of water and food insecurity and an acute crisis in the livelihoods of the population living in this region.

However, against this background, several initiatives have begun to be tested and implemented in recent years. They signal it is possible to reverse this scenario, seeking to favor adaptation to climate change. It is worth mentioning, on the one hand, the emergence of some public policies - even if they are still insufficient - that have an explicit concern with the resilience and sustainability of the population and environment of the semiarid region began to be implemented. We will mention as an example the minimum income programs, access to water, and the Rural Environmental Registry.

On the other hand, since the beginning of the 21st century, there is a growing concern with the redesign of production systems. There has been a growing conviction that these systems need to be profoundly renewed to enable the rural population to obtain their livelihoods while preserving the ecosystem. A transformation of production systems in a sense pointed out here is crucial to promote adaptation to ongoing climate change.

In the present study, several technical proposals, which fit the perspective of change indicated in the previous paragraph, were presented and evaluated. This evaluation indicates a valuable collection of sustainable practices that should feed the much-needed process of redesigning the backcountry production systems. In the analysis made, it was shown that these proposals have a considerable potential to increase and mainly to "stabilize" production in the face of the growing stress that climate change is causing. At the same time, these proposals, virtually by definition, seek to preserve and, where necessary, restore existing environmental resources. Thus, new production systems should allow better management of water and soils, preserve/restore native vegetation, and conserve local genetic resources.

Although this collection may still be enriched with new proposals, the main conclusion of this study is that the current challenge is to spread the use of these proposals much more widely, so that in the coming years a considerable area is being managed through Climate Resilient Productive Systems (CRPS).

This challenge is the central axis that should guide the performance of this project. Therefore, the present study also presents, in detail, the Planting Resilience Project, seen as a powerful instrument to be placed at the service of the much-needed changes outlined above. The examination of the axis indicates that this action should be entirely feasible.

On the other hand, while some public policies should be considered as initiatives that have a positive impact on resilience, it must be recognized that active policies for the dissemination of resilient production systems are very scarce today. In this context, the Project's intervention format - which will provide investment support and technical assistance - characterizes an innovative form of public action that, if successful, will represent a model to be used for designing public policies to support semiarid resilience in the future.

Project: Planting Resilience in Rural Communities of the Brazilian Semiarid

Feasibility Study

APPENDIXES

Project: Planting Resilience in Rural Communities of the Brazilian Semiarid

Feasibility Study

APPENDIX I

Principles and Practices for Design and Implementation of Climate Resilient Productive Systems (CRPS) in Semiarid Northeast Brazil

➢ Introduction

FAO[262] (based on IPCC[263]) classified technologies and practices that improve farmer's climate resiliency in improved agronomic practices, integrated nutrient management, tillage and residue management, water management, and agroforestry. These practices are often grouped and referred to as Climate Resilient Agriculture, or Climate-Smart Agriculture, and can consist of several methods, arrangements, and technologies. What is climate-resilient to one biome or a production system may not be applicable to another. Climate challenges are also varied in any given geography, and adaptation solutions depend on the size of the area and resources available to the farmer. Thus, IFAD hired a team of expert consultants including agronomists, environmental scientists, an anthropologist and a farmer; who spent three weeks in the field consulting several farmers, NGOs, technical assistance teams as well as universities and research institutions; to respond to the following question: <u>what is climate resilient agriculture for family farmers in the Brazilian semiarid?</u>

➢ Six guiding principles for Resilient Systems in Semiarid Northeast Brazil

The Project will encourage family farmers to apply principles and practices of resilient production to set up two integrated and interdependent agricultural subsystems ensuring productivity during the twelve months of the year: one specialized dry subsystem (only depending on the rainy season for water) and another specialized year-round production that makes use of specific water sources and storage particularly during the long dry season. In the semiarid region, IFAD found out that the concept of resilient climate production translates into practices that will increase <u>availability, flow and retention of water</u> in the system. Pragmatically, it means the simultaneous implementation of the following practices and principles, which shall define what Climate Resilient Productive Systems (CRPS) are:

(i) <u>Soil Preparation</u>: Maintenance of dispersed trees, setting up cradles and natural fertilization;
(ii) <u>Soil Protection</u>: Soil cover and biomass production with resilient plant varieties;
(iii) <u>Water management</u>: capture and storage (both in soil and vegetation), contour lines or curves and terraces;
(iv) <u>Planting practices</u>: seeking to enhance stratification, diversification and densification with herbaceous, shrub and tree species maximizing the photosynthetic capacity of the plot;
(v) <u>Management of cultivated vegetation</u>: active pruning and thinning;
(vi) <u>Sustainable animal husbandry</u>: pasture rotation and fences.

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[262] BRANCA, G. et al. **Climate-Smart Agriculture: A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management**. Rome: FAO, 2011. 35 p.
[263] IPCC. **Climate Change 2007: Mitigation of Climate Change. Working Group III contribution to the Fourth Assessment Report of the IPCC**. Cambridge, United Kingdom and New York, NY, USA Cambridge University Press, 2007.

While most practices to be supported (see Table A below) have the potential to yield sustainable land management benefits and increase production, they require a significant change in farmers' practices and quite substantial investments. GCF support will enable farmers to take a longer-term perspective in anticipation of the significant financial, economic and livelihood benefits achievable through the application of adaptation measures relative to the declines in production and income that are expected to result from the effects of climate change.

GCF support responds to the urgency which climate change projections give to the application of these practices, and recognizes that for them to function effectively as adaptation measures, they must be applied as part of a larger-scale program and be directed and adjusted considering the needs, priorities and cultural specificities, both regional and at the local levels, of productive units.

These practices are interlinked, and their benefits are synergic, which means they must be implemented together. Assembling an agricultural system with these elements makes it a water producer, not a consumer, which is the correct approach for a region with low water availability. Table A below presents the adaptation benefits that each principle provides to the family farmer.

Table A. Principles and Practices of Climate Resilient Agriculture in the Semiarid

Practices / Adaptation Benefits	Retain soil moisture	Recharge soil moistue	Increase organic matter in soil	Increase photosynthesis	Increase soil carbon	Capture water	Capture humidity in air	Improve microclimate	Reduce erosion
(i) Soil Preparation: Maintenance of dispersed trees, micro-valleys and natural fertilization	X		X	X				X	X
(ii) Soil Protection: Soil cover and biomass production with resilient plant varieties	X		X		X	X	X		X
(iii) Water retention: level curves and terraces		X				X			X
(iv) Planting: Stratification, diversification and densification			X	X		X		X	X
(v) Management: Active pruning and thinning;				X				X	
(vi) Grazing: Pasture rotation and fences.			X	X	X				X

(i) Soil Preparation

The first step in soil preparation is to eliminate the slash and burn as a method of land clearing. Studies show it is inappropriate for agricultural production in the semiarid because it continuously degrades soil and biodiversity of the *Caatinga*.[264] Land clearing for pastures and plantations will be performed by selecting, pruning and maintaining dispersed trees. Maintaining or even increasing the number of dispersed trees in the pastures in the dry tropics that endure prolonged dry periods represents an option to increase the productivity, profitability and sustainability of animal husbandry systems.[265] [266] The removed biomass from the land clearing will serve as soil cover, as explained in part (ii).

Soil preparation activities must be carried out during the dry period, well before the first rainfall, so the plants and animals can take advantage of all the water for their development, avoiding delays and the compromising of results. Cradles for planting seedlings or seeds should be opened, reserving the top soil to put back into the cradle at the time of planting. They must be rich in nutrients to allow the plants to have enough food to grow. The use of natural fertilization will be encouraged, be it the fertilizer of ruminants or the biomass produced by the system as well as phosphate and, if possible, rock dust. Fertilization is not a simple provision of nutrients to the plant. It has the function of activating the soil's biological activity and involves the cycle of water and minerals. If plantation lines are contemplated, they should be concave in their longitudinal axis to accommodate the natural humidity of the environment and favor the development of the plantation, creating a micro-valley where the root of the plant is located.[267]

[264] MAMEDE, M.; ARAÚJO, F. Effects of slash and burn practices on a soil seed bank of Caatinga vegetation in Northestern Brazil. **Journal of Arid Environments**, n. 72, p. 458 - 470, 2008.
[265] ARAÚJO FILHO, J. A. **Manejo pastoril sustentável da caatinga**. Recife, PE: Projeto Dom Helder Camara, 2013. 200 p.
[266] LASCO, R. D.; DELFINO, R. J. P.; ESPALDON, M. L. O. Agroforestry systems: helping smallholders adapt to climate risks while mitigating climate change. **Wiley Interdisciplinary Reviews: Climate Change,** v. 5, n. 6, p. 825 - 833, 2014.
[267] SOUSA, H.; MATOS ALMEIDA, S. R. **Jardinagem Florestal: Criando e manejando Agroflorestas de alimentos**. Sl: Edição do Autor, 2016.

(ii) Soil Protection

The soil is a living organism and, thus, needs feeding. Biomass, or organic matter, is the vital food of the soil, especially in the tropical climate, where nutrient cycling is vigorous, and the decomposition of organic matter is quick. A malnourished plant under stress of any origin, increases respiration, reduces photosynthesis, and consequently accumulates fewer carbohydrates, water and produces smaller harvests. A compacted soil with little macrobiotic life prevents roots from obtaining nutrients and water. Therefore, to meet the needs of the plant, the farmer must protect the soil from the sun, wind, and rain, in addition to nourishing the fauna. Healthier plants result in photosynthetic efficiency that ensures better yields. This gain is so significantthat if there is availability at low cost, family farmers will be encouraged to bringing biomass from outside sources to cover the soil.

In order to grow biomass, a plantation matrix must be constructed with specialized species that photosynthesize during the long dry season, which natural in the dynamic of the *Caatinga*. This means combining plants into a system that is capable of producing biomass and accumulating water all year long, including under the stress of climate-induced droughts. This matrix should consist of *cacti*, *euphorbiaceae*, *spondias* and *agavaceous*.

If possible, at the beginning of implementation, farmers will produce forage for animals and food for human consumption. However, the biomass withdrawn from the system should be the smallest part (1/3), leaving most of it (2/3) to feed the system itself. These fractions will reverse as the soil becomes more fertile and the system healthier.

(iii) Water management

Water can be considered the main limiting factor for agriculture and animal husbandry in the *Caatinga* zone. Nevertheless, the water debate should be focused <u>not</u> on its absence but on how to preserve water during the rainy season so that it can be used during the rest of the year.

It is fundamental to understand that the most important water reserve must be the soil itself. This can be accomplished by reconstructing the natural infiltration promoted by the forest systems that have been depleted. To build a Climate Resilient Agricultural System in degraded and compacted areas, such as the ones often found in the Semiarid region, it is necessary to plant in terraces and along contour lines, as well as installing artificial systems for capture, storage and infiltration of rainwater, such as ditches, reservoirs and microbasins, to eliminate runoff and promote forced recharge, and thus improve soil hydration.[268]

Component 2 details multiple water harvesting techniques which are being widely used in the region. It is crucial, nevertheless, to implement these technologies as a means to shift the culture of production in the *Caatinga* towards climate resiliency. Performed with the current agricultural practices, these technologies will only increase the dependency on external water and fertilization resources, as soils will continue to degrade and compact. Yet, with the development of the Climate Resilient Productive Systems proposed here, the infiltration can occur naturally making more springs perennial and promoting a biological water reserve in the roots and leaves of specialized vegetation (species such as forage cactuses, *mandacaru*, deer papaya, *umbú*, sisal, *piteira*, aloe).

(iv) Planting practices: stratification, diversification and densification

Stratified, diversified and densified cropping patterns increase the photosynthetic capacity of land, and therefore, the volume of biomass produced per cultivated area, improving water circulation and promoting an improvement in the microclimate[269].

The competition among plants takes place in the strata and not for water or nutrients. Plants of different strata harmonize because they have different light requirements. Crops of the lower layer produce in the shade, those

[268] BRANCA, G., et al. **Climate-smart agriculture: a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management**. Rome: FAO, 2011.35 p.

[269] LASCO, R. D.; DELFINO, R. J. P.; ESPALDON, M. L. O. Agroforestry systems: helping smallholders adapt to climate risks while mitigating climate change. **Wiley Interdisciplinary Reviews: Climate Change,** v. 5, n. 6, p. 825 - 833, 2014.

of the middle stratum need a little more luminosity, and so on, up to those of the emergent stratum that require full light. A system with photosynthetic efficiency associates plants belonging to different strata, that do not compete with each other.

According to Sousa**Error! Bookmark not defined.**, the strata and their respective occupancy rates can be:

- Ground stratum, plants can occupy 10 to 20% of the horizontal space
- Low stratum, plants can occupy 80 to 90% of the horizontal space
- Medium stratum, plants can occupy 50 to 60% of the horizontal space
- High stratum, plants can occupy 20 to 40% of the horizontal space
- Emergent stratum, plants can occupy 10 to 25% of the horizontal space

Whereas in a monoculture, the potential photosynthesis can reach up to 100% in any given area, in stratified plantations, it can vary from 160% to 235%. Considering that the sun is the only source of energy, this energy needs to be harnessed to the highest intensity. Thus, maximum plant cover is necessary. The horizontal density that complements the stratification uses both commercial and non-commercial species, the latter to be used to generate biomass that will be incorporated into the system.[270]

Several studies suggest that stratified systems may be more resilient to extreme climatic conditions than annual crops and tree-crop monocultures, as they have several mechanisms to reduce the impact of droughts, such as buffering of humidity, reduction of air and soil temperature extremes, windbreaks and shelter belts to slow wind speed and minimize water loss from evapotranspiration.[271,272]

The diversification and stratification must increase in time as the system progresses. First, the project will promote tested consortium models that can both improve the production conditions as well as stimulate discussions on new agricultural practices and combinations between the species the farmer is already familiar with. As the system becomes more productive, the diversity and quantity of products will increase and, in return, the system will produce water instead of consuming it.

(v) Management of cultivated vegetation: active pruning and thinning

Pruning, thinning and removal of the senile individuals, to open more space to restart the planting process under more evolved conditions is crucial to the success of the system. Short-cycle crops (herbaceous and shrubs) inter-cropped with tree species (timber and fruit) should be planned, so that after a few years of agricultural production, the trees may be cut to form a new clearing, thus restarting a new production cycle. As the productive environment improves permanently, increasing production and productivity, there is no need for the farmer to leave the plot and clear new land. [273]

Natural pruning - caused by wind, lightning, insects - is used by Nature to 'organize' natural forest systems. The function of pruning is the input of organic waste and the rejuvenation of the species and the system. In cultivated systems, pruning can serve several general purposes simultaneously: ensure structure in the stratum of the system; production of biomass to protect and feed soil; production of stakes and stems for planting or fences; forage production; or for marketing such as firewood, stakes, etc. Pruning can also be carried out with more specific objectives, as is the case of the pruning of food species to boost production and of timber species to produce a better stem.

Swidden agriculture is an ancestral technique; to a certain extent, it is the indigenous agriculture or itinerant cultivation, which, after abandoning the area, relies on Nature for the recovery of soil fertility, through the regeneration of the natural vegetation. Planned and practiced on the basis of the principles of forest management, CRP Systems are a model of food production that guarantees recovery, improvement and

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[270] SOUSA, H.; MATOS ALMEIDA, S. R. **Jardinagem Florestal: Criando e manejando Agroflorestas de alimentos**. Sl: Edição do Autor, 2016.
[271] BRANCA, G., et al. **Climate-smart agriculture: a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management**. Rome: FAO, 2011.35 p.
[272] MICCOLIS, A. et al. **Restauração Ecológica com Sistemas Agroflorestais: como conciliar conservação com produção. Opções para Cerrado e Caatinga.** Brasília: Instituto Sociedade, População e Natureza – ISPN/Centro Internacional de Pesquisa Agorflorestal – ICRAF, 2016. 266 p.

[273] SOUSA, H.; MATOS ALMEIDA, S. R. **Jardinagem Florestal: Criando e manejando Agroflorestas de alimentos**. Sl: Edição do Autor, 2016.

conservation of the soil, production of clean, sweet and crystalline water, abundance of healthy foods, and food security and sovereignty for the farming family.

It is important to reinforce that with this kind of active management; the whole system sprouts vigorously, generating more biomass production. When this practice is done correctly, and at the appropriate time, the system becomes resistant to drought periods and acquires resilience for good use of the rainy season.

(vi) Sustainable animal husbandry: pasture rotation and fences

Animal husbandry, especially goats and sheep, is the main activity of the family farmer beneficiaries of this Project. Many authors have shown that stratified systems with trees can provide benefits for this activity[274]. Trees can be an essential source of shade and shelter to animals improving productivity by reducing heat stress in tropical climates. In addition, some tree species produce leaves and pods which are highly palatable to these animals and are available during the dry season when pastures are of a low nutritional quality. Native trees of the *Caatinga* (such as *faveleira* or *carnaúba*) improve weight gain and milk production.[275] However, grazing and forage management need to be adapted so as to increase resilience to climate change.

Areas with a low grazing pressure show a higher diversity of plant species than areas with higher grazing intensity. To implement the climate resilient production systems, it is necessary to reduce free-roaming livestock, fodder storage and pasture rotation[276].

Forage will be grown with the system described above.[277] Especially in the first few years, nevertheless, animals should not interfere in the system, thus making fences necessary. The installation of live fence that requires no maintenance or renovation will be encouraged. These live fences/trees can be part of the system and fulfill several other functions such as wind-breaking, biomass production; fruits and fodder production and also serve as shelter for the animals.

- **Diversity of Climate Resilient Models**

In addition to the adaptation benefits laid out above, the practices prosed in this project have the potential to reduce atmospheric carbon by storing it in the aboveground biomass of trees, in soil organic carbon and, indirectly, by reducing pressure for forest clearance.

In the Brazilian semiarid, it should be noted that there are several concrete models that apply the practices and principles of CRPS cited in Table A. For instance, during one of the preparatory field missions, IFAD team had the opportunity to learn about the 'syntrophic'[278] model from a farming family in the municipality of Riachão do Jacuípe. This system is characterized by being extremely diversified, managed with pruning and densification, and for having as its main productive activities: goat rearing (milk and meat), vegetables and fruits. Another case observed during the project's design mission was the agroforestry model of forage production, which is based on the planting of forage cactuses and various other forage tree species.

There are records in the literature of CRPSs developed by Embrapa Goats and Sheep Research Centre, located in Sobral. This model is characterized by the management of *Caatinga* areas with thinning, 'lowering'[279] and enrichment techniques. This kind of system has already been successfully implemented in land reform

[274] ESQUIVEL MIMENZA, H. **Tree resources in traditional silvopastoral systems and their impact on productivity and nutritive value of pastures in the dry tropics of Costa Rica**. 2007. (MSc). CATIE, Turrialba, Costa Rica.
[275] ARAÚJO FILHO, J. A. **Manejo pastoril sustentável da caatinga**. Recife, PE: Projeto Dom Helder Camara, 2013. 200 p.
[276] SCHULZ, K. et al. Grazing, forest density, and carbon storage: towards a more sustainable land use in Caatinga dry forests of Brazil. **Regional Environmental Change,** v. 18, n. 7, p. 1969 – 1981, 2018.
[277] MICCOLIS, A. et al. **Restauração Ecológica com Sistemas Agroflorestais: como conciliar conservação com produção. Opções para Cerrado e Caatinga.** Brasília: Instituto Sociedade, População e Natureza – ISPN/Centro Internacional de Pesquisa Agorflorestal – ICRAF, 2016. 266 p.
[278] Syntropic' Agriculture is a term referring to a na agroforestry farming system (AFS) based on the concept of syntropy (contrary to entropy) characterized by the organization, integration, equilibrium and preservation of energy in the environment (MONTE, A. L. **Sintropia em agroecossistemas: subsídios para uma análise bioeconômica**. 2013. 112 p. (MSc). Mestrado Profissional em Desenvolvimento Sustentável, Universidade de Brasília, Brasília.).
[279] This means pruning the higher branches of trees so as to induce sprouting that is easy to reach for the grazing animals.

settlements located in Rio Grande do Norte[280], as a result of the work of the IFAD-funded Projeto Dom Helder Camara. It is also worth mentioning the *recaatingamento* model, which is designed for the recovery of degraded areas and is being used in the region that is known as the Sertão do São Francisco da Bahia Territory[281].

Mentioning these examples, we want to point out, on the one hand, that there are already some proposals of CRPS being implemented by family farmers with positive results. Although these examples follow the same general principles, the diversity (of size, crops, arrangement) is as a key element to deal with the different situations that characterize the reality of the target region. On the other hand, these examples also indicate that such initiatives are few and far between, not yet reaching a larger scale.

[280] SIDERSKY, P.; JALFIM, F.; RUFINO, E. Combate à pobreza rural e sustentabilidade no semi-árido nordestino: a experiência do Projeto Dom Helder Câmara. **Agriculturas: experiências em agroecologia,** v. 5, n. 4, p. 23 - 28, 2008.
[281] Retrieved at: http://www.recaatingamento.org.br/

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APPENDIX II

Technical Assistance services for beneficiaries of Productive Resilience Investments

The Technical Assistance (TA)[282] is considered an essential tool for the Program to achievedesired results. Recognizing that families in poverty and extreme poverty have the least access to scarce TA services and are those who need this support the most, the advice provided by the Project will play a major role in driving actions to be developed with the families and organizations with which it will work. In the broadest sense, the Program TA will have as its primary function to develop, among the beneficiary population, the necessary capacities for the success of the initiatives supported by the Program.

In the case of this Project, the Technical Advisory Service system will seek to incorporate the input of experienced farmers into specially identified climate resilient production practices. Often in development projects, technical assistance providers play a central role in teaching farmers what to do, instructing them on methods and techniques. However, it turns out that extension service providers are usually not practitioners and are not closely related to their advisors in the communities. The strategy for this Project postulates, contrary to conventional approaches, that technical advice should be a participatory process in which beneficiaries are involved in technology generation and dissemination. Farmers have local ties and continually interact with beneficiaries along the production value chain. Farmers who are 'from the community' are more sensitive to local crops, mannerisms, farming practices and family farmers' needs. Thus, the Program will seek to integrate some 'farmer-instructors' to contribute to its effort to disseminate resilient agrosilvopastoral systems in the Semiarid.

The incorporation of 'farmer instructors' into the Program's Technical Assiatance activities

Often extension services and communities (i.e. producer organizations or local authorities) select advisers / 'farmer instructors' together. A common procedure is for extension services to meet the criteria of community representatives, who then use the criteria to select 'farmer instructors'. Criteria may vary, including, for instance, good reputation, interest, and ability to share information, be implementing climate-resilient agrosilvopastoral systems (and therefore mastering Climate Change Resilient Productive Practices - CRRPP) and being a full-time resident in the community.

The contribution of these 'farmer instructors' can take many forms. In certain cases, they may be able to receive groups of visitors to learn about the resilient systems that they are implementing. In others, 'farmer instructor' may be incorporated into TA teams.

Nevertheless, these 'farmer-instructors' need strong support from extension services. TA approach must shift the conventional technology transfer model, in which communication is one-way (from the extension team to farmers), to the reorientation toward a participatory model. Thus, 'farmer-instructors' will usually serve as a complement to existing extension systems rather than substitutes. In this model, farmers will be protagonists,

[282] In this document the concept of Technical Assistance (TA) or Technical Assistance Services (TAS) should be understood in a broad sense, which includes the various advisory services necessary for the development of families, communities and rural population organizations. In the international literature, this broad interpretation of TA services has been termed 'Rural Advisory Services' or 'Rural Advisory Services - RAS'. (ADOLF, B. **Rural Advisory Services Worldwide**. Lindau, Switzerland: GFRAS, Available at http://www.g-fras.org/en/knowledge/gfras-publications/file/6-rural-advisory-services-worldwide%202011 ; and SULAIMAN, R.; BLUM, M. L. **Tailoring rural advisory services for family farms**. Rome: FAO and GFRAS, 2016. 65 p.)

knowledge bearers, while extension technicians should play a facilitating role in promoting farmer networks and exchanges.

– TA desirable attributes.

In accordance with the national policy - PNATER - the TA to be provided by the Program should have a set of attributes, which will need to contribute to its better performance with beneficiary families. Firstly, TA teams should have a regular presence in the communities and proximity with families. It should also be multipurpose in terms of the issues worked on, covering technical, market access, organizational strengthening and other topics. In terms of work methodology, TA should have a participatory stance that seeks to enhance the knowledge of all involved. It will also seek to "adopt the principles of agroecology as the guiding axis of actions"[283]. It will need to work to strengthen gender equity and youth participation as well.

The primary mandate of TA Services provided by the Program to both Components I and II beneficiaries will be to support the transformation of backyard agroecosystems through the establishment of agroforestry systems and other resilience practices. To this end, it should develop the necessary capacities to ensure the successful implementation of CRPS and all innovations supported by the Project. TA should also support community organization and market access.

The action of TA teams will have the above methodological roadmap as their primary guide. At the same time, it will adopt working methods that allow the activities to be carried out with the public served (including those related to productive investments) to be identified, designed, planned, implemented and evaluated in a participatory manner, with the active participation of key stakeholders.

– TA tools

There are several 'classic' tools that have been used by rural extension for a long time, such as training courses and events, technical lectures, field days, leaflets and booklets, movies and photos, etc. Theywill undoubtedly play a role in implementing a rural program advisory proposal[284]. But the Project will encourage the use of less usual tools, which privilege, whenever possible, 'farmer to farmer' contact. These tools include exchange visits, experimentation and joint efforts[285].

- *Exchange visits*

Improving crop and rearing performance, or harnessing potential often requires fresh ideas and information. Knowledge exchanges can be a way of meeting these needs for information and education.

Exchange visits involve organizing a group of farmers to visit another farmer or another group (community, settlement, association, etc.). In this type of initiative, peers are the main source of information, ideas, etc.. At the same time, although a group or family that is 'more advanced' on a particular subject is usually paid a visit, usually the visitor also discusses and comments what is being observed. Thus, this initiative is a real 'exchange', not a 'one-way' process. Due to the proximity of language and the life situation,often the exchange visit (between farmers) have more effect than courses or lectures given by technicians on the same subject. For example, if a settlement is having health problems in milk production, it is often more interesting to arrange a visit to a group of farmers who have managed to overcome this problem, rather than calling a researcher to talk about the issue.

It is imperative that the purpose of the exchange is clear to all those involved. The visiting group needs to consider visitors needs and what they want to know. A second point for 'visitors' is the choice of people to attend the exchange, as there are usually more applicants than vacancies. Once the group has been defined, it

[283] BRASIL et al. **Política Nacional de Assistência Técnica e Extensão Rural**. Brasília: MDA/SAF/DATER, 2004.
[284] There are many publications that deal with these tools. In Ruas et al. and in Coelho you can find information on several of these tools. (COELHO, F. M. G. **A arte das orientações técnicas no campo: concepções e métodos**. Viçosa: Editora da UFV, 2005. 139 p.; e RUAS, E. D.; AL., E. **Metodologia participativa de extensão rural para o desenvolvimento sustentável - MEXPAR**. Belo Horizonte: EMATER-MG, 2006. 134 p.)
[285] INCRA. **Referenciais metodológicos para o Programa de ATES**. Brasília, DF: INCRA / MDA, 2010. 120 p. Available at: http://www.incra.gov.br/portal/arquivos/projetos_programas/port_01_dd_ates.pdf

is useful to have a preparatory meeting with them to better organize the observation, determine what will be taken, and also organize the logistics (timetable, snacks, etc.).

Although exchange events are premised as spaces for peer communication, this does not mean that visitors need to be quiet all the time. Sometimes a question about an aspect that has been overlooked, which has been poorly explained, can be critical. At other times technical input or questioning may be necessary.

- *Experimentation*

Experimentation can be an excellent resource for organizing rural advisory action in the form of participatory development of solutions to chosen issues. It is important to remember here that experimentation, understood here as testing new ideas, is something that has been present in the peasant environment for a long time in various parts of the world, including the Brazilian semiarid. As a teaching tool, experimentation of this kind means putting into practice innovation and monitoring its development over a period of time. Often, the performance of the innovative practice is compared with that of an equivalent conventional practice. In this context, TA Services agents should always remember that the experimentation we are discussing here is primarily a **learning instrument**.

- *Mutirão*

It is common throughout Brazil the practice of forming groups (which usually gathers neighbors and relatives) who perform various types of work (agricultural, housing construction, etc.) without remuneration, for the benefit of one person or family. Although the beneficiary does not 'pay' for this work, it is usually up to him to 'welcome' his 'guests', for example, with a good meal. Since joint efforts work on the principle of reciprocity, those who receive the support of a group must somehow "return" the "favor" received.

There are rural advisory experiences that have taken advantage of this traditional social practice, making it a very interesting reflection and training event. It is a matter of giving the 'task force' an explicit didactic character. For instance, in a settlement in the southern region of the country, families are installing grape cultivation and learning the different techniques needed to succeed with this initiative. One of these techniques is the annual pruning of the vine. As most vine growers do not master this practice, the settlement technician organizes a joint effort in the plot of one of the families that have vines to prune. Either he or some farmer who has mastered the technique will be in charge of guiding the participants in the task force on how pruning should be performed. They will prune the host's vineyard, always under the supervision of the instructor(s). It is expected that, by the end of the event, participants have mastered the technique. At the same time, the group will have done an excellent job on the host plot.

– <u>About TA teams</u>

The teams will be sized according to the number of families to be served (approximately one technician for up to 150 families) and activities to be implemented so that they can dedicate themselves exclusively to the care of this public. Beneficiary families are expected to be served for 36 months for Component I activities. For Component 2, there will be 24 months of assistance.

Teams will consist of extension agents of various types. These generalist technical teams with experience in agroecological / agroforestry rural extension will integrate the teams. At the same time, they will have a person who specializes in management issues, who will be responsible for monitoring procurement, accountability, and other enforcement issues. Finally, these TA teams should incorporate some people from their own communities, whether they are 'farmer-instructor' (as discussed in the 'Incorporating' farmer-instructor 'text box into the Program Technical Advisory activities' above), or young children from farming families who have been educated at the Agricultural Family Schools (EFAs).
At the same time, the Program will seek to strengthen contracted TA teams with capacity building activities so that they can improve the quality of services provided to Project beneficiaries, especially in relation to SPRMC.

TA teams should work in line with the 'Young Communicators' program as part of a Knowledge Management work of component 3.

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APPENDIX III

Production model details (ref. chapter 5)

Table A. Main characteristics / assumptions for Component I models.

Aspects / Models	Agroforestry on rain-fed land for forage Production **1**	Agroforestry on rain-fed land for forage Production **2**	Agroforestry diversification of *Opuntia* monoculture plots **1**	Agroforestry diversification of *Opuntia* monoculture plots **2**
Main activity	**Goats and sheep breeding**	**Poultry**	**Goats and sheep breeding**	**Dairy production / Cows breeding**
Area	5-10 ha total area /0.5 ha Agroforestry Proposal	1-5 ha total area /0.5 ha Agroforestry Proposal	10-25 ha total area /0.5 ha Agroforestry Proposal	25-50 ha total area /0.5-1 ha Agroforestry Proposal
Current and Foreseen Crops / Production	Goats and Sheep (current) Licurí, Umbú, Passion Fruit, Cajú, Sisal, Palma Capim, Sorgho, Milheto, Painço, Feijao, Andu (foreseen)	Chicken and eggs (current) Licurí, Umbú, Cajú, Sisal, Palma Capim, Sorgho, Milheto, Painço, Feijao, Andu (foreseen)	Goats and Sheep / *Opuntia* (current) Licurí, Umbú, Cajú, Sisal, Palma Capim, Sorgho, Milheto, Painço, Feijao, Andu (foreseen)	Milk / *Opuntia* (current) Licurí, Umbú, Cajú, Sisal, Palma Capim, Sorgho, Milheto, Painço, Feijao, Andu (foreseen)
Strategy	Biomass production / Stratification / Densification / Diversification		Biomass production / Stratification / Densification / Diversification	
Quantities	Same 45 animals sold per year. 20/30 fruit trees with 20-30 fruits per year each Additional Forage production: 56 t	Same 6500 eggs and 93 chicken sold per year. 20/30 fruit trees with 20-30 fruits per year each Additional Forage production and sales: 14 t	Same 45 animals sold per year. 20/30 fruit trees with 20-30 fruits per year each Additional Forage production: 18 t	Same 129.000 l sold per year. 20/30 fruit trees with 20-30 fruits per year each Additional Forage production: 24 t
Labour per Yr	95 days / Family labour	140 days / Family labour	125 days / Family labour	95 days / Family labour 3 rural workers (2 permanent)
Self-Consumption	5-25%	25-40%	5-25%	5-10%
Financing	- Own savings and gains	Own savings and gains	Own savings / Agroamigo / BdB	Credit / BdN / BdB
Forage Demand / year	57 tons	17 tons (supply)	57 tons	82 tons

Main Investments	Fencing, seeds, plants, tools and equipment, land preparation, technical assistance (3 years)	Fencing, seeds, plants, tools and equipment, land preparation, technical assistance (3 years)	Seeds, plants, tools and equipment, land preparation, technical assistance (3 years)	Technical Assistance (2 years)
Without Project situation	Overgrazing, low commercial perspective.	No diversification	Overgrazing, low commercial perspective.	Overgrazing, low commercial perspective.
Income generated/year	From R$ 3.600 to R$ 3.800	From R$ 4.000 to R$ 4.600	From R$ 757 to R$ 3.200	From R$ 40.000 to R$ 45.000

Table B. Main characteristics / assumptions on Component I, models 4 and 5.

Aspects / Models	**Micro-enterprise Machinery**	**Bee-keeping**
Main activity	Commerce / Entrepreneurs	Honey production
Participants	Youths- 3 people group	18 people
Current and Foreseen Crops / Production	Adapted Pieces	Honey, bee wax.
Proposal	Buy and adapt equipment for Agroforestry for family farming	Income generation activity
Quantities	24 pieces per year	360 kg per farmer
Labour per Yr	3 full-time wages / 12 months	36 days / Family labour
Financing	Credit	Project Funding
Main Investments	Revolving fund to start the activity	Hives, inputs, tools and equipment
Without Project (WOP) situation	Even if the real alternative is unemployment, additional benefits are compared to a WOP situation where the farmer is having some incomes sporadically for the equivalent time in labor days required for the proposal	Natural Resources exploitation and overgrazing
Incomes generated per year	From R$ 15.000 to 21.000	From R$ 3.000 to R$ 4.000

Table C. Main characteristics/assumptions for Component II models

Aspects/Models	Fruit trees and Vegetable beds irrigated with Gray Water Reuse equipment (1.a)	Fruit trees and Vegetable beds irrigated with Cisterns and Micro-dams (1.b and 1.c)
Area / Irrigated	0.25 ha / 1250 sq meters irrigated	0.5 ha / 3750 sq meters irrigated
Current and Foreseen Crops	Vegetables: Lettuce, Onions, Cabbage, Coriander, Beet, among others (foreseen). Fruits: *Umbú*, Citrus, Manga (foreseen).	
Impact proposition	Access to water for production and agroforestry conversion.	
Quantities	Lettuce: 1 bed 10sqm / 3 cycles/yr, Onions: 2 beds 10sqm / 2 cycles/yr, Cabbage: 1 bed 1sqm / 1 cycle/yr Coriander: 2 beds 10sqm / 2 cycles/yr Beet: 1 bed 10 sqm / 3 cycles/yr Citrus: 10 trees from 3 to 50 fruits per year each Manga: 10 trees from 3 to 50 fruits per year each Umbú: 10 trees from 5 to 20 fruits per year each	Lettuce: 3 beds 10sqm / 3 cycles/yr, Onions: 6 beds 10sqm / 2 cycles/yr, Cabbage: 3 beds 1sqm / 1 cycle/yr Coriander: 6 beds 10sqm / 2 cycles/yr Beet: 3 beds 10 sqm / 3 cycles/yr Citrus: 30 trees from 3 to 50 fruits per year each Manga: 30 trees from 3 to 50 fruits per year each Umbú: 30 trees from 5 to 20 fruits per year each
Labour per Yr	24 days/family labour	72 days/family labour
Self-Consumption	50-80%	30-60%
Financing	Project support and own savings	
Post-harvest Losses	10%	
Main Investments	Seeds and plants, access to water infrastructure, 2-year technical assistance, tools and equipment.	
WOP situation	Even if the real alternative is unemployment, additional benefits are compared to a WOP situation where the farmer is having some incomes sporadically for the equivalent time in labor days required for the proposal.	
Incomes generated	Approximately from R$1500 to R$ 3500 depending on the self-consumption rate.	

Table D – Income impact Indicators per Model

ITEM	Unit	Models								
		Model 1a- Veg. Beds and Fruit trees 1- Grey Water Reuse	Model 1b- Veg. Beds and Fruit trees 2- Other Water infrastructure	Model 1c- Veg. Beds and Fruit trees 3- Cisterns	Model 2a- Forage production and Agroforestry diversification in native lands 1	Model 2b- Forage production and Agroforestry diversification in native lands 2	Model 3a- Forage production and Agroforestry diversification in palm monoculture lands 1	Model 3b- Forage production and Agroforestry diversification in palm monoculture lands 2	Model 4- Micro-entrepreneur Business development	Model 5- Bee-keeping
Without Project		*	**	***	***		**	***		
Incomes without project / Equivalent labour	*$R/yr*	*724*	*2,171*	*2,171*	*1,376*	*1,847*	*4,176*	*63,563*	*34,452*	*1,080*
With Project										
Family income	*$R/yr*	*6,358*	7,606	*9,194*	*7,154*	*8,706*	9,919	*74,093*	*78,038*	*4,927*
% increase	*%*	*779*	*250*	*323*	*420*	*371*	*138*	*17*	*127*	*356*
% impact / poverty line	*%*	*25%*	*24%*	*31%*	*26%*	*31%*	*26%*	*47%*	*194%*	*17%*
International Poverty line- World Bank (5,5 USD per day / family)	*$R/yr*					*$22,484*				
% impact / Average income per house-hold	*%*	*18%*	*17%*	*22%*	*18.32%*	*22%*	*17%*	*22%*	*138%*	*12.20%*
Average income per household Brazil	*$R/yr*					*$31,542*				
% Impact / International Poverty line	*%*	*28%*	*27%*	*34%*	*28.27%*	*34%*	*27%*	*34%*	*213%*	*18.82%*
International Poverty line (5USD per day / family)	*$R/yr*					*$20,440*				
60% Minimum Salary	*$R/yr*					*$13,493*				
Impacts in HH Income (%)	*%*	*42%*	*40%*	*52%*	*43%*	*51%*	*43%*	*78%*	*323%*	*29%*
75% Minimum Salary	*$R/yr*					*$16,866*				
Impacts in HH Income (%)	*%*	*33%*	*32%*	*42%*	*34%*	*41%*	*34%*	*62%*	*258%*	*23%*
50% Minimum Salary	*$R/yr*					*$11,244*				
Impacts in HH Income (%)	*%*	*50%*	*48%*	*62%*	*51%*	*61%*	*51%*	*94%*	*388%*	*34%*
Minimum Salary (2 person HH)	*$R/yr*					*$22,488*				
Impacts in HH Income (%)	*%*	*25%*	*24%*	*31%*	*26%*	*30%*	*26%*	*47%*	*194%*	*17%*

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APPENDIX IV

State short profiles

BAHIA

Precipitation

The average annual rainfall is approximately 550 mm / year decreasing by 91.70 mm since 1981. For the period 1981 – 2019, December has been the rainiest month on average with 92.74 mm while September presents the lowest average rainfall at 11.40 mm. Rainfall patterns are erratic with deviations ranging from -74.59 to 179.63mm.

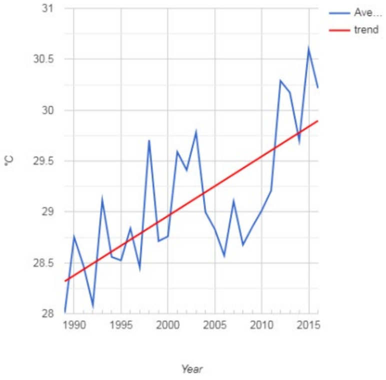
Temperatures

The average annual minimum temperature is 20.15°C, while the maximum temperature is 29.90°C. For the period 1981 – 2016 October presents the highest average temperature at 30.59°C, while August was the lowest at 17.48°C; minimum and maximum temperature have increased by 0.87°C and 1.58°C respectively.

Land Productivity Dynamics

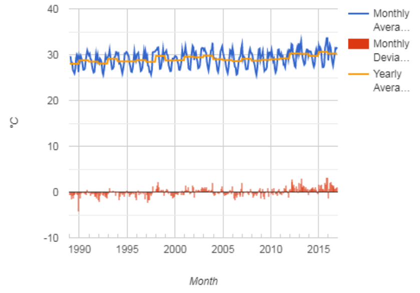
Caatinga portion of Semiard Bahia has 72% of land with declining productivity, an additional 20% present early signs of decline or are stable but stressed. Similar patterns apply throughout B.

Max Temperature 1989 – 2016



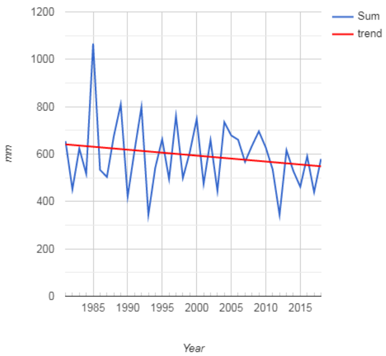
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2016



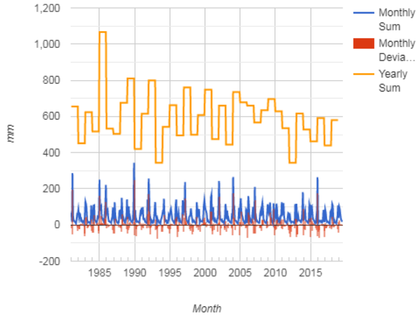
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



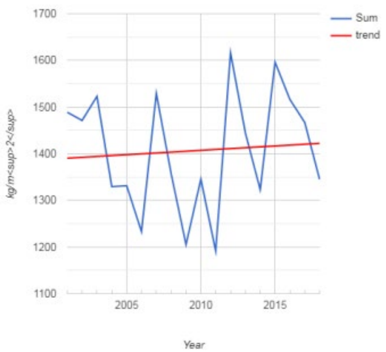
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



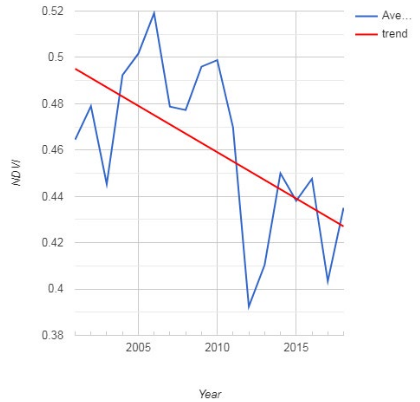
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



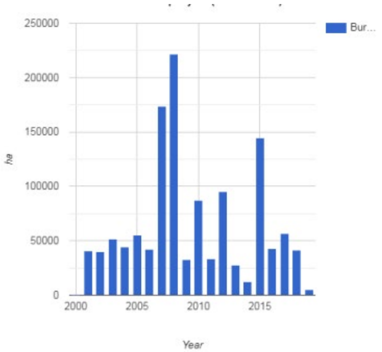
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



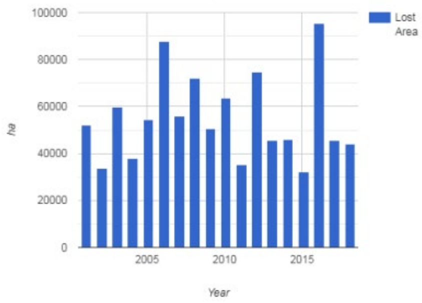
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[286]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is highly vulnerable to droughts, river floods, and wildfire; and mildly to highly vulnerable to water scarcity and extreme heat.[287] The annual decrease in rainfall in the region and the increase in temperature could have a negative impact on the agricultural sector if trends continue. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events could have a significant impact on soils.

[286] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. “High-Resolution Global Maps of 21st-Century Forest Cover Change.” Science 342 (15 November): 850–53.

[287] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

PIAUI

Precipitation

The average annual rainfall is approximately 760 mm / year decreasing by 66.31 mm since 1981. For the period 1981 – 2019, March has been the rainiest month on average with 182.25 mm while August presents the lowest average rainfall at 2.12 mm. Rainfall patterns are erratic with deviations ranging from -105.94 to 263.85 mm.

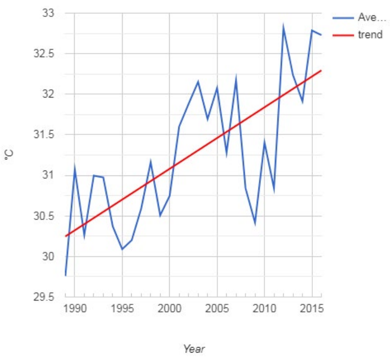
Temperatures

The average annual minimum temperature is 22.81°C, while the maximum temperature is 32.29°C. For the period 1981 – 2016 October presents the highest average temperature at 34.17°C, while July was the lowest at 20.85°C; minimum and maximum temperature have increased by 1.20°C and 2.05°C respectively.

Land Productivity Dynamics

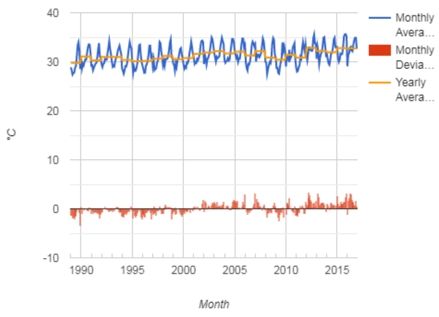
Caatinga portion of Semiard Piaui has 81% of land with declining productivity, an additional 13.5% present early signs of decline or are stable but stressed. Similar patterns apply throughout the entire region.

Max Temperature 1989 – 2016



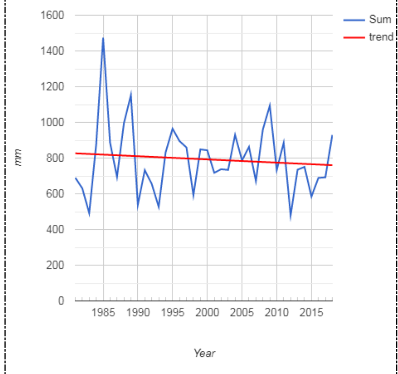
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2016



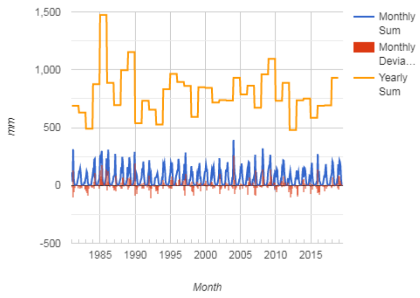
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



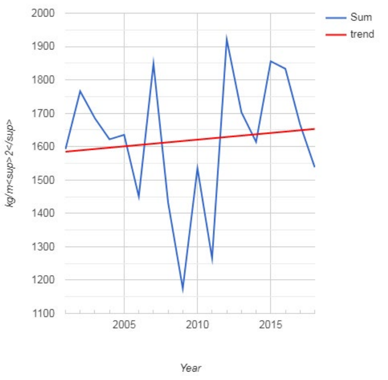
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



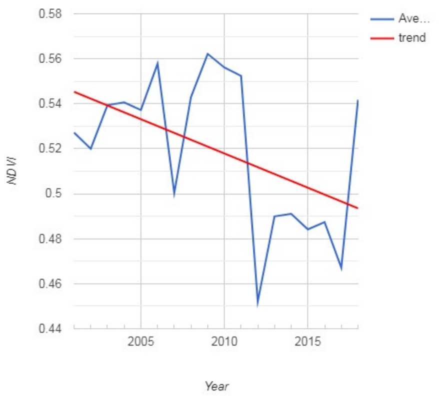
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



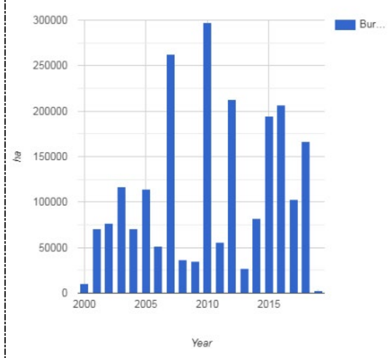
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



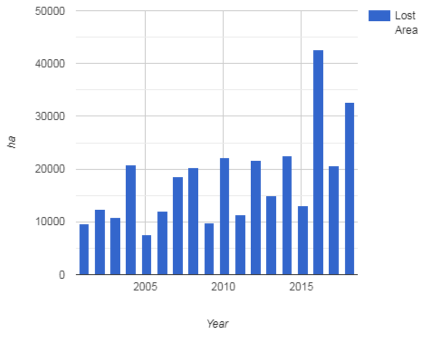
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[288]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in drought tendency and in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is highly vulnerable to droughts, river floods, and loss of tree cover and wildfire (particularly high risk for the Serra das Confusoes national park); and medium to high vulnerability to water scarcity and extreme heat.[289] The annual decrease in rainfall in the region and the increase in temperature could have a negative impact on the agricultural sector if trends continue. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events could have a significant impact on soils.

[288] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

[289] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

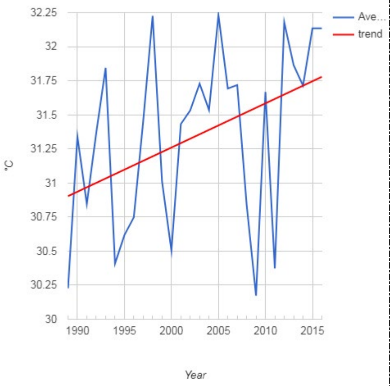
CEARA

Precipitation
The average annual rainfall is approximately 735 mm / year decreasing by 85.90 mm since 1981. For the period 1981 – 2019, March has been the rainiest month on average with 200.92 mm while September presents the lowest average rainfall at 3.47 mm. Rainfall patterns are erratic with deviations ranging from -117.33 to 261.48 mm.

Temperatures
The average annual minimum temperature is 22.37°C, while the maximum temperature is 31.78°C. For the period 1981 – 2016 November presents the highest average temperature at 33.72°C, while July was the lowest at 21.20°C; minimum and maximum temperature have increased by 0.59°C and 0.88°C respectively.

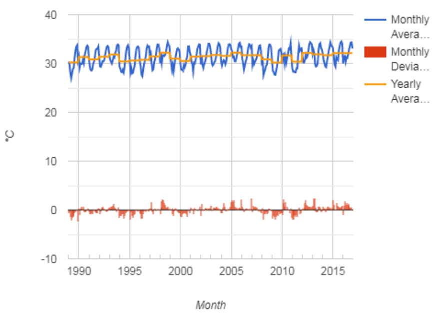
Land Productivity Dynamics
Caatinga portion of Semiard Ceara has 71% of land with declining productivity, an additional 14.5% present early signs of decline or are stable but stressed. Similar patterns apply throughout the entire region.

Max Temperature 1989 – 2016



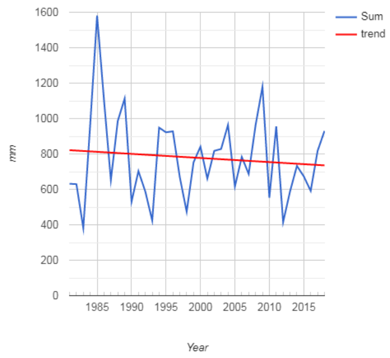
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2016



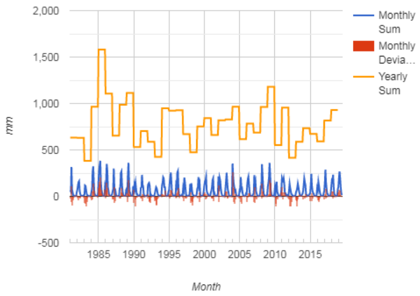
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



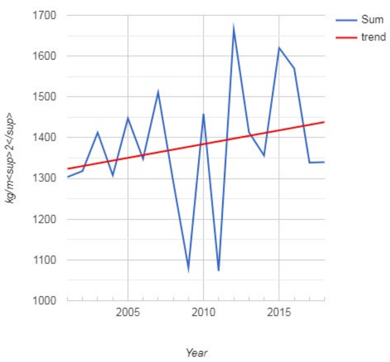
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



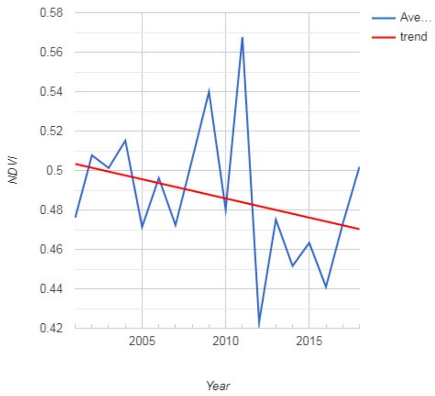
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



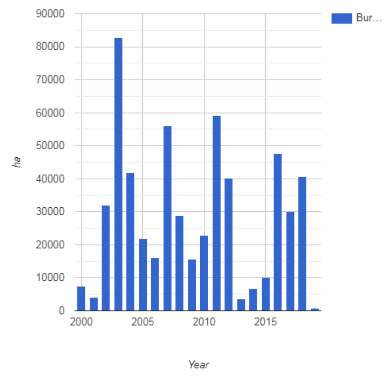
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



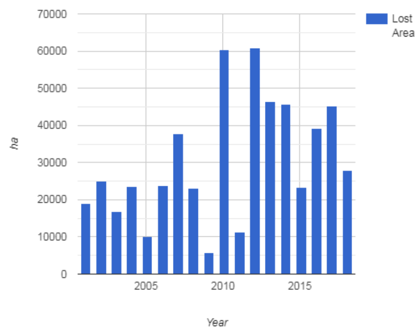
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[290]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in drought tendency and in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is extremely vulnerable to wildfire; highly vulnerable to droughts, river and coastal floods; and medium to high vulnerability to water scarcity, earthquakes, and extreme heat.[291] The annual decrease in rainfall in the region and the increase in temperature could have a negative impact on the agricultural sector if trends continue. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events and the potential reduction in tree cover could have a significant impact on soils (e.g. increased erosion).

[290] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

[291] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

RIO GRANDE DO NORTE

Precipitation

The average annual rainfall is approximately 671 mm/year decreasing by 46.14 mm since 1981. For the period 1981 – 2019, March has been the rainiest month on average with 162.29 mm while October presents the lowest average rainfall at 4.63 mm. Rainfall patterns are erratic with deviations ranging from -124.69 to 218.62 mm.

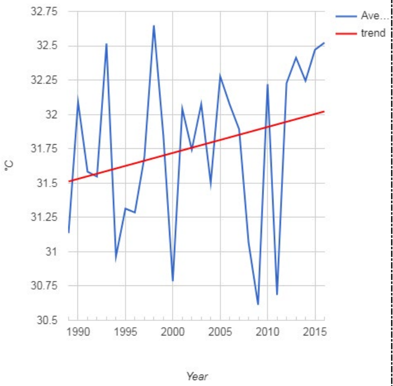
Temperatures

The average annual minimum temperature is 22.48°C, while the maximum temperature is 32.02°C. For the period 1981 – 2016 November presents the highest average temperature at 33.52°C, while July was the lowest at 29.99°C; minimum and maximum temperature have increased by 0.50°C and 0.51°C respectively.

Land Productivity Dynamics

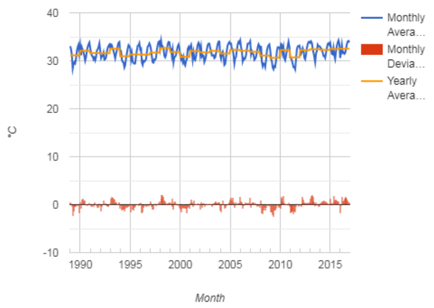
Caatinga portion of Semiarid Rio Grande do Norte has 77% of land with declining productivity, an additional 6.82% present early signs of decline or are stable but stressed. Similar patterns apply throughout the entire region.

Max Temperature 1989 – 2016



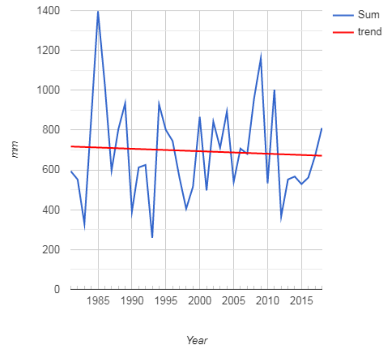
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2016



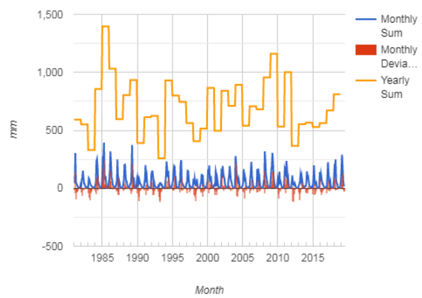
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



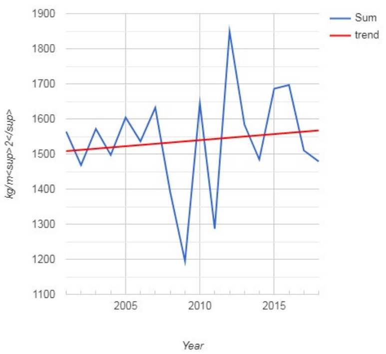
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



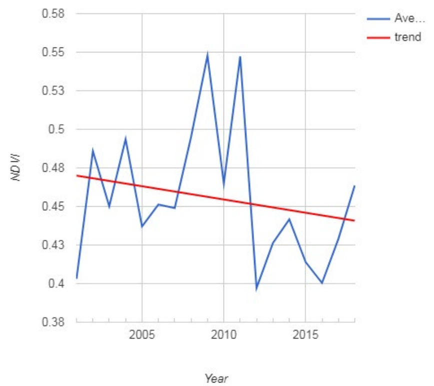
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



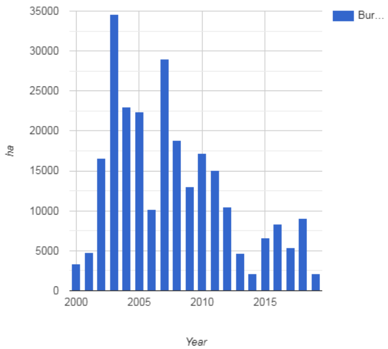
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



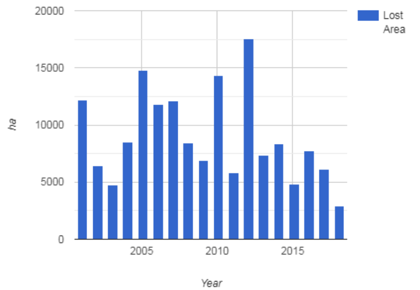
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[292]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in drought tendency and in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is highly vulnerable to droughts, river floods, and wildfire; and medium to high vulnerabilty to water scarcity, earthquake, and extreme heat; and low to very low risk of cyclones and tsunamis.[293] The annual decrease in rainfall in the region and the increase in temperature could have a negative impact on the agricultural sector if trends continue. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events could have a significant impact on soils.

[292] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

[293] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

PARAIBA

Precipitation

Average annual rainfall is approximately 693 mm/year decreasing by 4.69 mm since 1981. For the period 1981 – 2019, March has been the rainiest month on average with 155.83 mm while October presents the lowest average rainfall at 7.85 mm. Rainfall patterns are with deviations ranging from -99.98 to 249.23 mm.

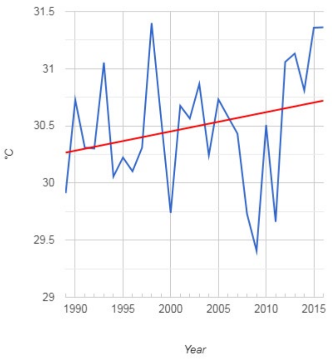
Temperatures

The average annual minimum temperature is 20.77°C, while the maximum temperature is 30.72°C. For the period 1981 – 2016 December presents the highest average temperature at 32.175°C, while August was the lowest at 18.87°C; minimum and maximum temperature have increased by 0.45°C and 0.45°C respectively.

Land Productivity Dynamics

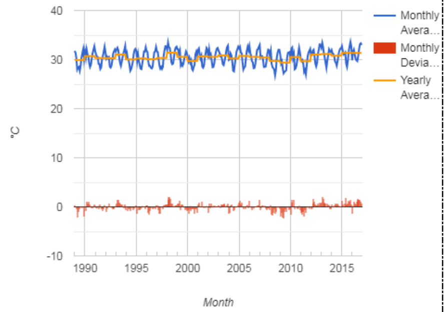
Caatinga portion of Semiard Paraiba has 80% of land territory with declining productivity, an additional 5.38% present early signs of decline or are stable but stressed. Similar patterns apply throughout the entire region.

Max Temperature 1989 – 2016



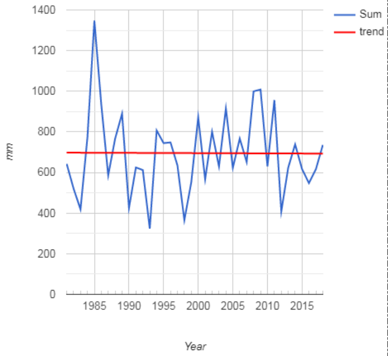
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2019



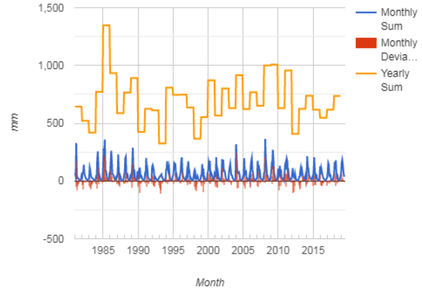
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



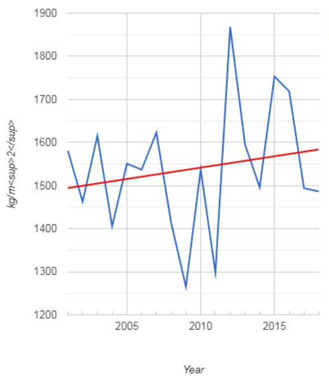
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



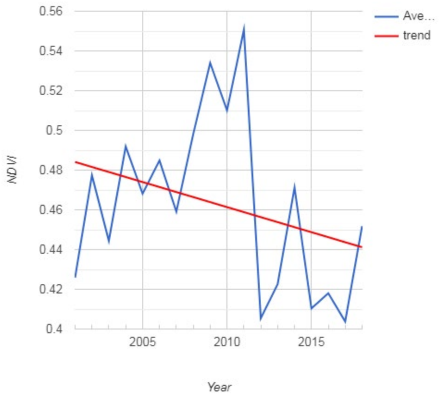
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



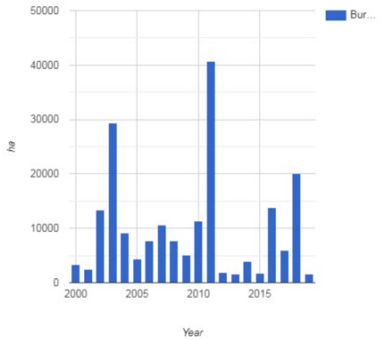
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



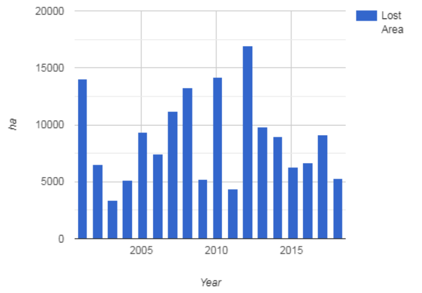
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[294]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in drought tendency and in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is highly vulnerable to droughts, and wildfire; and medium to high vulnerability to river floods, earthquakes, water scarcity and extreme heat.[295] Paraiba presents the smallest variations to date in temperature and precipitation, the region is nonetheless still at risk of decreased precipitation and increased temperature with potential negative impacts on the agricultural sector. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events could have a significant impact on soils.

[294] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

[295] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

PERNAMBUCO

Precipitation

Average annual rainfall is approximately 570 mm/year decreasing by 57.55 mm since 1981. For the period 1981 – 2019, March has been the rainiest month on average with 127.067 mm while September presents the lowest average rainfall at 9.06 mm. Rainfall patterns are erratic with deviations ranging from -100.67 to 255.82 mm.

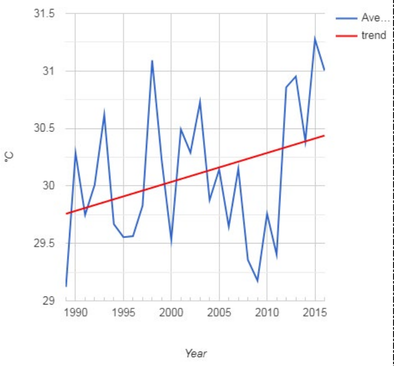
Temperatures

The average annual minimum temperature is 20.42°C, while the maximum temperature is 30.44°C. For the period 1981 – 2016 November presents the highest average temperature at 32.38°C, while August was the lowest at 18.08°C; minimum and maximum temperature have increased by 0.39°C and 0.68°C respectively.

Land Productivity Dynamics

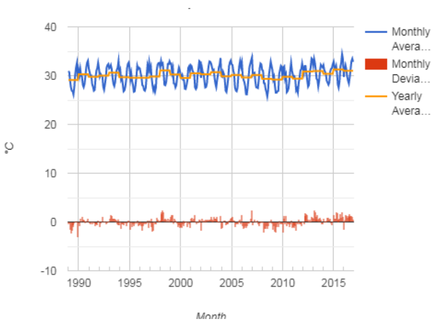
Caatinga portion of Semiard Pernambuco has 82% of land territory with declining productivity, an additional 8.89% present early signs of decline or are stable but stressed. Similar patterns apply throughout the entire region.

Max Temperature 1989 – 2016



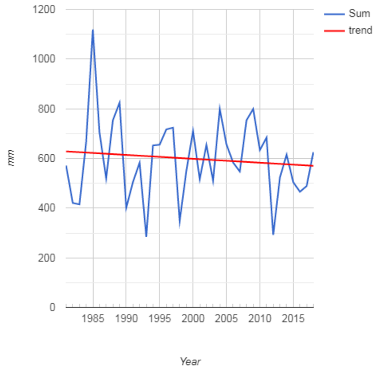
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2019



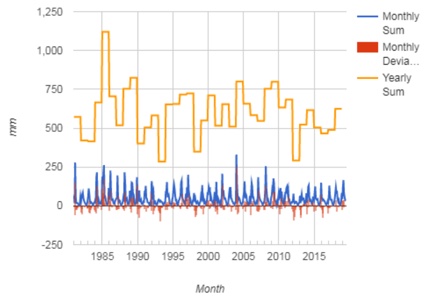
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



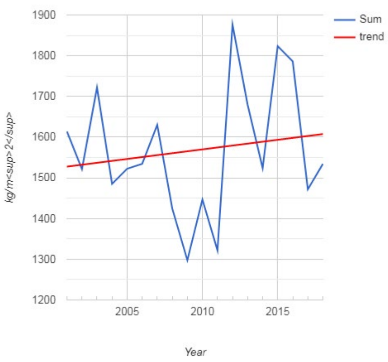
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



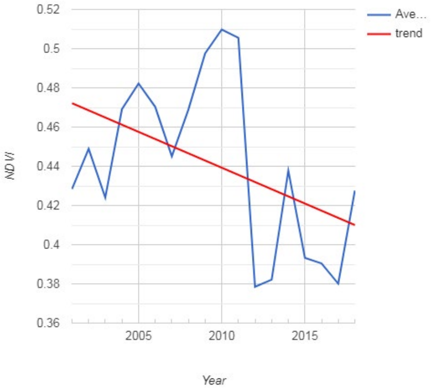
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



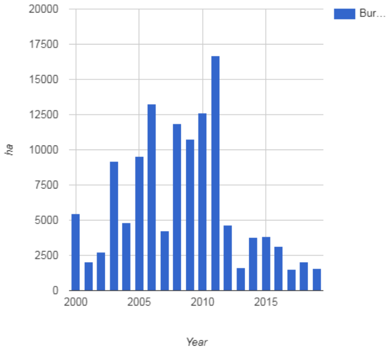
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



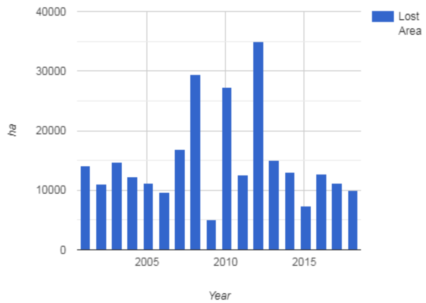
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[296]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in drought tendency and in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is highly vulnerable to droughts, river floods, and wildfire; and medium to high vulnerability to water scarcity and extreme heat.[297] The annual decrease in rainfall in the region and the increase in temperature could have a negative impact on the agricultural sector if trends continue. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events could have a significant impact on soils.

[296] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

[297] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

ALAGOAS

Precipitation

Average annual rainfall is approximately 673 mm/year decreasing by 60.98 mm since 1981. For the period 1981 – 2019, July has been the rainiest month on average with 116.74 mm while November presents the lowest average rainfall at 17.94 mm. Rainfall patterns are erratic with deviations ranging from -75.51 to 196.14 mm.

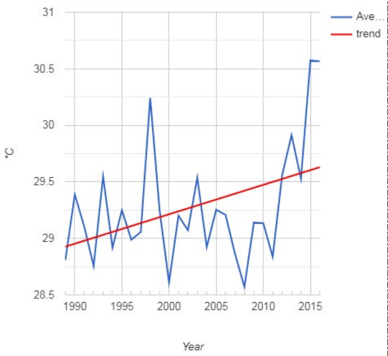
Temperatures

The average annual minimum temperature is 21.37°C, while the maximum temperature is 29.63°C. For the period 1981 – 2016 December presents the highest average temperature at 31.82°C, while August was the lowest at 19.06°C; minimum and maximum temperature have increased by 0.58°C and 0.70°C respectively.

Land Productivity Dynamics

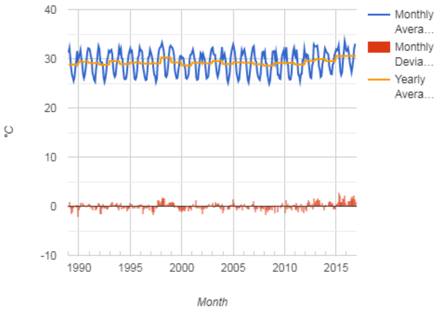
Caatinga portion of Semiard Alagoas has 64% of land territory with declining productivity, an additional 3.19% present early signs of decline or are stable but stressed. Similar patterns apply throughout the entire region.

Max Temperature 1989 – 2016



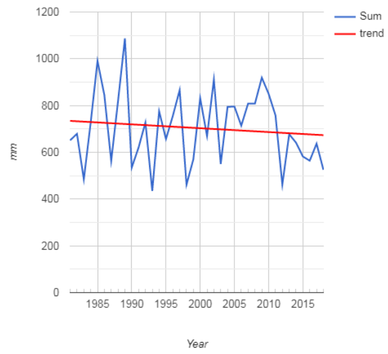
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2019



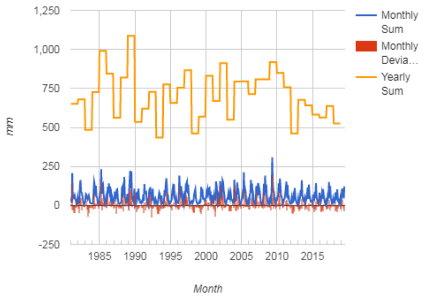
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



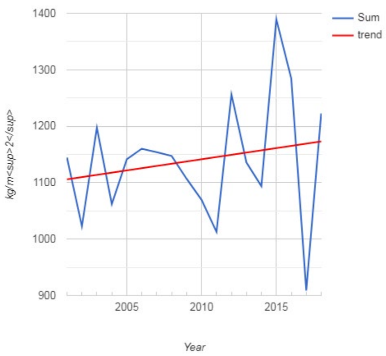
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



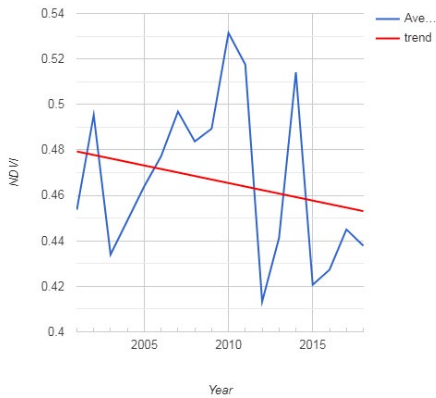
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



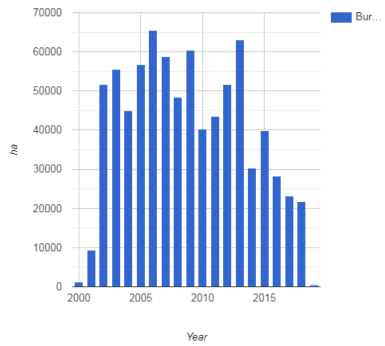
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



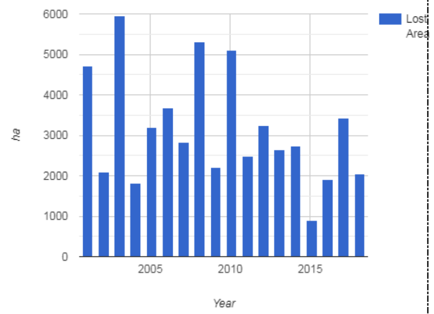
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[298]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in drought tendency and in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is highly vulnerable to droughts, river and coastal floods, and wildfire; and medium to high vulnerability to water scarcity and extreme heat.[299] The annual decrease in rainfall in the region and the increase in temperature could have a negative impact on the agricultural sector if trends continue. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events could have a significant impact on soils.

[298] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

[299] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

SERGIPE

Precipitation

Average annual rainfall is approximately 735 mm/year decreasing by 12.01 mm since 1981. For the period 1981 – 2019, June has been the rainiest month on average with 124.44 mm while October presents the lowest average rainfall at 29.097 mm. Rainfall patterns are erratic with deviations ranging from -68.27 to 185.09 mm.

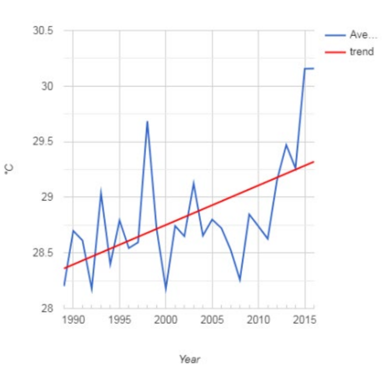
Temperatures

The average annual minimum temperature is 21.°C, while the maximum temperature is 29.32°C. For the period 1981 – 2016 December presents the highest average temperature at 31.27°C, while August was the lowest at 19.03°C; minimum and maximum temperature have increased by 1.01°C and 0.96°C respectively.

Land Productivity Dynamics

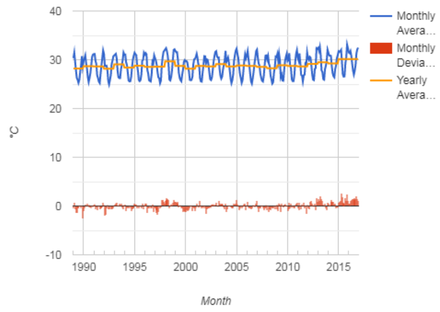
Caatinga portion of Semiard Sergipe has 71% of land territory with declining productivity, an additional 8.44% present early signs of decline or are stable but stressed. Similar patterns apply throughout the entire region.

Max Temperature 1989 – 2016



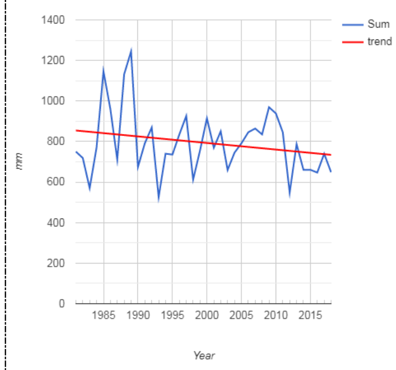
Source: ECMWF; ENSEMBLES

Max temp. Monthly time series 1989-2019



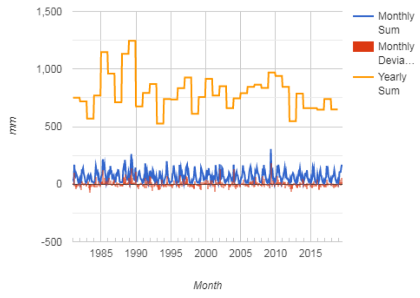
Source: ECMWF; ENSEMBLES

Average Annual Prec. 1981 - 2019



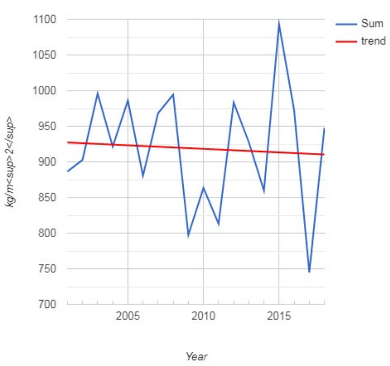
Source: CHIRPS (v2.0)

Prec. monthly time series 1981 – 2019



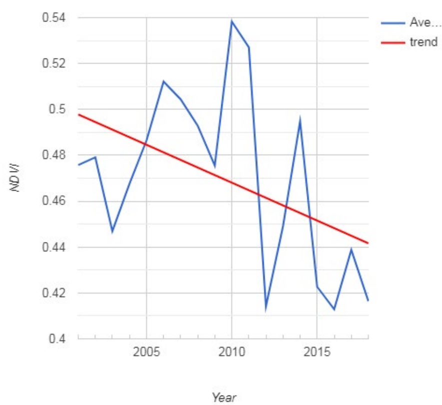
Source: CHIRPS (v2.0)

Climatic Water Deficit 2001 – 2018



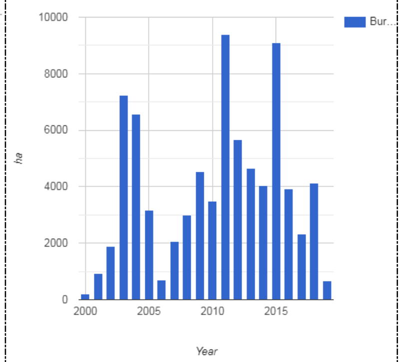
Source: MOD16A2 - MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid

NDVI MODIS (250m) 2001-2018



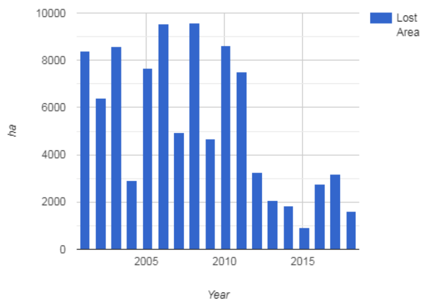
Source: NDVI from NIR-RED bands - MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m

Burned area per year 2000-2018



Source: MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006

Forest Change 2000 - 2018



Source: Global Forest Change 2000–2018[300]

Climatic Vulnerabilities and Risks

Modeled projections of future climate identify a likely increase in drought tendency and in the frequency of fire weather occurrence in this region, including an increase in temperature and greater variance in rainfall. The project area is highly vulnerable to droughts, river floods, and wildfire; and medium to high vulnerability to coastal flooding, water scarcity and extreme heat.[301] The annual decrease in rainfall in the region and the increase in temperature could have a negative impact on the agricultural sector if trends continue. The dry period will be even warmer, droughts may be more intense and frequent, and natural vegetation may suffer from water stress. Given interannual seasonality, it is likely that plantations and rain-dependent crops will decrease their productivity in the coming years. In addition, the increase in extreme events could have a significant impact on soils.

[300] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

[301] Global Facility for Disaster Reduction and Recovery (GFDRR), 2019. "Think Hazard tool"

Project: Planting Resilience in Rural Communities of the Brazilian Semiarid

Feasibility Study

APPENDIX V

Results Management Framework

E.3. Fund-level impacts						
Expected Results	**Indicator**	**Means of Verification (MoV)**	**Baseline**	**Target**		**Assumptions**
				Mid-term	Final	
A1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities and regions	*A1.2 Number of males and females benefiting from the adoption of diversified, climate resilient livelihood options (including fisheries, agriculture, tourism, etc.)*	Geo-referencing, and resilience scorecard at baseline, mid-term and completion surveys.	N/A	Male 240,000 Female 160,000	Male 600,000 Female 400,000	Activity 1.1.2 268,000 beneficiaries consisting of: • 31,000 families in family farms • 36,000 families in backyard gardens. Activity 1.1.3 412,000 beneficiaries consisting of: • 1,800 families from 60 communities • 1,000 schools with an average of 100 families per school • 1,200 families benefiting from 24 bio-saline productive systems; Activity1.1.4 116,840 beneficiaries consisting of: • 24,000 farmers participate in exchange events / workshops • 5,000 middle size farmers participate in farmers network • 70 microenterprise each with an average of 3 employees – 210 beneficiaries. Activity 3.1.1 85,440 beneficiaries consisting of: • 300 trainings for women with an average of 25 women per training (7,500 women) • 360 workshops and meetings with an average of 25 participants (9,000 women) • 243 trainings for youths with an average of 20 youths each Activity 3.1.2 • 117,720 beneficiaries consisting of: Newsletters, communication materials and informative reports disseminating innovative solutions will reach and influence directly an audience of 29,430 families (300 families per municipality approximately) (117.720 beneficiaries) • Assuming an average family size of 4 people

						per family and 60% male and 40% female. Total of 1,000,000 direct beneficiaries
A2.0 Increased resilience of health and well-being, and food and water security	*A2.2 Number of food secure households (in areas/periods at risk of climate change impacts)*	Resilience scorecard at baseline, mid-term and completion surveys.	2,414 households led by women 13,668 households led by men[302]	4,663 Households led by women 26,425 households led by men	8,040 households led by women 45,560 households led by men	Diversification strategies are effective and taken up by family farmers, including through backyards gardens. Food security is defined according to FAO (2006)
A4.0 Improved resilience of ecosystems and ecosystem services	*A4.1 Coverage/scale of ecosystems protected and stregthened in response to climate variability and change*	Studies of satellite imagery in areas with recovered vegetation[303]. Mid-term and completion surveys.	N/A	CRPS in family farms and backyard gardens 11,500 ha Collective Resilient Investments 15,000 ha Farmers Network 7,150 ha	CRPS in family farms and backyard gardens 23,000 ha Collective Resilient Investments 36,124 ha Farmers Network 25,000 ha	Widespread uptake of CRPS together with sufficient water access / availability allow for measurable impact of ecosystem services.
M3.0 Reduced emissions from buildings, cities, industries and appliances	*M3.1 Tonnes of carbon dioxide equivalent (t CO2 eq) reduced or avoided - buildings, cities, industries, and appliances*	Ex ACT monitoring tool progress reports, Supervision missions.	N/A	-17,567 tCO_{2e}	- 35,135 tCO_{2e}	Methodology described in Annex 22, page 19 and 20. Annual emission reduction: 4.07 tCO_{2e} per appliance per year 20 year project lifetime emission reduction: 87,938 tCO_{2e}
M4.0 Reduced emissions from land use, reforestation, reduced deforestation, and through sustainable forest management and conservation and enhancement of forest carbon stocks	*M4.1 Tonnes of carbon dioxide equivalent (t CO2 eq) reduced or avoided (including increased removals) - forest and land use*	Ex ACT monitoring tool progress reports, Geo-referencing and studies of satellite imagery; diagnostic soil studies.	N/A	-2.3 $MtCO_{2e}$	-4.6$MtCO_{2e}$	FAO EX-ACT Methodology is applied described in Annex 22. Annual emission reductions: -6.7 tCO2eq per hectare per year 20 year project lifetime emission reductions: 11,266,014 tCO2eq

E.4. Fund-level outcomes

Expected Outcomes	Indicator	Means of Verification (MoV)	Baseline	Target		Assumptions
				Mid-term)	Final	
A5.0 Strengthened institutional and regulatory systems for climate-responsive planning and development	*A5.2 Number and level of effective coordination mechanisms*	Coordination mechanism published, Supervision, and completion Study.	No coordination mechanism exists for sanitary regulations specific for family farmers No coordination mechanism exists for legal reserve credit Mechanisms exist for domestic violence, but implementation is	1 mechanism implemented and partially effective for sanitary regulations specific for family farmers 1 mechanism implemented but not operational for legal reserve credit	1 mechanism implemented and effective for sanitary regulations specific for family farmers 1 mechanism implemented and partially effective for legal reserve credit 1 mechanism enhanced to treat	

302 The exact baseline of food insecure households will be determined in the baseline survey upon selection of participating states. A conservative initial estimate is presented based on the project targeting policy. The project will target municipalities in which at least 70% of the population is registered in the Cadastro Unico (earning less than or equal to 50% of the minimum income). The conservative estimate assumes that the maximum allowable target population not registered in the Cadastro Unico (30%) is food secure.
303 A repository for satellite imagery and studies developed will be established and accessible at DATA.IFAD

			weak in the rural area	1 mechanism enhanced to treat domestic violence, in the rural areas	domestic violence, in the rural areas	
A7.0 Strengthened adaptive capacity and reduced exposure to climate risks	*A7.1 Use by vulnerable households, communities, businesses and public-sector services of Fund-supported tools instruments, strategies and activities to respond to climate change and variability*	Resilience scorecard at baselined and completion survey, Geo-referencing and satellite imagery. Mid-term and completion survey	0 households apply CRPS practices and principles.	30,000 households have adopted at least one strategy to respond to climate change	75,000 households have adopted at least one strategy to respond to climate change	Sustained interest, uptake and referral of project tools by family farmers.
M7.0 Lower energy intensity of buildings, cities, industries and appliances	*M7.1 Energy intensity/improved efficiency of buildings, cities, industries and appliances as a result of Fund support*	Resilience scorecard at baselined and completion survey, supervisions missions.	Persistent use of wood, coal and LPG stoves contributing to deforestation.	236 520 kwh of Biogas production replacing fuelwood extraction and combustion emissions	473 040 kwh of Biogas production replacing fuelwood extraction and combustion emissions	Methodology described in Annex 22.
M9.0 Improved management of land or forest areas contributing to emissions reductions	*M9.1 Hectares of land or forests under improved and effective management that contributes to CO2 emission reductions*	Normalized difference vegetation index (NDVI), Geo-referencing and satellite imagery. Mid-term and completion survey	N/A	15,000 ha of Caatinga dry forests will be improved through the introduction of live fences, pasture rotation and silage as well as an improved management of shrubs and dry forests through live fences. 7,150 ha of Baja-caatinga pastures with declining productivity will be converted into silvopastoral system. 11,500 Mono-culture crops will be converted into CRPS.	36,000 ha of Caatinga dry forests will be improved through the introduction of live fences, pasture rotation and silage as well as an improved management of shrubs and dry forests through live fences. 25,000 ha of Baja-caatinga pastures with declining productivity will be converted into silvopastoral system. 23,000 Mono-culture crops will be converted into CRPS.	CRPS are adopted and sustained throughout NEB, reducing impact of droughts.

E.5. Project/programme performance indicators

Expected Results	Indicator	Means of Verification (MoV)	Baseline	Target		Assumptions
				Mid-term	Final	
Output 1.1. *Increase climate resilience for family farmers and traditional communities while mitigating carbon emissions by applying CRPS.*	Families with increased resilience score through adoption of CRPS (by sex and age; 40% women and 50% youth)	Resilience scorecard, tracking of PMEL[304] system, field sampling verification	0	68,000	170,000	Farmers will adopt and sustain CRPS correctly at sufficient scale to yield benefits of improve fertility, increase water availability which will in turn increase resilience of the families and their income as well as overall
	Reduced agricultural losses during drought periods by applying CRPS as compared to the 2010-2020 baseline. (measured at the municipal level, reported as project aggregate)	Resilience scorecard at baselined and completion survey, municipal reports on agricultural yield,	0	4% reduction in losses during drought periods.	8% reduction in losses during drought periods.	

[304] Project Planning, Monitoring Evaluation and Learning System (PMEL).

		productivity and losses.				environmental and ecosystem service provision. Families will benefit from the diverse production yields of CRPS and incorporate these nutritional ingredients in their diets.
	Increased soil moisture (%) during the dry season by applying CRPS	Diagnostic soil studies measuring soil water content and plant available water (PAW)	0	4%	10%	
	Households receiving productive investments report increased production. Disaggregated by sex of head of household	Baseline, mid-term and completion surveys	0	10,720	26,800	
	Percentage of individuals demonstrating an improvement in empowerment (IFAD CI IE.2.1)	Project-level women's empowerment index (pro-WEAI) at baseline and completion	0	0	70%	
	People provided with climate information services (IFAD CI 3.1.2)	Resilience scorecard, tracking of PMEL system and supervision missions.	0	49,600	124,000	
	Percentage of women, 15-49 years of age, who consume at least 5 out of 10 food groups (MDD-W) (IFAD CI 1.2.8)	Minimum Dietary Diversity-Women indicator at baseline and completion	0	0	75%	
	Number of persons/households reporting adoption of environmentally sustainable and climate-resilient technologies and practices (IFAD CI 3.2.2)	Tracking of PMEL system and supervision missions.	0	9,920	24,800	
	People trained in production practices and/or technologies. (IFAD CI 1.1.4) (by sex and age; 40% women and 50% youth)	Tracking of PMEL system and supervision missions.	0	Male 5,760 Female 3,840	Male 14,400 Female 9,600	
	Number of micro-enterprises that develop tools and services for CRPS.	PMEL Team tracking of investments, and supervision missions.	0	28	70	
Output 2.1 *Improve water access to family farmers and traditional communities to reduce the impact of severe droughts by investing in small-scale technologies for harvesting, reuse, treatment and storage.*	Families with increased resilience score through adoption rainwater harvest and storage (by sex and age; 40% women and 50% youth)	Tracking of PMEL system, geo referencing of infrastructure and satellite imagery, and supervision missions.	0	8,400	21,000	There will be enough rainwater during implementation of the PCRP so that these water harvesting systems can irrigate the CRPS.
	Rural households that report a reduction in the water shortfall in relation to the production requirements (IFAD CI 1.2.3)	Resilience scorecard at baseline, mid-term and completion.	0	11,520	28,800	
	Number of hectares of farmland with water-related infrastructure built/rehabilitated (IFAD CI 1.1.2)	Tracking of PMEL system, geo referencing of infrastructure and satellite imagery, and supervision missions.	0	1,800 ha	4,500 ha	
	Number of families with improved health by installing green septic systems and greywater reuse.	Tracking of PMEL system, geo referencing of infrastructure and satellite imagery, and supervision missions.	0	6,000	15,000	
Output 3.1 *CRPS and small-scale water harvesting system disseminated in the NEB*	Number of women, youth and traditional community members who report increased capacity and applying their knowledge	Inputs from SIU Gender, Youth and Ethnicity team, progress reports;	0	3,600	9,000	Women, youth and traditional community members will be motivated and

semiarid and abroad to increase climate resilience of vulnerable communities.		supervisions missions				participate in the training programs.
	Number of young communicators who report using social communication tools to register and systematize activities developed in communities.	Inputs from SIU Gender, Youth and Ethnicity team, progress reports; supervisions missions	0	166	414	Institutional arrangements will be developed for other states and dryland regions to implement CRPS.
	Use of climate information products/services in decision-making in climate sensitive sectors	Resilience scorecard, baseline and completion survey.	0	107,200	268,000	
	Scale up locations (national and international) adopting CRPS and small-scale water harvesting technologies due to SSTC	Progress reports, learning route publications, and supervision missions.	0	3	7	
	Number of policy changes that boost family farmers' inclusion and income.	Progress reports and supervision missions.	0	1	3	
	Percentage of Financial / physical execution of the AWPB.	Progress and financial reports; supervision missions.	0	-	>75%	

E.6. Activities

Activity	Description	Sub-activities	Deliverables
Activity 1.1.1. Select Project Areas and develop TRIPs	Selection of communities to receive investments.	Develop a baseline study to select project area	State proposals, one study per state to select project area
	Design of TRIPs with full involvement of selected communities.	Design and approve TRIPS	575 TRIPS
Activity 1.1.2 Implement CRPS in family farms and backyard gardens	Application of productive activities following the six principles and practices of CRPS in family farms, not only to increase resilience but also to contribute to increase families' production, efficiency and nutrition.	- Implement CRPS in Family Farms - Provide TA for implementation	31,000 families benefited
	Application of productive activities following the six principles and practices of CRPS in backyard gardens, not only to increase resilience but also to contribute to increase families' production, efficiency and nutrition and encourage women's leadership.	- Implement CRPS in BYGs in conjunction with activities in Component 2; - Provide TA for implementation	Male 86,400 Female 57,000 Persons provided with targeted support to improve their nutrition (IFAD CI 1.1.8)
Activity 1.1.3 Implement Collective Resilient Investments	Implement Collective Areas Sustainable Management (CASM) to Improve the ecosystem services provided by the Caatinga, such as microclimate regulation, carbon capture, sequestration and fixation, pest and disease control, water supply, waste decomposition, natural pollination of crops and other plants, and supply of raw materials (e.g. wood, oilseeds and fruits)	- Recover degraded areas using CRPS; - Decrease timber demand by implementing eco-efficient stoves and bio-digestors; - Increase supply and efficient use of water for production; - Structure community seedbanks and nurseries; - Promote low-impact productive activities in collective areas (e.g. beekeeping). - TA	1,800 families benefited
	Implementation of climate-resilient agricultural practices in schools.	- CRPS teaching and experimentation; - Development and maintenance of nurseries and seedbanks; - Promotion of entrepreneurship in CRPS; and - Trainings cooks and students on the nutritional value of native fruits	1,000 schools benefited

		and vegetables to diversify and enrich diets - TA	
	Implementation of Biosaline agriculture practices in communities with installed desalination devices.	- Fish breeding; - Irrigation of halophyte plants in small areas	1,200 families benefited
Activity 1.1.4 Build a Farmers Network and Promote local entrepreneurship for products and services that support family farming	Farmers' network is built by providing technical assistance training. Farmer Trainers are trained to enhance their knowledge on CRPS, water access and gender/youth/traditional communities' sensitive approach). Farmers participate in workshops and visits to improve their knowledge in productive practices and new technologies.	-Training sessions - Exchanges carried out at local and regional levels; - Workshops and training for family farmers and community leaders promoted	550 professionals trained 24,000 participants
	Promotion of entrepreneurship in CRPS		70 microenterprises supported
Activity 2.1.1 Build boardwalk cisterns	Build rainwater reservoir to produce food, forage, seedlings and/or animal water consumption.	- Building cisterns with community participation; - Irrigation systems - TA	20,000 cisterns and irrigation systems
Activity 2.1.2 Implement social technologies for water supply	Build small farm ponds to Irrigate plots and support short-cycle crops during dry season.	- Building trench barriers with community participation; - Irrigation systems - TA	trench barriers and irrigation systems
	Groundwater Storage. Build small underground dams to store water to produce food, seedlings, forage and/or animal water consumption.	- Building underground dams with community participation; - Irrigation systems - TA	500 small underground dams and irrigation systems
Activity 2.1.3 Implement treatment and reuse systems for household wastewater	Greywater reuse. Water treatment systems that allow greater water availability for food production.	- Building greywater treatment systems with community participation; - Irrigation systems - TA	10,000 treatment and irrigation systems
	Blackwater treatment. Biological treatment of sewage and biomass production	- Build wastewater biological treatment systems with community participation; -TA	5,000 treatment systems
Activity 3.1.1 Raise awareness and build capacities of women, youth and traditional communities	Young communicators use social communication tools to register and systematize actions developed in communities.	-Workshops for youth communicators; - Inter-state exchange visits; -Inter-regional exchange visits; - Training for youth; -Learning scholarships for youth.	414 young communicators
	Events for the inclusion of women and traditional communities in processes of decision-making and knowledge-sharing of sustainable technologies.	-Training for Women on sustainable technologies; - Workshops and meetings for Women; - Exchange visits for women; - Training for TA in Gender approach, race and ethnicity; - Compilation of Case Studies Childcare support activities	699 events promoted and 3 case studies developed
Activity 3.1.2 Drive scaling-up, unlock policy barriers and experiment with CRPS and resilience participatory monitoring model	SSTC - Capacity building through the exchange of knowledge, skills, resources and technologies across countries.	- National Learning Route / Exchange-Visit; - International Learning Route / Exchange visit (LAC); - International Learning Route / Exchange Visit (Africa)	7 events promoted
	Actions for influencing and disseminating public policies with the goal to support CRPS in family farms.	- Thematic studies; - Forums and Meetings at local, state and federal levels	8 studies and 103 events carried out 3 working group moderators
	Building a monitoring methodology that can be applied with CRPS demonstrations in each territory, allowing a clear visualization of socio-environmental transformations that will occur during the intervention period.		108 events

Activity 3.1.3 Plan, Monitor, Evaluate and Learn	Technical activities for projects' follow-up, monitoring results and publicizing good practices at national level. Including baseline and impact evaluation surveys.	- National Impact Evaluation; - GIS Evaluations; -Planning and Communication Services; - M&E Services; - Planning Workshops; -Studies and other KM products. - Compilation of Studies and other KM products; - Planning Workshops; -Territorial Committee Meetings; - M&E Meetings	75 documents elaborated or events carried out
	Technical activities for projects' follow-up, monitoring results and publicizing good practices at state level.	State specific studies, territorial committee meetings, KM products.	32 documents elaborated

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APPENDIX VI

Images referring to Social Technologies (See Section 4.2.3)

I. **<u>Eco-stoves (Fogões ecoeficientes)</u>**

Photo A - Newly built eco-efficient stove in the kitchen of a country house

Photo B - Stove on the outside of a country house.[305]

[305] SARAIVA, D. P.; XENOFONTE, G. H. S. **Fogão geoagroecológico**. Ouricuri, PE: CAATINGA, 2014. 28 p.

Photo C - Farmer by her stove [306].

II. Biodigestors (Biodigestores)

Photo D – Farmer couple, “loading” their biodigester with water and manure[307]

[306] IDER. **Fogões ecoeficientes. Manual de construção**. Fortaleza: Instituto de Desenvolvimento Sustentável e Energias Renováveis (IDER); Associação Caatinga; Projeto Clima na Caatinga, Sem data. Disponível em: http://www.terrabrasilis.org.br/ecotecadigital/pdf/fogoes-eco-eficientes-manual-de-construcao.pdf

[307] MATTOS, L. C.; FARIAS JR, M. **Manual do biodigestor sertanejo**. Recife: Projeto Dom Helder Camara, 2011. 55 p.

Photo E - Sertanejo family, next to the bidigester [308]

III. **Cistern (Calçadão)**

Photo F - Farmer showing her vegetable garden bed, irrigated with water from the cistern. S. do Araripe, 08.2011[309]

[308] MATTOS, L. C.; FARIAS JR, M. **Manual do biodigestor sertanejo**. Recife: Projeto Dom Helder Camara, 2011. 55 p.

[309] Foto: Pablo Sidersky

Photo G - Cistern - sidewalk, with manual pump [310]

Photo H – 52 thousand litre cistern in construction [311]

[310] ASA-BRASIL. **Cisterna - Calçadão**. 10a. edição. Recife, PE: Articulação do Semiárido Brasileiro, 2014. Disponível em: https://www.asabrasil.org.br/acervo/publicacoes?artigo_id=273&start=10
[311] ASA-Brasil, as infoot-note above.

Photo I – Sidewalk in construction [312]

Photo J - Vegetable garden, irrigated with production cistern water (52 thousand liters), Ceará, 06.2016[313]

[312] ASA-Brasil, as infoot-note above.
[313] Foto: Pablo Sidersky

IV. Underground dam (Barragem subterrânea)

Photo K- Tractor with mechanical shovel dug into an underground dam (BS)[314]

Photo L- Placement of canvas for the construction of an underground dam [315].

[314] MELO, R. F. D. et al. **Barragem Subterrânea: Tecnologia para Armazenamento de Água e Produção de Alimentos**. Circular Técnica, 104. Petrolina, PE: Embrapa Semiárido, 2013. Disponível em: www.cpatsa.embrapa.br

[315] OLIVEIRA, J. B.; ALVES, J. J.; FRANÇA, F. M. C. **Barragem subterrânea**. Fortaleza, CE: PRODHAM – Projeto de Desenvolvimento Hidroambiental do Estado do Ceará, 2010. 31 p.

Foto M – Vista de uma barragem subterrânea terminada. Note-se o cacimbão feito de anéis de cimento e o barramento de pedra que marca o local onde está a valeta com a lona enterrada. Photo M - View of a finished underground dam. Note the cacimbão made of cement rings and the stone dam that marks the place where the ditch with the buried tarp is [316]

V. Greywater reuse system (Sistema de reuso de águas cinzas)

Photo O - Agroecological backyard irrigated with water from a Family Bio Water Treatment System [317]

[316] OLIVEIRA, J. B.; ALVES, J. J.; FRANÇA, F. M. C. **Barragem subterrânea**. Fortaleza, CE: PRODHAM – Projeto de Desenvolvimento Hidroambiental do Estado do Ceará, 2010. 31 p.

[317] SANTIAGO, F. et al. **Bioágua Familiar. Reuso de água cinza para produção de alimentos no Semiárido**. Recife: Projeto Dom Helder Camara-SDT-MDA, 2012. 19 p.

Photo P - Agro-ecological backyard of Family Bio-water System, in the municipality of Olho d'Água dos Borges, RN [318]

VI. **<u>'Green pit' - Simplified sewage treatment system (‘Fossa verde’ – Sistema simplificado de tratamento de esgoto)</u>**

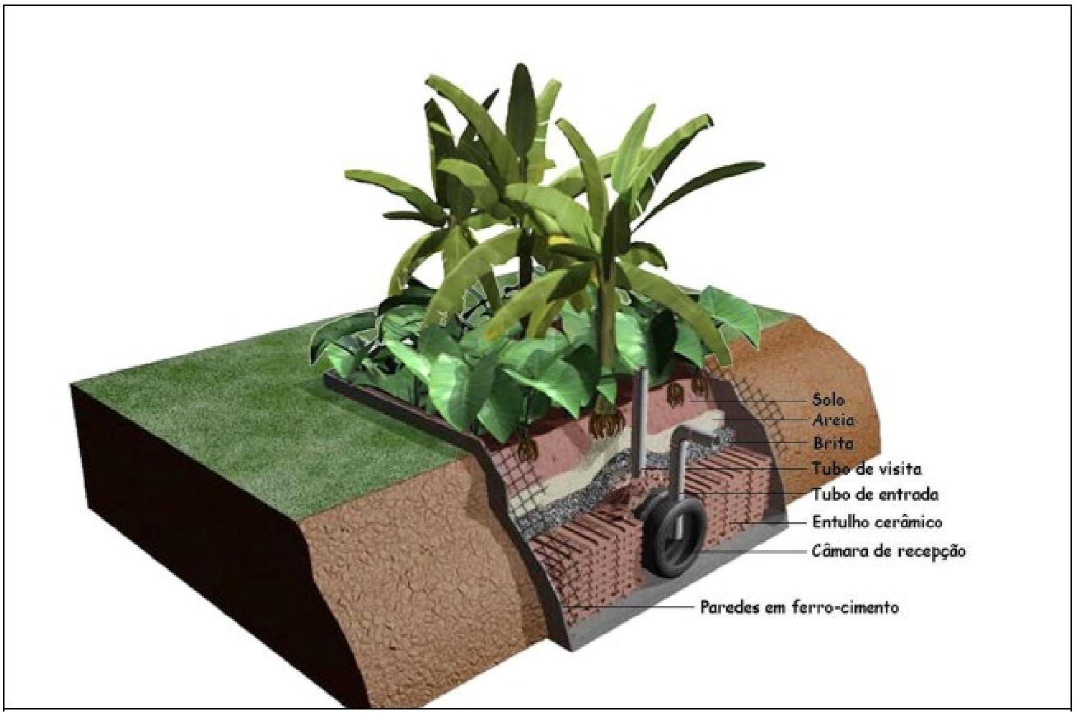

Photo Q - Perspective cut of 'green pit' or Evapotranspiration tank.[319]

[318] Foto: Pablo Sidersky

[319] GALBIATI, A. F. **Tratamento domiciliar de águas negras através de tanque de evapotranspiração**.(Dissertação de Mestrado). Centro de Ciências Exatas e Tecnologia, Universidade Federal de Mato Grosso do Sul, Campo Grande, MS, 2009

Photo R - Photographic record of a green septic tank planted with banana trees and other crops [320]

[320] GALBIATI, A. F. **Tratamento domiciliar de águas negras através de tanque de evapotranspiração**. (Dissertação de Mestrado). Centro de Ciências Exatas e Tecnologia, Universidade Federal de Mato Grosso do Sul, Campo Grande, MS. 2009

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APPENDIX VI

Research Project: Drought in the Brazilian Semi-Arid

Authors:
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Lucas Rolo Fares

1. Introduction

The original objective of this study was to verify if municipalities affected by droughts in the Brazilian drylands have suffered negative impacts in their agricultural production, with emphasis on family/subsistence farming. If positive, the second stage of the study was to provide preliminary estimates of the economic value of these impacts.

In order to do so, climatic effects were identified by episodes where there was an official statement of drought ("seca") or dry spell ("estiagem") according to the Civil Defense, or, alternatively, by episodes of very low annual precipitation averages. Dry spells ("estiagens") refer to drought events that happened in a relatively short period of time, while drought ("seca") refers to a long lasting drought.
The next sections detail the main procedures and results of the research. There are statistically significant results showing robust correlation between climate disasters and agricultural (cultivation and livestock) loss, especially for the crops typically associated with family/subsistence agricultural production in the drylands of the Brazilian Northeast and Minas Gerais. For cultivation, the analysis was based in both loss of productive area and output value, while for livestock we considered only the output value.
The results confirmed the hypothesis that drought and dry spell events (i) have significant economic impacts, (ii) affect proportionally more crops typically associated with family/subsistence farming, and (iii) have increased in recent years.

2. Data and variables

2.1. Data base

In order to study the impact of droughts on the agricultural production of the Brazilian semi-arid region, a municipal database was built for the Brazilian Northeastern region and the state of Minas Gerais. The database includes information on average precipitation, disaster episodes and agricultural production and cultivated/harvested area. Municipalities ("municípios") were chosen from all of these states, even if not located in drylands with the objective to provide treatment/control groups for econometric reasons.
In order to strengthen the results and analyze the progression of these effects over the last decades, taking into account the worsening effects of climate change, the study analyzed the 1981- 2016 period. However,

since many variables are not available for the entire period, the analysis has focused on the last twenty years of the time series.

Two different variables were collected and constructed to estimate climate effects (in econometric terms, they are the independent variables - variables that have an effect on other dependent variables):

- municipalities with drought and dry spell episodes in a certain year, provided by the historical series of the Integrated Disaster Information System (S2iD); and
- the annual average precipitation, measured by the year monthly precipitation, collected by the National Meteorological Institute (INMET) stations and made available in the Meteorological Database for Teaching and Research (BPMED).

Both variables play a similar role in this study, identifying the municipalities that suffered from lack of rain in prolonged periods. However, the historical series of drought and dry spell episodes are only available from 2003 onwards. Therefore, for the 1981-2002 period, only statistics using INMET precipitation data were considered.

Climate disaster information from S2iD is already available from the geocode of the municipality that reported the drought or dry spell event. Therefore, they are included directly in the database using the municipality geocode. However, precipitation data is provided by the INMET meteorological information collection station, in spatial terms, that are not defined according to the political-administrative frontiers. In order to include them in the database, the ArcMap software was used in two stages: first, the data of the stations were interpolated by the Kriging method, using their respective geographical coordinates and generating a map for each year (Figure 1). From the interpolated maps, we used the Zonal Statistics function of ArcMap, adopting as mask the shapefile of municipalities in the Northeast and Minas Gerais, and obtaining the means of precipitation for each municipality (Figure 2). The unit of average precipitation is mm/month.

Figure 1. Climate stations and interpolated map, 2003.

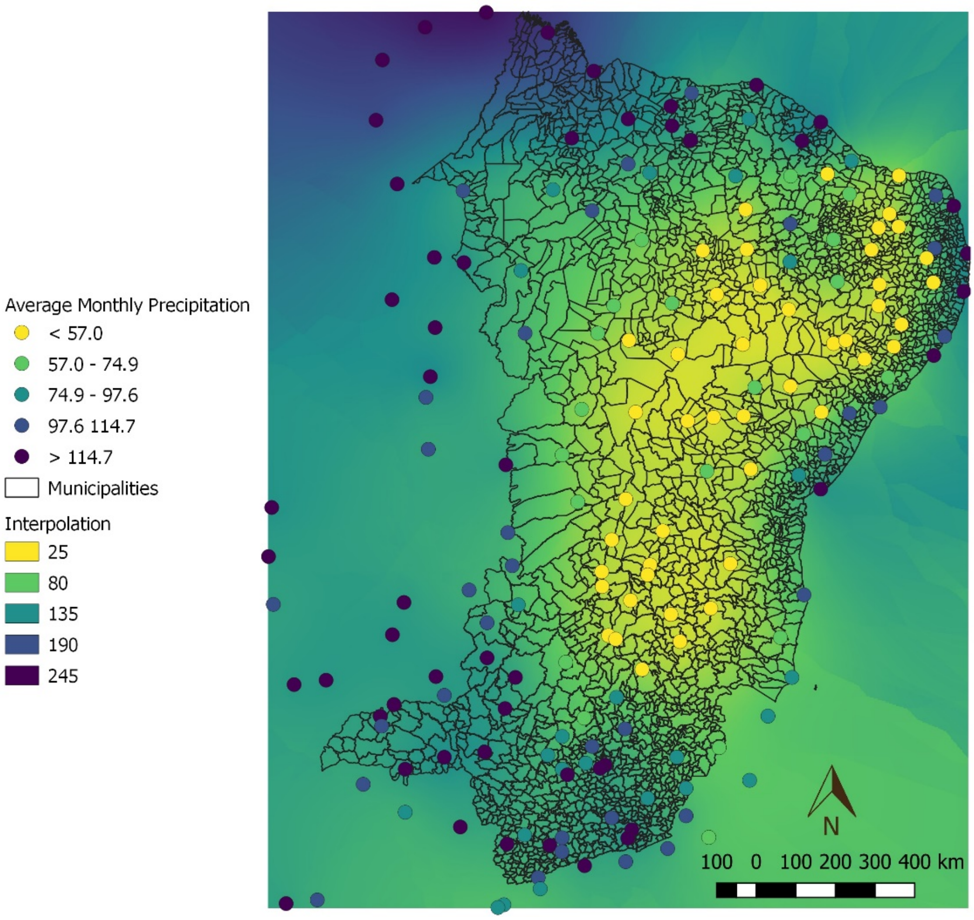


Figure 2. Municipal precipitation average, 2003.

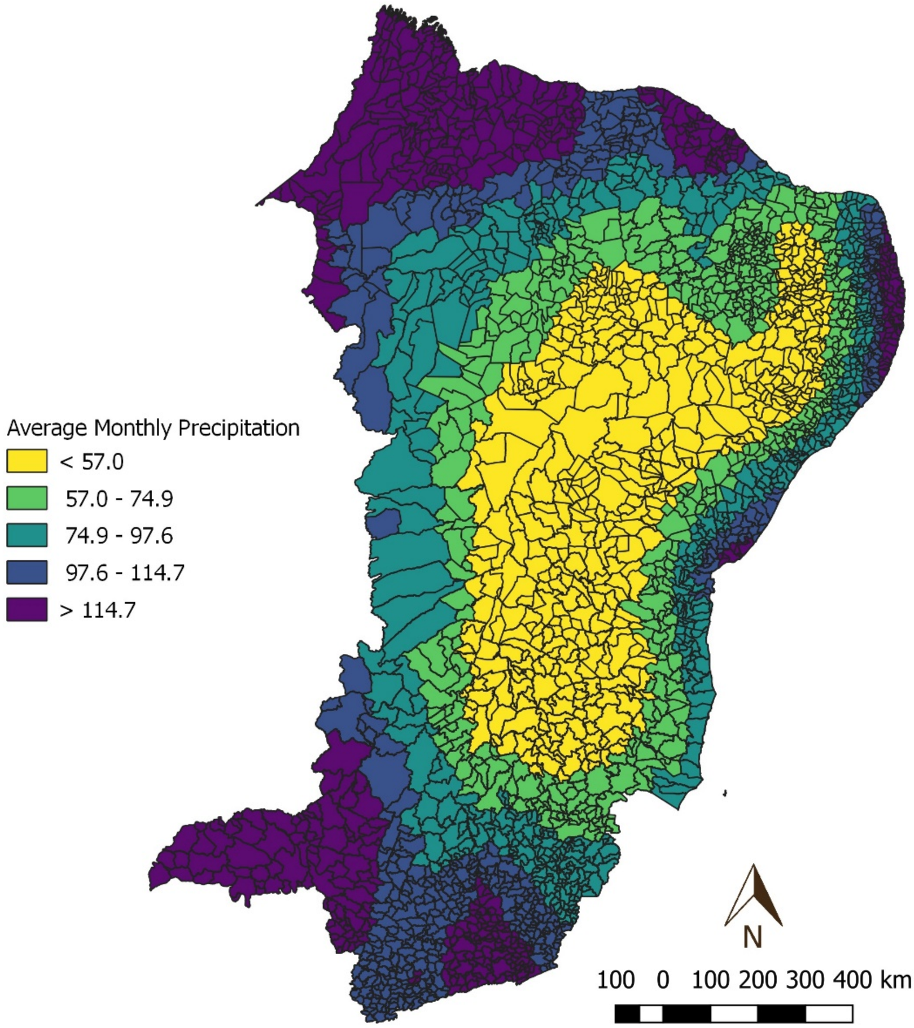
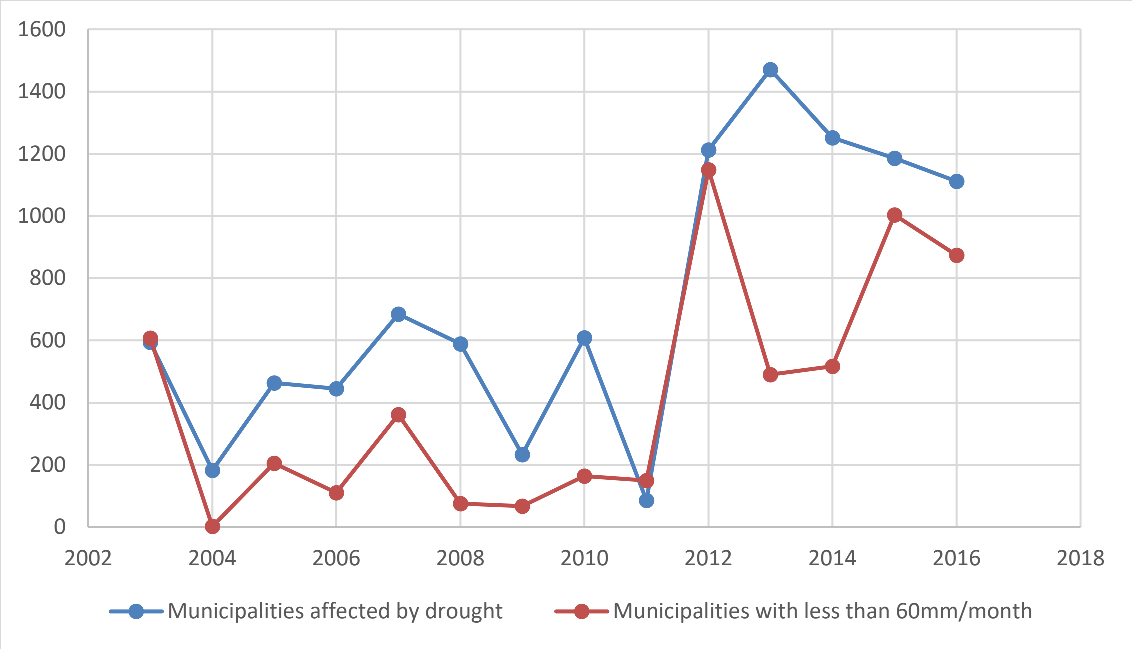


Figure 3 shows the evolution of municipalities that were subject to drought disaster and municipalities that the average precipitation was below 60mm/month over time. It is clear that (i) there is a strong correlation between these two variables (statistical evidence of this is provided in this report), and (ii) there was an increase of drought episodes in the second half of the period.

Figure 3. Evolution of municipalities affected by drought disasters ("seca" or "estiagem") and municipalities with less than 60mm/month in Brazilian drylands, 2003-2016.



Source: Integrated Disaster Information System (S2iD) and Meteorological Database for Teaching and Research (BPMED)

Table 1 presents the distribution of drought events per Brazilian states accumulated over the 2003-2016 period. The most affected states are Ceará (CE), Piauí (PI) and Bahia (BA), followed by Minas Gerais (MG) and Rio Grande do Norte (RN).

Table 1. Accumulated drought events per Brazilian states, 2003-2016

State	"Seca" events	"Estiagem" events	Total drought events
AL	507	170	677
BA	68	1,939	2,007
CE	1,052	1,553	2,605
MA	-	210	210
MG	307	1,405	1,712
PB	169	2,670	436
PE	10	1,560	166
PI	359	1,781	2,140
RN	1,036	565	1,601
SE	193	73	266
Total	3,701	11,926	15,627

Source: Integrated Disaster Information System (S2iD)

Data on agricultural production was collected from the Brazilian Institute of Geography and Statistics (IBGE), for physical output, production value and cultivated/harvested areas. These agricultural variables are the dependent variables of this study - variables that are impacted by the independent variables - and are used with the purpose of evaluating the losses (in output, value and cultivated area) due to droughts in the semi-arid region of Brazil.

For the agricultural output and area, data were collected from the table identified with the code 5457 in the IBGE Automatic Recovery System (SIDRA). It provides information on the following variables: area planted or intended for harvest, area harvested, quantity produced, average yield and value of production. The data are presented in a historical series - used in this research from 1981 to 2016 - with the annual values at the municipal level. These statistics come from the survey of Municipal Agricultural Production (PAM), held annually by IBGE.

SIDRA also provides livestock data, resulting from the survey on Municipal Livestock Production (PPM) - conducted annually. The tables identified with codes 3939, 95, 94 and 74 by SIDRA were collected for this study. The variables presented in each table are, respectively, the number of herds broken down by type (bovine, buffalo, equine, total swine, swine - pigs, goats, sheep, chickens - chickens, chickens and quails); quantity of sheared sheep (heads); milked cows (heads); volume and monetary values of products of animal origin (milk in thousand liters, chicken eggs in a thousand dozen, quail eggs in a thousand dozen, bee honey in kilograms, silkworm cocoons in kilograms and wool in kilograms). All are also broken down by municipalities and in a historical series - also used in this research from 1981 to 2016.

In order to focus on the effects on family/subsistence farming, we used the Agricultural Census, carried out by IBGE every ten years. The 2006 Agricultural Census presented a specific classification of "Family Agriculture" based on the definitions of Law No. 11,326/2006, which makes it possible to identify the main crops and family farms in that year. From this, it was possible to collect in annual PAMs and PPMs the quantities produced and yields of the crops with the highest family participation. Two tables were used: (i) SIDRA table 949, which shows, by municipality, the number of agricultural establishments, quantity produced, area harvested and production value by family and non-family farming and type of crop production - brown rice, black beans, colored beans, beans, cassava, corn, soybeans, wheat, coffee, coffee canephora (robusta, conilon) in grain ("green"); and (ii) table 1118, which also shows the number of agricultural establishments with production in the year and the value of production in the year by type of production - animal, subdivided into large, medium and small sizes and birds; vegetable, subdivided into permanent, temporary, horticulture, forestry and extraction; agroindustry.

The other Agricultural Censuses do not present a specific discrimination for family agriculture. However, the Censuses of 1995 and 2017 present statistics according to the size of agricultural establishments, which allows to identify the municipalities where small properties are more common, in absolute and relative terms. For this, an assumption was made that the category of family agriculture is characterized by the small area of the property (indeed, the concept of family agriculture in Law n. 11,326 is based on the property size). SIDRA tables 312 (in the 1995 Census) and 6710 (in the 2017) present the quantities of establishments with less than 1 hectare, between 1ha and 2ha, between 2ha and 5ha, between 5ha and 10ha, between 20ha and 50ha, between 50ha and 100ha, between 100ha and 200ha, between 200ha and 500ha, over 500ha and the establishment with no declared area.

2.2. Descriptive Statistics

Table 2 presents average statistics for the cultivated area ("Área Plantada"), the harvested area ("Área Colhida"') and the average agricultural output (in constant 2016 R$) for municipalities that have suffered with drought events ("seca" or "estiagem") and those who did not. It is clear that drought events increase the loss of productive areas and considerably reduces the average annual agricultural output per hectare.

Table 2. Cultivated and harvested area, and average agricultural and livestock output, according to the occurrence of drought disasters, 2003-2016.

Drought events	Average cultivated area (ha)	Average harvested area (ha)	Average lost area (ha)	Average lost area (in %)	Average agricultural value (thousand R$)	Average livestock value (thousand R$)
No dry spells	6,890	6,696	195	2.8%	R$ 26,435	R$ 6,828
With dry spells	5,924	5,354	570	9.6%	R$ 13,395	R$ 4,029
No droughts	6,826	6,563	263	3.9%	R$ 24,639	R$ 6,283
With droughts	4,733	4,270	463	9.8%	R$ 9,622	R$ 5,352
Total (average)	6,624	6,349	275	4.1%	R$ 23,386	R$ 6,165

Table 3 presents similar results, but using average annual precipitation, rather than disaster declarations. In both methods, the results show that less precipitation are correlated with more loss of productive area and smaller annual average agricultural output per hectare. However, using the average annual precipitation, the magnitude of the loss is considerably larger than the results with disaster declarations.

Table 3. Cultivated and harvested area, and average agricultural and livestock output, according to the annual precipitation, 2000-2016.

Precipitation categories	Average cultivated area (ha)	Average harvested area (ha)	Average lost area (ha)	Average lost area (in %)	Average agricultural value (thousand R$)	Average livestock value (thousand R$)
Less than 30mm (4)	4,744	2,805	1,939	40.9%	R$ 14,315	R$ 3,046
Between 30mm and 60mm (3)	5,215	4,363	852	16.3%	R$ 13,368	R$ 3,721
Between 60mm and 100mm (2)	6,427	6,168	259	4.0%	R$ 18,391	R$ 4,651
More than 100mm (1)	7,013	6,937	76	1.1%	R$ 29,090	R$ 7,669
Total (average)	6,499	6,221	278	4.3%	R$ 22,278	R$ 5,814

In order to analyze the consequences to family agriculture, the same statistics were made only for beans and corn. These crops were chosen as proxies for family agriculture because, according to the 2006 Brazilian Agricultural Census, beans and corns are produced mainly by family farming in the states selected in this study.

Cassava was not considered in the analysis because, even though most of production comes from family agriculture (88% of the harvested area, as shown in table 4), it represents a very minor share of the subsistence agriculture: table 5 shows that beans and corn have a much higher importance in total family agriculture output). This is clear in tables 4 and 5, which shows that

Table 4. Total and family agriculture harvested area (hectares) per different crops, in absolute and relative terms, according to IBGE 2006 Agricultural Census

Crop	Total harvested area (ha)	Total harvested area by family agriculture (ha)	% harvested by family agriculture
Rice	787,948	648,060	82.2%
Beans	3,163,011	2,688,850	85.0%
Cassava	822,969	724,329	88.0%
Corn	4,235,213	3,115,650	73.6%
Soy	2,170,132	32,722	1.5%
Coffee	878,980	323,046	36.8%
Total	12,058,253	7,532,657	62.5%

Table 5. Total and family agriculture relative share of each in terms of harvested area (%), according to IBGE 2006 Agricultural Census

% of each crop in harvested area	Total	Family agriculture
Rice	6.5%	8.6%
Beans	26.2%	35.7%
Cassava	6.8%	9.6%
Corn	35.1%	41.4%
Soy	18.0%	0.4%
Coffee	7.3%	4.3%

Total	100.0%	100.0%

Table 6 suggests that bean and corn plantations suffer the higher loss of cultivated area, (regardless of climate events) than the average of all crops (shown in Table 2). However, the presence of drought or dry spell events intensifies the losses areas for these crops of majority family production, measured by the difference between cultivated and harvested areas.

Table 6. Cultivated and harvested area, and average agricultural output for bean and corn crops, according to the occurrence of drought disasters, 2003-2016.

	Drought events	Average cultivated area (ha)	Average harvested area (ha)	Average lost area (ha)	Average lost area (in %)	Average agricultural value (thousand R$)
Bean	No dry spells	801	736	64	8.0%	R$ 1,287
	With dry spells	1,359	1,169	191	14.0%	R$ 1,094
	No drought	900	812	88	9.8%	R$ 1,280
	With drought	1,222	1,078	145	11.8%	R$ 779
	Total (average)	915	824	91	10.0%	R$ 1,234
Corn	No dry spells	1,510	1,425	85	5.6%	R$ 2,712
	With dry spells	1,728	1,435	294	17.0%	R$ 1,196
	No drought	1,553	1,432	121	7.8%	R$ 2,491
	With drought	1,620	1,360	261	16.1%	R$ 917
	Total (average)	1,544	1,415	129	8.4%	R$ 2,359

Table 7 shows the results of cultivated and harvested area, and average agricultural output for bean and corn crops, according to the annual precipitation, 2000-2016. Results are similar to those obtained according to disaster declarations. Using precipitation categories, the average loss in bean and corn cultivated area is greater than the average loss for all crops in all precipitation categories. However, in categories 3 and 4 (the ones with less rain), there is a significant worsening in the losses of planted area, especially for corn: 73.5% average loss for municipalities with less than 30mm/month, and 26.6% loss for municipalities with an average of precipitation between 30 and 60mm/month.

Table 7. Cultivated and harvested area, and average agricultural output for bean and corn crops, according to the annual precipitation, 2000-2016.

	Precipitation categories	Average cultivated area (ha)	Average harvested area (ha)	Average lost area (ha)	Average lost area (in %)	Average agricultural value (thousand R$)
Bean	Less than 30mm (4)	1,133	456	677	59.8%	R$ 248
	Between 30mm and 60mm (3)	1,456	1,160	296	20.3%	R$ 976
	Between 60mm and 100mm (2)	1,186	1,099	87	7.4%	R$ 1,364

	More than 100mm (1)	528.1	514.1	14	2.7%	R$ 1,177
	Total (average)	939	849	90	9.6%	R$ 1,220
Corn	Less than 30mm (4)	1,460	387	1,073	73.5%	R$ 122
	Between 30mm and 60mm (3)	1,652	1,213	439	26.6%	R$ 664
	Between 60mm and 100mm (2)	1,599	1,481	118	7.4%	R$ 1,850
	More than 100mm (1)	1,425	1,405	20	1.4%	R$ 3,170
	Total (average)	1,530	1,401	129	8.4%	R$ 2,240

2.3. Regression structure

The explanatory (independent) variables were:
- Climatic disasters (drought and drought): variable dummy (whether or not there was a drought disaster in the municipality in the year in question). Source of information: historical series of Atlas of Disasters, from data of the Civil Defense
- Precipitation: categorical variable of the mean precipitation of the year, in the municipality in question (data of rainfall stations, interpolated by municipality, INMET data). The choice by categorical variables (by average precipitation range) and non-linear variables is due to the fact that results fit better, considering the wide range of variation of numerical results.

Four main groups of dependent variables were considered:
(i) "loss of productive area = cultivated area - harvested area" (average absolute loss) and "percentage loss of productive area = (cultivated area – harvested area)/cultivated area" (average relative loss);
(ii) "value of agricultural production" and the "natural logarithm of the value of agricultural production" (to examine the percentage loss);
(iii) "value of livestock production (total)" and the "natural logarithm of the value of livestock production" (to examine the percentage loss);
(iv) "effective of the herds (bovine, goat, etc.)" and the "natural logarithm of the effective of the herds" (to examine the percentage loss).

Different regressions were made with changes on the functional form and the categorization of the activities considered. In order to emphasize the effects on subsistence farming, two set of regressions was made using only the production of bean and corn, considering (i) the loss of productive area and (ii) the value of agricultural production.

For livestock, exercises were performed comparing herds of different animals (cattle, goats, sheep) and honey, but the results were very similar and, therefore, we worked only with the aggregate series, considering the overall "pecuária" IBGE category (livestock and other animal products) production. The main reason for the low sensitiveness of changes of results considering different livestocks is that livestock outputs are less affected by the climatic variation than crop cultivation.

In spatial terms, the analysis was carried out in two different levels: (i) municipalities ("municípios"); and (ii) aggregation according to the IBGE micro-regions. This decision was made due to a trade-off between these two strategies: while the results by municipality may have bias due to the creation and dismemberment of municipalities in the period, [321] which damages the comparison over time since the area of the affected municipalities change, the microregions have much more stable delimitations.[322] However, the identification of correlations (coefficients tend to be underestimated because of a greater diffusion of cause and effect

[321] In 1980, there were 3,991 municipalities. In 2010, the number of municipalities increased to 5,565, and in 2017 they are 5,570. https://ww2.ibge.gov.br/home/geociencias/geografia/default_evolucao.shtm
[322] In 2017 there are 558 IBGE micro-regions in Brazil, the same number as in 1980.

indicators) is more difficult using the higher aggregation level of microregions. In this description the analyzes take into account mainly the regressions by municipality, but the interpretations of the coefficients are very similar for the regressions by micro-region.

Natural logarithm was the chosen functional form to find the impact of explanatory variables on the output value of agricultural and livestock production, and also on the size of livestock herds. The resulting coefficients were normalized so that their interpretation was done in terms of percentage points (unit for the arithmetic difference of two percentages).[323]

3. Regressions Exercises

3.1. Exercise 1: Droughts x Average Precipitation

The first set of regressions was made to investigate the correlation between droughts that were reported by Civil Defense as climatic disasters ("seca" and "estiagem") and the average precipitation in the region. In order to reduce the wide variation in this variable, the average precipitation was also divided by categories (1: greater than 100 mm/month, 2: 60 to 100mm/month, 3: from 30 to 60mm/month, 4: less than 30mm/month). The average of maximum temperature of each month was used, from the INMET base, was used as a control variable. Table 6 presents the results.[324]

Table 8. Correlation between climatic disasters (droughts and drought) and average precipitation, linear and by category (1: greater than 100 mm / month, 2: 60 to 100, 3: from 30 to 60, 4: less than 30), analysis per municipalities.

	(1)	(2)
Variables	Dummy Disasters	
Precipitation (mm/month)	-0.00197***	
	(0.000124)	
Dummy Precipitation (2)		0.0445***
		(0.00585)
Dummy Precipitation (3)		0.268***
		(0.00980)
Dummy Precipitation (4)		0.385***
		(0.0247)
Constant	0.405***	0.153***
	(0.0124)	(0.00730)
Period	Post 2003	
Level	Municipality	
Observations	37,030	37,058

[323] As the series studied are very long, it is difficult to add control variables at the municipal (or micro-regional) level. Thus, we chose to construct only one monthly average maximum temperature control variable, using the same INMET database and the same precipitation interpolation methodology. To control other effects that impacts on the dependent variables, we run the regression in panel format with fixed effects in years and municipalities (or micro-region). These fixed effects allows us to control one-dimensional effects: variables that impacts the municipality *i* in the same way during all years (topographic conditions, distance from the municipality to the coast); and variables that impact all municipalities in the same way in year *t* (agricultural prices, dollar quotation). This empirical strategy, in addition to the long period observed, is enough for us to believe in the robustness of the used model.
[324] The results as a percentage of table 8 to table 13 should actually have the coefficients interpreted as an increase in percentage points (for example, if a coefficient is 0.05, the interpretation is an increase of 5 percentage points). In tables 14 to table 19, where percentage results were reached using the natural logarithms of absolute values, the interpretation should be done at a percentage increase (eg if the coefficient is 0.05, the interpretation is that there is an increase of 5%).

R-squared	0.220	0.245
Number of Mun	2,645	2,647
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Both regressions demonstrate strong adherence, as expected: the categories of lower average precipitation (3 and 4) are strongly correlated with drought disasters.

The probability of a municipality in category 4 being subject to a drought or dry spell is 38.5 percentage points higher than in category 1; in the category 3, this probability is 26.7 percentage points higher; and in 2 it is only 4.45 percentage points higher. All these results are statistically significant at the 1% level.
We proceeded the same analysis considering IBGE micro-regions, instead of municipalities (table 9).
Table 9. Correlation between climatic disasters and average precipitation, linear and by category (1: greater than 100 mm/month, 2: 60 to 100, 3: from 30 to 60, 4: less than 30), analysis per micro-regions

	(1)	(2)
Variables	Dummy Disasters	
Precipitation (mm/month)	-0.00199***	
	(0.000456)	
Dummy Precipitation (2)		0.0682***
		(0.0230)
Dummy Precipitation (3)		0.121***
		(0.0327)
Dummy Precipitation (4)		-0.0366
		(0.0899)
Constant	0.646***	0.416***
	(0.0397)	(0.0269)
Period	Post 2003	
Level	Microregion	
Observations	3,542	3,556
R-squared	0.196	0.196
Number of Micro	253	254
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

In the analysis based on micro-regions, Category 4 data are statistically non-significant (they do not differ from Category 1). This is because micro-region observations in Category 4 are very scarce. However, as expected, under category 3, the probability of the micro-region presenting a disaster is 12.1 percentage points higher than in category 1; while in Category 2 the probability is 6.8 percentage points higher.

Our conclusion is that results validate the expected hypothesis that droughts in the Brazilian drylands can be measured either using data on the occurrence of reported drought and dry spell events in the Atlas of Natural Disasters, or using the average precipitation (linear or by category), using INMET data.

We also considered that results using the average precipitation are statistically more robust that those using disaster declarations. Therefore, in the next exercises, we proceeded only with the estimates according to the annual average precipitation.

3.2. Second Exercise: Loss of Productive Area x Drought Disasters or Average Precipitation

The second set of regressions shows the correlation between climatic variables (measured either by the number of drought occurrences or average precipitation) and the loss of productive area, measured by the difference between cultivated area and harvested area in each municipality or IBGE micro-region.
As a control variable for the regressions that used the climatic disaster dummy, an interval of one year before and one year after the year of the disaster incidence was considered, since the effects of this disaster on the production can present temporal lags (dry spells and drought event may have been declared after a long period of lack of precipitation, or the effects of dry spells or droughts may persist for some time after the disaster declaration).

The results in table 10 show the effect of drought occurrence in the productive area in terms of municipalities, while table 9 presents the same results in terms of IBGE micro-regions. The first column refers to the impact on the total lost area in absolute terms without considering a time-lag effect, while the second column introduces a two-period time lag. The third column refers to the total loss of productive area in percentage points, while the two last columns focus on specific corps associated with family/subsistence agriculture (beans and corn, also in percentage points), all of them considering time lag dummies in the analysis. All regressions show statistically significant reduction of productive area, and this loss is more intense in the traditional family agriculture (beans and corn) than in other crops.

Table 10. Regression analysis of the loss productive area (in absolute and relative terms) and the occurrence of drought disasters, by municipalities

	(1)	(2)	(3)	(4)	(5)	
Variables	Total Lost Area (ha)	Total Lost Area (%)	Beans Lost Area (%)	Corn Lost Area (%)		
Dummy Disaster	32.74	-43.16*	0.0282***	0.0319***	0.0464***	
	(23.56)	(25.71)	(0.00322)	(0.00408)	(0.00461)	
Dummy Disaster (t-1)		79.18***	0.0271***	0.0410***	0.0509***	
		(22.05)	(0.00270)	(0.00352)	(0.00401)	
Dummy Disaster (t+1)		19.99	0.00286	0.00734*	0.0123***	
		(24.92)	(0.00309)	(0.00390)	(0.00428)	
Average Max Temperature	94.91***	97.09***	0.0288***	0.0255***	0.0435***	
	(15.64)	(15.16)	(0.00246)	(0.00313)	(0.00353)	
Constant	-2,661***	-2,654***	-0.816***	-0.706***	-1.245***	
	(479.6)	(458.1)	(0.0744)	(0.0944)	(0.106)	
Period	Post 2003	Post 2004	Post 2004	Post 2004	Post 2004	
Level	Municipality	Municipality	Municipality	Municipality	Municipality	
Observations	36,880	31,303	31,288	29,484	29,709	
R-squared	0.011	0.012	0.095	0.100	0.126	
Number of mun		2,640	2,613	2,613	2,551	2,554
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

Table 11. Regression analysis of the loss productive area (in absolute and relative terms) and the occurrence of drought disasters, by IBGE micro-regions

	(1)	(2)	(3)	(4)	(5)
Variables	Total Lost Area (ha)	Total Lost Area (%)	Beans Lost Area (%)	Corn Lost Area (%)	
Dummy Disaster	-735.1	-1,095	-0.0113	-0.0139	-0.0134

	(642.5)	(739.7)	(0.00735)	(0.0106)	(0.0113)	
Dummy Disaster (t-1)		56.13	-0.00417	-0.00255	0.00813	
		(202.7)	(0.00462)	(0.00754)	(0.00782)	
Dummy Disaster (t+1)		296.4	-0.0140*	-0.0219**	-0.0211**	
		(505.2)	(0.00760)	(0.00966)	(0.0104)	
Average Max Temperature	1,157***	1,172***	0.0287***	0.0297***	0.0442***	
	(394.3)	(390.6)	(0.00590)	(0.00852)	(0.00997)	
Constant	-32,749***	-32,503***	-0.803***	-0.808***	-1.240***	
	(12,118)	(11,944)	(0.179)	(0.258)	(0.301)	
Period	Post 2003	Post 2004	Post 2004	Post 2004	Post 2004	
Level	Microregion	Microregion	Microregion	Microregion	Microregion	
Observations	3,542	3,036	3,036	2,995	2,963	
R-squared	0.026	0.027	0.123	0.145	0.168	
Number of micro		253	253	253	252	250
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

Tables 12 and 13 are similar to tables 10 and 11, with the difference that precipitation categories were used, instead of the occurrence of drought disasters. Again, results are statistically significant, even though their interpretation is better understood when the driest categories (3 and 4) are compared to the wettest (category 1). Also, it shows that the effect in the loss of productive areas is higher in corn and beans than for other crops.

Table 12. Regression analysis of the loss productive area (in absolute and relative terms) and precipitation categories, by municipalities

Variables	Total Lost Area (ha)	Total Lost Area (%)	Beans Lost Area (%)	Corn Lost Area (%)
Dummy Precipitation (2)	2.131	-0.00382**	-0.00260	0.000819
	(10.18)	(0.00150)	(0.00207)	(0.00230)
Dummy Precipitation (3)	455.4***	0.101***	0.126***	0.164***
	(41.07)	(0.00377)	(0.00492)	(0.00531)
Dummy Precipitation (4)	1,179***	0.264***	0.406***	0.490***
	(133.3)	(0.0123)	(0.0154)	(0.0153)
Average Max Temperature	57.27***	0.0169***	0.0117***	0.0199***
	(9.874)	(0.00115)	(0.00148)	(0.00153)
Constant	-1,475***	-0.485***	-0.327***	-0.586***
	(293.8)	(0.0346)	(0.0444)	(0.0459)
Period	Post 1988	Post 1988	Post 1988	Post 1988
Level	Municipality	Municipality	Municipality	Municipality
Observations	72,920	72,905	69,346	69,527
R-squared	0.031	0.141	0.152	0.184
Number of Mun	2,644	2,644	2,632	2,636
Robust standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table 13. Regression analysis of the loss productive area (in absolute and relative terms) and precipitation categories, by IBGE micro-regions

	(1)	(2)	(3)	(4)	
Variables	Total Lost Area (ha)	Total Lost Area (%)	Beans Lost Area (%)	Corn Lost Area (%)	
Dummy Precipitation (2)	-658.0	-0.00335	-0.00138	0.00500	
	(1,521)	(0.00404)	(0.00572)	(0.00646)	
Dummy Precipitation (3)	5,261**	0.103***	0.146***	0.179***	
	(2,524)	(0.0104)	(0.0134)	(0.0147)	
Dummy Precipitation (4)	13,089**	0.282***	0.444***	0.517***	
	(5,315)	(0.0337)	(0.0404)	(0.0377)	
Average Max Temperature	-2,753	0.0135***	0.00708*	0.0192***	
	(2,213)	(0.00281)	(0.00408)	(0.00444)	
Constant	12,242	-0.381***	-0.184	-0.566***	
	(62,610)	(0.0856)	(0.125)	(0.135)	
Period	Post 1988	Post 1988	Post 1988	Post 1988	
Level	Microregion	Microregion	Microregion	Microregion	
Observations	9,108	7,336	7,254	7,197	
R-squared	0.506	0.199	0.221	0.251	
Number of Micro		253	253	253	253
Robust standard errors in parentheses					
*** p<0.01, ** p<0.05, * p<0.1					

The results of the regressions in tables 10 and 11 (lost area X occurrence of disasters) generally show a loss of cultivated area lower than in the regressions of tables 12 and 13 (lost area X average precipitation). This is possibly a consequence of the statistical limitation imposed by the information presented by the Atlas of Natural Disasters, which consists of the declaration of the number of occurrences of drought or drought in the municipality, but without presenting details or qualitative and quantitative information about the size of this disaster.

The results in table 11 do not present statistically significant coefficients. This is probably due to the smaller number of observations when aggregating by microregion, which increases the standard deviation of the coefficients. In Table 13, where the observations are also by microregion, the results are, for the most part, statistically significant. Although the standard deviations are also higher, the division by precipitation bands is a more complete and less biased empirical strategy, allowing a stronger correlation with lost areas and drought.

The average precipitation variable allows a greater range of situations, establishing a degree of comparison about the intensity of the rainfall. For this reason, we recommend that the regression results be used in the subsequent analyzes, since the regressions in tables 10 and 11 may underestimate the drought sizing, since it considers in equivalent terms a municipality with no problems of rainfall with another one that has had a considerable fall in precipitation but which has not reached the required gravity for the decree of a drought disaster. Furthermore, the categorization of "seca" (drought) and "estiagem" (dry spell) situations depends on the interpretation of the local authority, which is influenced by factors which may vary from municipality to municipality.

3.3. Third Exercise: Agriculture Production Value x Drought Disasters or Average Precipitation

We also analyzed the effects of droughts on the output production value using the annual Municipal Agricultural Survey of the IBGE in both absolute and relative terms, for the total production, beans and corn. Tables 14 and 15 consider the occurrence of drought events. The difference between them is that regression presented in table 14 used municipalities, while in table 15 we use IBGE micro-regions. Results are statistically significant, showing that droughts affect negatively agricultural output, and this effect is higher in family agriculture crops (corn, in first place, and then beans) than in the total production.

Table 14. Regression analysis of the effects of drought disasters in agricultural production (in absolute and relative terms), by municipalities.

Variables	Agricuture Production Value (thousand R$)	Agricuture Production Value (%)	Bean Production Value (%)	Corn Production Value (%)	
Dummy Disaster	-2,306***	-1,867***	-0.1918***	-0.2576***	-0.335***
	(784.3)	(652.0)	(0.0126)	(0.0259)	(0.0269)
Dummy Disaster (t-1)		-1.193	-0.096***	-0.2327***	-0.2517***
		(713.6)	(0.0129)	(0.0243)	(0.0253)
Dummy Disaster (t+1)		-709.5	0.0337**	0.1595***	0.1723***
		(474.8)	(0.0137)	(0.0251)	(0.0250)
Average Max Temperature	-1,194***	-1,105***	-0.1829***	-0.2825***	-0.3849***
	(367.6)	(392.9)	(0.0118)	(0.0217)	(0.0213)
Constant	57,274***	54,234***	14.78***	15.54***	20.25***
	(11,228)	(11,563)	(0.357)	(0.653)	(0.640)
Period	Post 2003	Post 2004	Post 2004	Post 2004	Post 2004
Level	Municipality	Municipality	Municipality	Municipality	Municipality
Observations	36,880	31,303	31,303	31,303	31,303
R-squared	0.013	0.012	0.124	0.147	0.213
Number of mun	2,640	2,613	2,613	2,613	2,613
Robust standard errors in parentheses					
*** p<0.01, ** p<0.05, * p<0.1					

Coefficients in an exponential form (EXP(coef)-1)

Table 15. Regression analysis of the effects of drought disasters in agricultural production (in absolute and relative terms), by IBGE micro-regions

Variables	Agricuture Production Value (thousand R$)	Agricuture Production Value (%)	Bean Production Value (%)	Corn Production Value (%)	
Dummy Disaster	19,672	17,612	0.0295	0.0520	0.2214**
	(15,889)	(15,088)	(0.0244)	(0.0645)	(0.0828)
Dummy Disaster (t-1)		28,798*	0.0934***	0.1491***	0.2008***
		(15,501)	(0.0226)	(0.0481)	(0.0526)
Dummy Disaster (t+1)		8,812	0.1162***	0.3337***	0.5128***
		(9,164)	(0.0253)	(0.0660)	(0.0612)
Average Max Temperature	-20,802***	-17,657***	-0.1521***	-0,27094055	-0.4184***
	(6,401)	(6,121)	(0.0251)	(0.0653)	(0.0695)
Constant	843,976***	727,830***	16.26***	17.71***	24.36***
	(195,734)	(185,430)	(0.760)	(1.979)	(2.092)
Period	Post 2003	Post 2004	Post 2004	Post 2004	Post 2004
Level	Microregion	Microregion	Microregion	Microregion	Microregion
Observations	3,542	3,036	3,036	3,036	3,036
R-squared	0.044	0.047	0.106	0.177	0.251
Number of micro	253	253	253	253	253
Robust standard errors in parentheses					
*** p<0.01, ** p<0.05, * p<0.1					

Tables 16 and 17 are analogous to tables 14 and 15, but using average precipitation categories instead of drought events. The regression presented in table 16 uses municipalities, while the regression in table 17 considers IBGE micro-regions. Again, results are statistically significant showing that droughts affect negatively agricultural output, and this effect is higher in family agriculture crops (corn, in first place, and then beans) than in the total production.

Table 16. Regression analysis of the precipitation categories in agricultural production (in absolute and relative terms), by municipalities

Variables	Agricuture Production Value (thousand R$)	Agricuture Production Value (%)	Bean Production Value (%)	Corn Production Value (%)
Dummy Precipitation (2)	-12.69	-0.0522***	-0.00143	-0.0471***

	(532.8)	(0.00902)	(0.0153)	(0.0155)
Dummy Precipitation (3)	-1,505**	-0.352***	-0.529***	-0.6641***
	(752.8)	(0.0181)	(0.0305)	(0.0290)
Dummy Precipitation (4)	-3,682***	-0.6171***	-0.9111***	-0.9433***
	(773.2)	(0.0401)	(0.0764)	(0.0713)
Average Max Temperature	1,418***	0.00672	-0.0107	-0.0684***
	(289.0)	(0.00754)	(0.0117)	(0.0115)
Constant	-30,675***	8.560***	6.386***	7.532***
	(8,817)	(0.221)	(0.344)	(0.336)
Period	Post 1981	Post 1981	Post 1981	Post 1981
Level	Municipality	Municipality	Municipality	Municipality
Observations	87,685	87,685	87,685	87,685
R-squared	0.026	0.072	0.118	0.189
Number of mun	2,645	2,645	2,645	2,645
Robust standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Tabela com coeficientes relevantes na fórmula EXP(coef)-1				

Table 17. Regression analysis of the precipitation categories in agricultural production (in absolute and relative terms), by IBGE micro-regions

Variables	Agricuture Production Value (thousand R$)	Agricuture Production Value (%)	Bean Production Value (%)	Corn Production Value (%)
Dummy Precipitation (2)	-4,302	-0.0200	0.00798	-0.0346
	(9,988)	(0.0252)	(0.0402)	(0.0433)
Dummy Precipitation (3)	-15,259	-0.2591***	-0.4674***	-0.6404***
	(12,511)	(0.0462)	(0.0734)	(0.0811)
Dummy Precipitation (4)	-25,402*	-0.4779***	-0.8907***	-0.9565***
	(13,966)	(0.0889)	(0.253)	(0.237)
Average Max Temperature	10,790**	0.00810	-0.00887	-0.0558
	(5,304)	(0.0181)	(0.0306)	(0.0339)
Constant	-212,938	10.74***	8.690***	9.184***
	(165,505)	(0.522)	(0.891)	(0.989)
Period	Post 1981	Post 1981	Post 1981	Post 1981
Level	Microregion	Microregion	Microregion	Microregion
Observations	9,108	9,108	9,108	9,108
R-squared	0.083	0.134	0.147	0.257
Number of micro	253	253	253	253
Robust standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

The results of the regressions using the value of the agricultural production (from table 14 to table 17) indicate that the size of the losses caused by less precipitation is even more expressive, considering both estimation methods (declared disaster events and precipitation bands). Overall, despite the difference in the magnitude of the results, the conclusions reached by this set of regressions is relatively similar to the regressions by the lost areas.

3.4. Fourth Exercise: Livestock Production Value x Drought Disasters or Average Precipitation

Finally, we proceeded a similar analysis for the value of livestock production using data from the Annual Municipal Livestock Survey (PPM/IBGE). The results are also statistically significant in terms of the reduction in livestock output value associated to drought disasters or less precipitation. The regressions in tables 18 and 19 consider the occurrence of drought disasters, while the regressions in tables 20 and 21 used precipitation categories. Tables 18 and 20 are based on municipal data, while tables 19 and 21 are based on IBGE micro-regions.

Table 18. Regression analysis of the effects of drought disasters in livestock production (in absolute and relative terms), by municipalities

Variables	Livestock Production Value (thousand R$)	Livestock Production Value (thousand R$)	Livestock Production Value (%)

Dummy Disaster	-572.6***	-532.6***	-0.029***
	(92.60)	(81.48)	(0.00747)
Dummy Disaster (t-1)		-90.68	-0.00868
		(110.9)	(0.00720)
Dummy Disaster (t+1)		-565.2***	-0.0177**
		(76.08)	(0.00742)
Average Max Temperature	-24.36	-20.22	0.00307
	(84.53)	(72.05)	(0.00608)
Constant	5,463**	5,387**	7.384***
	(2,612)	(2,158)	(0.182)
Period	Post 2003	Post 2004	Post 2004
Level	Municipality	Municipality	Municipalit y
Observations	37,006	31,410	31,410
R-squared	0.053	0.054	0.104
Number of mun	2,645	2,619	2,619
Robust standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			
Tabela com coeficientes relevantes na fórmula EXP(coef)-1			

Table 19. Regression analysis of the effects of drought disasters in livestock production (in absolute and relative terms), by IBGE micro-regions

Variables	Livestock Production Value (thousand R$)	Livestock Production Value (thousand R$)	Livestock Production Value (%)
Dummy Disaster	-3,108*	-2,431*	-0.00400
	(1,596)	(1,422)	(0.0137)
Dummy Disaster (t-1)		-1,496	-0.000332
		(1,455)	(0.0155)
Dummy Disaster (t+1)		-2,779**	-0.0159
		(1,365)	(0.0158)
Average Max Temperature	-632.5	-228.3	-0.000323
	(1,695)	(1,471)	(0.0149)
Constant	68,941	57,398	10.06***
	(52,383)	(44,381)	(0.452)
Period	Post 2003	Post 2004	Post 2004
Level	Microregion	Microregion	Microregion
Observations	3,542	3,036	3,036
R-squared	0.154	0.155	0.216
Number of mun	253	253	253
Robust standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			

Table 20. Regression analysis of the precipitation categories in livestock production (in absolute and relative terms), by municipalities

Variables	Livestock Production Value (thousand R$) - Total	Livestock Production Value (%) - Total
Dummy Precipitation (2)	-172.3***	0,00748
	-58,46	-0,00662
Dummy Precipitation (3)	-249.6**	-0.0342***
	-98,7	-0,0109
Dummy Precipitation (4)	-366.9***	-0.1672***
	-135,9	-0,0205
Average Max Temperature	178.8***	0.0129**
	-52,36	-0,00617
Constant	-2,855*	6.681***
	-1565	-0,18
Period	Post 1981	Post 1981
Level	Municipality	Municipality
Observations	87871	87871
R-squared	0,069	0,216
Number of Mun	2645	2645
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Table 21. Regression analysis of the precipitation categories in livestock (in absolute and relative terms), by IBGE micro-regions

Variables	Livestock Production Value (thousand R$)	Livestock Production Value (%)
Dummy Precipitation (2)	-2,788**	0.0365*
	-1105	-0,0185
Dummy Precipitation (3)	-3,029*	0,0118
	-1743	-0,0291
Dummy Precipitation (4)	-3371	-0.1121**
	-2290	-0,0471
Average Max Temperature	424,2	0,0134
	-867,3	-0,0167
Constant	12899	8.917***
	-26050	-0,484
Period	Post 1981	Post 1981
Level	Microregion	Microregion
Observations	9108	9108
R-squared	0,205	0,404
Number of micro	253	253
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

The regressions of the value of livestock production points to less expressive results than the regressions by the lost area and by the value of agricultural production. In fact, when we use the micro-region aggregation level for both drought events and precipitation bands, the coefficients are statistically non-significant. For the results of the regressions by municipalities, the losses are statistically significant – once again, the results by the precipitation range are stands out – but at a lower level than in the previous cases.

These results indicate that cattle ranching and other animal livestock activities are more resilient t climate events. Therefore, in the estimation of the economic losses caused by climate events, we focused only on cultivation.

4. Valuation of economic losses

This section estimates the costs of droughts in the Brazilian Semi-Arid (Caatinga) with the regression results from the previous sections. After that, we use forecasts about future reduction in precipitation in the region due to climate change in order to calculate the potential loss in agricultural production in the 2017-2030 and 2017-2050 periods.

The methodology was based on the use of selected results of the regressions from the previous section that presented the best fit. Only results for cultivation (total and bean and corn) were considered, since they presented the most significant econometric results. This means that the results presented in this section underestimate the total agricultural losses due to droughts since the livestock production was not considered since the regressions presented smaller degrees of statistical confidence.

More specifically, we chose to use the coefficients from the regressions with the empirical strategy based on the precipitation bands by municipalities, to quantify the relative losses of planted area and respective value of agricultural production. For this reason, only the coefficients for categories 3 and 4 of precipitation (monthly averages less than 60mm) were considered and applied to municipalities and years that fit in these bands. To evaluate the losses of subsistence agriculture, we considered the losses for bean and corn as proxies, since they are the most representative for smallholders.

4.1. Losses of production areas over time

To estimate the losses of productive area in the period 1990-2016, we selected the coefficients from table 10 for the categories of very low precipitation "3" (monthly average between 30 and 60mm) and "4" (monthly average less than 30mm). Results are presented in table 22.

Table 22. Coefficients of lost production area by precipitation category

Precipitation	Lost Area (%)	Lost Area - Bean (%)	Lost Area - Corn (%)
Between 30 and 60mm/month (3)	10.1%	12.6%	16.4%
Less than 30mm/month (4)	26.4%	40.6%	49.0%

The municipalities with the lowest precipitation average ("4", less than 30mm/month), on average, lost 26.4% of their productive area, considering all crops. In the municipalities where the droughts are less intense ("3", between 30 and 60mm/month) the average loss was 10.1%. However, the losses are much more significant for the crops typically produced by family agriculture (bean and corn), especially in the worst case (category "4"), where the loss of cultivated area is more than 40% on average (40.6% for beans and 49.0% for corn). This is a strong indication that the effects of intense reduction in precipitation are disproportionally higher in the typical products of family agriculture.

Assigning the coefficients to the municipalities that fall within each category and, subsequently, multiplying by the respective planted areas, we estimate the productive areas lost due to the drought.

$$Lost\ Area\ due\ Drought_t = Productive\ Area_t * Lost\ Area\ Coefficient$$

Figure 4 shows the estimates of lost productive area due to droughts, in absolute and relative terms, for the 1990-2016 period.[325]

Figure 4. Lost area due to drought over time, 1990-2016.

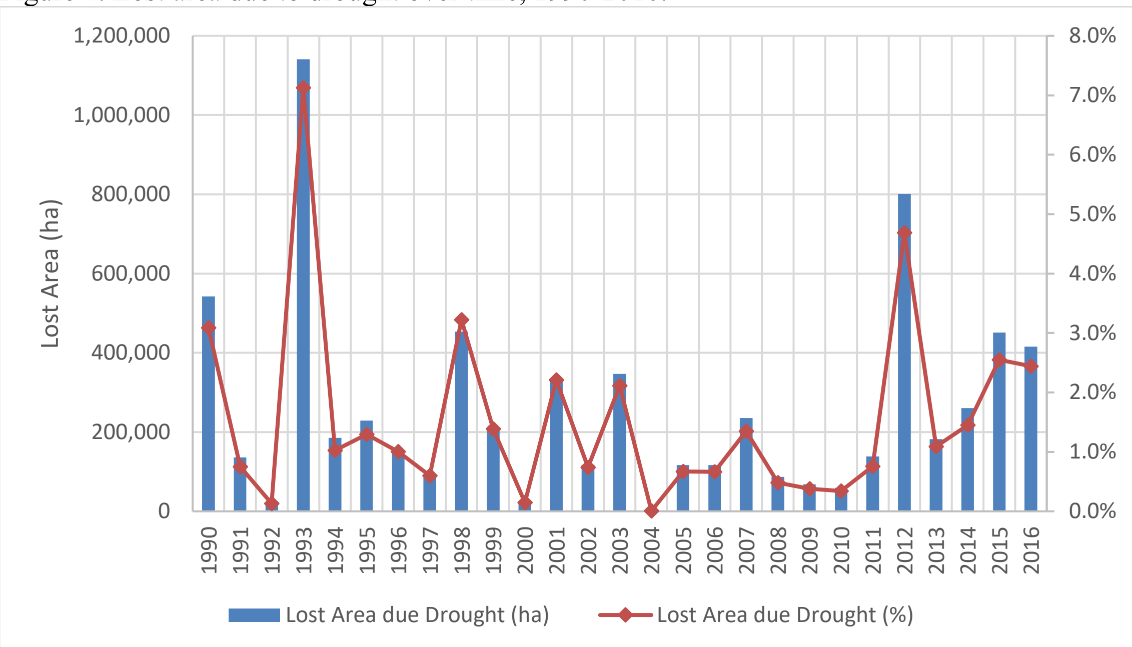
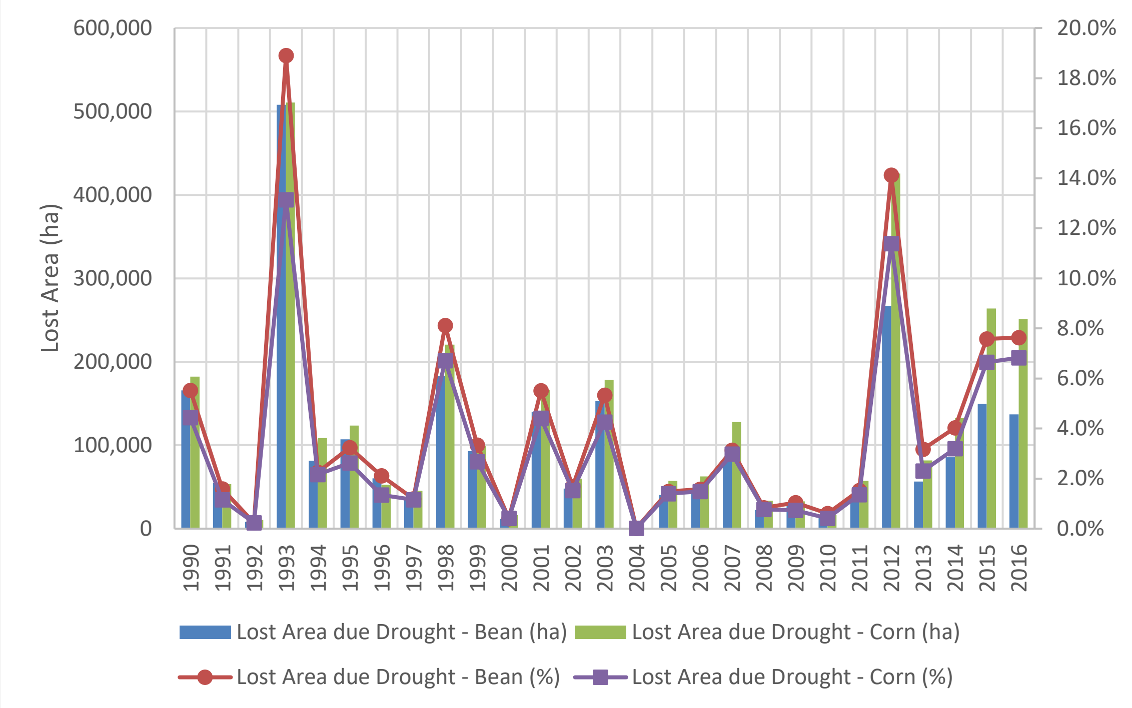


Figure 5 shows the absolute and relative losses of productive area only for bean and corn cultivation. The trends are similar to the total lost productive areas in Figure 4. However, it is clear that the percentage lost in the production of beans and corn is considerably higher than that observed in all other crops.

[325] Table II in the Appendix presents the number results.

Figure 5. Bean and corn area lost due to drought over time, 1990-2016.



Although 1993 was the year in which maximum losses were recorded, the figures suggest a relatively erratic pattern of the productive areas lost over the years up to 2012. However, since that year, there is a change in the pattern of the losses estimated by drought: the graphs suggest that the average area lost in this decade is relatively higher than in previous decades - even with the large losses observed in 1993.

~~This less erratic and more stationary pattern in recent years may indicate a more prolonged effect of droughts.~~ As pointed out by Marengo et al. (2017), analyzing the climatic characteristics of the 2010-2016 drought in the semiarid Northeast Brazil region:
“The analysis of this event using drought indicators as well as meteorological fields shows that since the middle 1990s to 2016, 16 out of 25 years experienced rainfall below normal. This suggests that the recent drought may have in fact started in the middle-late 1990s, with the intense droughts of 1993 and 1998, and then the sequence of dry years (interrupted by relatively wet years in 2007, 2008, 2009 and 2011) after that may have affected the levels of reservoirs in the region, leading to a real water crisis that was magnified by the negative rainfall anomalies since 2010.”

Table 23 shows ten-year averages of the relative lost areas of the last three decades. In addition to confirming that the present decade presents larger average losses, the table shows, again, that the increase of these losses has more intensity in the most typical crops used in family agriculture (bean and corn).

Table 23. Average lost area due to drought, by decade.

Decade	Lost Area due Drought (%)	Lost Area due Drought - Bean (%)	Lost Area due Drought - Corn (%)
1991-2000	1.7%	4.1%	3.2%
2001-2010	0.9%	2.1%	1.8%
2011-2016	2.2%	6.3%	5.3%

4.2. Losses of agricultural production value over time

The estimate of the value of agricultural output lost by drought consists of the product between the area lost by the drought, estimated in the previous sub-section, and the average value of the production per hectare harvested.

$$Lost\ Value\ due\ Drought_t = Lost\ Area\ due\ Drought_t * Average\ Agricultural\ Value_t$$

Figure 6 shows the losses of value of agricultural production during the last decades. Similar to the area lost by drought, the series shows an erratic behavior, with large variations, until 2012, when there is a more stable pattern of greater than the average losses due to drought.

Figure 6. Lost Agricultural Production Value due to drought over time, 1990-2016.

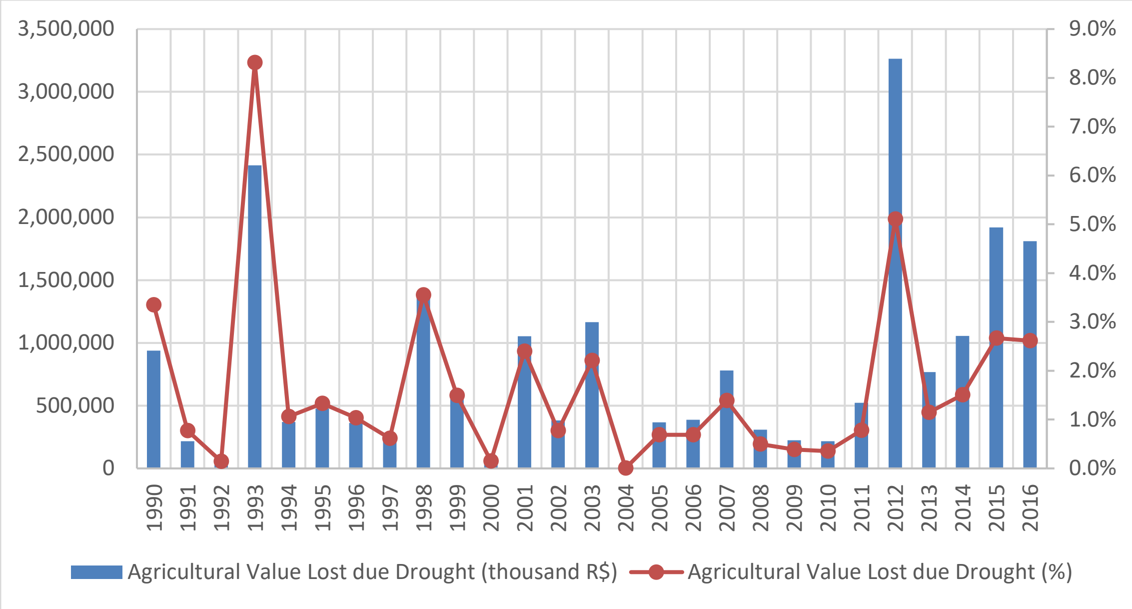


Figure 7 shows the losses in the production value of beans and corn only. The interpretation remains unchanged: the tendency of the curves is similar to the trend of Figure 6, although the percentage losses are much more pronounced.

Figure 7. Bean and corn production value lost due to drought over time, 1990-2016

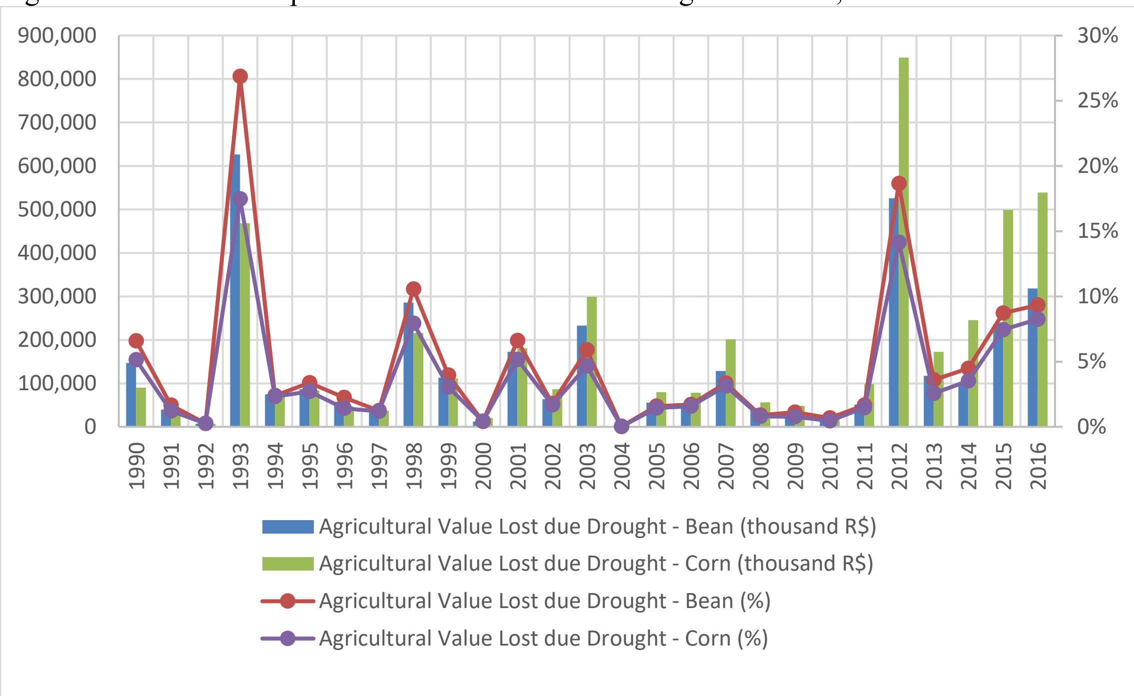


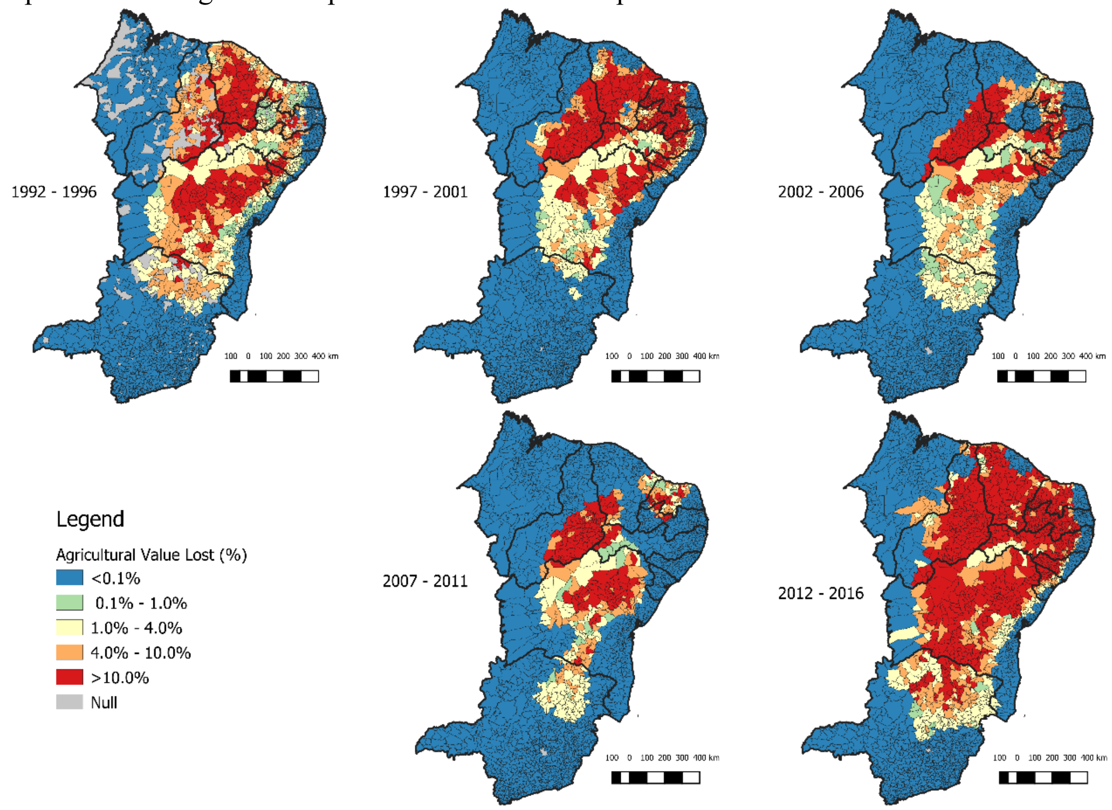
Table 24 shows the averages of the relative losses of the value of agricultural production per decade. It can be seen that, despite the large losses in 1993, the average of the present decade is higher, both for total agricultural production and for mostly family crops. Therefore, it is evident that losses in recent years are more persistent than in the previous years.

Table 24. Average agricultural production value lost due to drought, by decade.

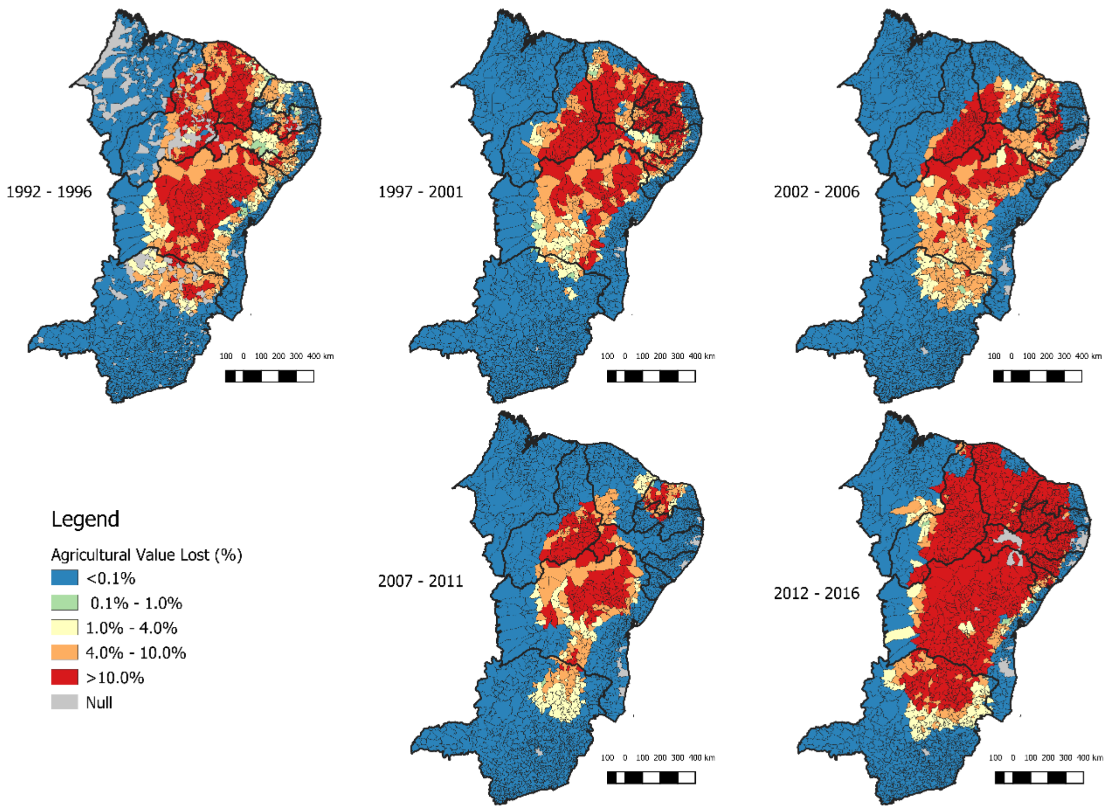
Decade	Lost Value due to Drought - Total agricultural production (% of the total)	Lost Value due Drought - Beans (% of the total)	Lost Value due Drough- Corn (% of the total)
1991-2000	1.8%	5.3%	3.8%
2001-2010	0.9%	2.4%	2.0%
2011-2016	2.3%	7.7%	6.2%

Maps 1 and 2 show the evolution of these losses over time in spatial terms, considering the average loss in agricultural production considering five-year averages.

Map 1. Value of agricultural production lost to all crops



Map 2. Value of lost agricultural production for beans and corn



The results indicate that municipalities in the semi-arid Caatinga suffered much more losses than the rest of Brazilian Northeast and Minas Gerais. Again, they confirm that bean and corn cultivation suffer more than the other crops.

Finally, it is evident that the drought effects since 2012 became much more severe, in accordance to the specialists that are already identifying a change in climate conditions in this region. According to Marengo (2008), the temperature in Brazil increased 0.7ºC in the 1958-2007 period, but in the Brazilian Northeast the maximum temperature increased between 1.5 and 2ºC in a similar period.

In a more recent paper, Marengo et al. (2017, p. 1196) considered that "regarding the historical simulation, it is possible to identify an increase of temperature from 1901 to 2000 of about 0.8 °C." They concluded that: "Future climate projections show temperature increases and rainfall reductions, and the tendency for increases in CDD (a measure of drought) suggests an increase in the tendency for greater frequency/intensity of dry spells and droughts and toward aridification in the region. All these conditions lead to an increase in evaporation in reservoirs and lakes, affecting irrigation and soil moisture and impacting agriculture and population." (Marengo et al., 2017, p. 1198)

Lacerda et al. (2017) also found an increasing trend in temperature and declining rainfall in a set of cities in the state of Pernambuco:
"The trend analysis of rainfall showed statistically significant negative values for all stations but Vitória and Caruaru, which showed non-significant trend values. The highest rainfall reductions were detected in Petrolina and Recife, with trend values exceeding -40 mm/decade. The station data trend analyses showed increased maximum temperatures over all stations and decreased rainfall over all stations but Vitória's. However, the minimum temperature trends showed both positive and negative values."
According to Cunningham et al. (2017, p.361), this is related to a global trend: "Possibly related to the warming climate, droughts have increased in frequency and intensity over most of the planet in recent decades (Dai et al., 2004; Marengo et al., 2008; Zhou et al., 2011). The percentage of area that was affected by droughts doubled from the 1970s to the early 2000s (Nagarajan, 2009)."

In order to calculate the economic dimension of this problem, the next subsection provides estimates of the losses in agricultural production due to climate change.

4.2. Economic costs of climate change

It is extremely difficult to define in quantitative terms the dimension of economic costs climate change, especially downscaling to the regional level of the Brazilian Semi-Arid. First of all, the literature (Machado Filho et al. 2016, Marengo et al. 2017, among others) there is a considerable uncertainty in the results from the models, since they present wide variation according to the different hypothesis and procedures in which they are based:

"Studies that assess the impacts of climate change, vulnerability and adaptation need a more localised approach (INPE 2015). Nevertheless, despite the improvements since the release of the AR4 in 2007, regional-scale simulations of temperature changes and precipitation patterns are less precise than those on large scales (IPCC 2013)." (Machado Filho et al 2016, p. 3)
Moreover, rainfall in the Brazilian Semi-Arid is known for its wide variability in both spatial and time dimensions (Marengo 2007, p. 1). There is also a problem concerning the lack of information on socioeconomic variables associated with the consequences of droughts. For example, economic data for agriculture is presented in aggregate terms, without much details in terms of the social conditions of the production process.

Nevertheless, there is relatively stable set of papers forecasting future deviations in temperature and precipitation due to climate change (table 23). In general terms, in they range from an increase in temperature between 1.5ºC and 4ºC, and a reduction in precipitation between 10% and 20% (table 23).

Table 25. Forecasts of climate change in the Brazilian Northeast

Paper	Model	Temperature	Precipitation
Marengo et al. (2007)	HadAM3 B2 "optimistic"	More 1-3ºC	Less 10-15% of the average
Marengo et al. (2007)	HadAM3 A2"pessimistic"	More 2-4ºC	Less 15-20% of the average
Lacerda et al. (2015)	Same as Marengo et al. (2007)	More 1-3ºC	Less 1-2 mm/day, or 10-15% of the average
Lacerda et al. (2015)	Same as Marengo et al. (2007)	More 2-4ºC	Less 2-4 mm/day, or 15-20% of the average
Machado Filho et al. (2016)	RCP4.5	More 0.5–2ºC	Less 10-20% of the average
Machado Filho et al. (2016)	RCP8.5	More 0.5–2ºC	Less 10-20% of the average, but -20% is more likely

Considering these forecasts, we projected two alternative scenarios considering precipitation reduction due to climate change: a moderate reduction of 10% ("optimistic"), and a strong reduction in 20% of average precipitation ("pessimistic").

Then, we projected changes in output assuming that *ceteris paribus* all remaining production conditions (productivity, cultivation area, relative prices, etc.) remain the same as in the average of the 1990-2016 period. The annual average lost area for total crops due to droughts in the 1990-2016 period was 221,973 hectares (89,497 hectares for bean and 10,276 for corn). In the scenario of less 10% of precipitation, considering a proportional reduction, the total cultivated area lost because of climate change would be 22,197 hectares (8,950 for bean and 10,276 for corn). This would represent an average annual loss of R$ 96.7 million in agriculture production value (R$ 20.8 million for bean and R$ 22.1 million for corn). In the 20% rainfall reduction scenario, these losses increase to 44,395 hectares (17,899 for bean and 20,552 for corn), and an average annual loss of R$ 193.3 million in agriculture production value (R$ 41.5 million for bean and R$ 44.1 million for corn).

Table 26. Average lost per year in agricultural production value due to climate change

	Average Lost Area due Drought - 1990-2016 (ha)	Average Lost Area due to Climate Change - 10% (ha)	Average Lost Area due to Climate Change - 20% (ha)	Average Agricultural Value Lost due to Climate Change - 10% (thousand R$)	Average Agricultural Value Lost due to Climate Change - 20% (thousand R$)
Bean	89,497	8,950	17,899	20,763	41,526
Corn	102,761	10,276	20,552	22,062	44,124
Total	221,973	22,197	44,395	96,662	193,324

If projected to the 2017-2030 period, *ceteris paribus*, this would represent an accumulated loss between R$ 1.4 to 2.7 billion (current values), about half of this concentrated in the two crops mostly identified with family agriculture, bean and corn (table 27). If the period is extended to 2017-2050, the accumulated losses increase to R$ 3.3 to R$ 6.6 billion (current values).

Table 27. Accumulated loss in agricultural production value due to climate change, 2017-2030 and 2017-2050 periods

	2017-2030		2017-2050	
Crop	Total Agricultural Value Lost due to Climate Change - 10% (thousand R$)	Total Agricultural Value Lost due to Climate Change - 20% (thousand R$)	Total Agricultural Value Lost due to Climate Change - 10% (thousand R$)	Total Agricultural Value Lost due to Climate Change - 20% (thousand R$)
Bean	290.685	581.371	705.950	1.411.900
Corn	308.867	617.734	750.106	1.500.212
Total	1.353.269	2.706.538	3.286.510	6.573.020

Note these are underestimates of the total costs of climate change, since they do not consider livestock and other agriculture activities. Also, there is an implicit assumption that costs are proportional to the reduction in average rainfall. However, there are possible discontinuities in this relationship, and losses are very likely to be more than proportional to the reduction in rainfall.

5. Conclusion

The results of our statistical analysis considering the effects of droughts, either measured by the occurrence of climatic disasters (droughts and dry spells) or very low levels of precipitation, in the agricultural production (cultivation and livestock) in the Brazilian drylands of the Northeastern Region and Minas Gerais.

We showed that:

- There is a significant correlation between climatic disasters (droughts) X average precipitation, so we can use both as proxies for climate change;
- There is a significant correlation between climatic disasters (droughts) or average precipitation X agricultural production (crops cultivation or livestock, the effect is higher on cultivation);
- There is a significant correlation between climatic disasters (droughts) or average precipitation X agricultural production of specific products related to family/subsistence farming (beans and corn), and this effect is higher than in the average agricultural production.

We considered many different ways of testing the hypothesis that droughts reduce either the productive area and output, and all of them were robust in terms of statistically significant results. However, we believe that the exercises which presented the best fit were based on the use of rainfall categories, rather than the occurrence of extreme drought events. On the other hand, there are pros and cons using the results based on municipalities and micro-regions, and we suggest to present results expressed in both terms.
We projected two alternative scenarios considering precipitation reduction due to climate change: a moderate reduction of 10% (”optimistic”), and a strong reduction in 20% of average precipitation (“pessimistic”). The annual average lost area for total crops due to droughts in the 1990-2016 period was 221,973 hectares (89,497 hectares for bean and 10,276 for corn). In the scenario of less 10% of precipitation, considering a proportional reduction, the total cultivated area lost because of climate change would be 22,197 hectares (8,950 for bean and 10,276 for corn). This would represent an average annual loss of R$ 96.7 million in agriculture production value (R$ 20.8 million for bean and R$ 22.1 million for corn). In the 20% rainfall reduction scenario, these losses increase to 44,395 hectares (17,899 for bean and 20,552 for corn), and an average annual loss of R$ 193.3 million in agriculture production value (R$ 41.5 million for bean and R$ 44.1 million for corn).
Considering the 2017-2030 period, this would represent an accumulated loss between R$ 1.4 to 2.7 billion, and in the 2017-2050, the accumulated losses increase to R$ 3.3 to R$ 6.6 billion.
It is important to highlight that these exercises underestimate the total costs of climate change, since they do not consider livestock and other agriculture activities. Also, there is an implicit assumption that costs are proportional to the reduction in average rainfall. However, there are possible discontinuities in this relationship, and losses are very likely to be more than proportional to the reduction in rainfall.

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Vulnerabilidade, impactos e adaptação à mudança do clima no semi-árido do Brasil. Jose A. Marengo, 2008. Optimist scenario: average rainfall reduction between 10-15% (less 1-2 mm/day), pessimist scenario: average rainfall reduction between 15-20% (less 2-4 mm/day),

Possíveis impactos da mudança de clima no Nordeste. Jose A. Marengo. 2007. Rainfall reduction in the range between 10% and 15%.

Appendix

Table A. I. Number of municipalities in each precipitation category by year, 1981-2016.

Year	Precipitation (1)	Precipitation (2)	Precipitation (3)	Precipitation (4)	Total
1981	517	695	792	92	2,096
1982	523	637	816	120	2,096
1983	678	694	651	79	2,102
1984	613	1,177	315	-	2,105
1985	1,786	320	-	-	2,106
1986	1,101	628	417	-	2,146
1987	875	811	461	-	2,147
1988	884	1,127	135	-	2,146
1989	1,497	682	-	1	2,180
1990	472	1,155	601	-	2,228
1991	1,330	815	83	1	2,229
1992	1,491	726	11	-	2,228
1993	367	880	674	384	2,305
1994	1,210	929	170	-	2,309
1995	1,052	976	282	-	2,310
1996	916	1,188	207	-	2,311
1997	1,079	1,341	214	-	2,634
1998	683	1,117	681	151	2,632
1999	847	1,373	411	1	2,632
2000	1,667	934	28	-	2,629
2001	914	1,148	569	4	2,635
2002	1,170	1,323	141	-	2,634
2003	993	1,035	606	-	2,634
2004	1,565	1,067	2	-	2,634
2005	1,338	1,092	205	-	2,635
2006	1,295	1,228	110	-	2,633
2007	816	1,454	362	-	2,632
2008	1,373	1,183	76	-	2,632
2009	1,742	826	67	-	2,635
2010	1,017	1,454	164	-	2,635
2011	1,685	800	150	1	2,636
2012	615	873	774	375	2,637
2013	1,255	891	490	-	2,636
2014	437	1,682	517	-	2,636
2015	590	1,039	988	15	2,632
2016	815	946	822	52	2,635
Total	37,208	36,246	12,992	1,276	87,722

Table A.II. Productive area and lost area due to drought by year, 1990-2016.

Year	Productive Area (ha)	Lost Area due Drought (ha)	Lost Area due Drought (%)
1990	17,574,873	542,312	3.1%
1991	18,097,613	136,071	0.8%
1992	18,130,928	24,086	0.1%
1993	16,004,964	1,140,912	7.1%
1994	18,107,040	185,363	1.0%
1995	17,719,902	229,011	1.3%
1996	14,552,851	146,033	1.0%
1997	15,167,092	90,710	0.6%
1998	14,083,041	453,495	3.2%
1999	14,897,146	206,804	1.4%
2000	15,586,060	23,263	0.1%
2001	15,160,835	335,197	2.2%
2002	15,962,789	117,840	0.7%
2003	16,424,362	347,260	2.1%
2004	17,417,494	1,159	0.0%
2005	17,411,154	116,574	0.7%
2006	17,578,387	116,578	0.7%
2007	17,457,318	235,128	1.3%
2008	18,021,888	86,655	0.5%
2009	17,964,019	67,807	0.4%
2010	17,275,892	59,167	0.3%
2011	18,271,084	138,194	0.8%
2012	17,084,280	800,956	4.7%
2013	16,736,006	182,462	1.1%
2014	17,967,790	260,318	1.4%
2015	17,674,195	450,974	2.6%
2016	17,011,817	415,463	2.4%

Table A.III. Bean and corn productive area and lost area due to drought by year, 1990-2016.

Year	Productive Area - Bean (ha)	Lost Area due Drought - Bean (ha)	Lost Area due Drought -Bean (%)	Productive Area - Corn (ha)	Lost Area due Drought - Corn (ha)	Lost Area due Drought - Corn (%)
1990	2,999,158	165,587	5.5%	4,101,663	182,197	4.4%
1991	3,443,058	54,542	1.6%	4,640,237	53,553	1.2%
1992	3,406,149	8,032	0.2%	4,548,737	10,450	0.2%
1993	2,687,020	507,891	18.9%	3,887,952	510,627	13.1%
1994	3,605,785	81,335	2.3%	5,024,418	108,526	2.2%
1995	3,311,408	107,148	3.2%	4,706,780	123,697	2.6%
1996	2,851,546	60,418	2.1%	3,879,071	52,462	1.4%
1997	2,884,767	34,565	1.2%	3,932,769	45,339	1.2%
1998	2,255,166	183,035	8.1%	3,284,363	220,460	6.7%
1999	2,779,858	92,847	3.3%	3,728,348	99,516	2.7%
2000	2,867,684	11,504	0.4%	3,854,552	16,145	0.4%
2001	2,539,780	139,873	5.5%	3,770,889	166,579	4.4%
2002	2,872,456	48,160	1.7%	3,925,926	60,040	1.5%
2003	2,867,646	153,081	5.3%	4,183,921	178,405	4.3%
2004	2,933,776	692	0.0%	4,281,227	484	0.0%
2005	2,721,467	40,346	1.5%	4,104,175	57,139	1.4%
2006	2,776,063	43,886	1.6%	4,199,226	62,609	1.5%
2007	2,597,872	81,537	3.1%	4,283,178	127,643	3.0%
2008	2,681,862	22,333	0.8%	4,339,924	33,363	0.8%
2009	2,738,344	28,431	1.0%	4,415,170	32,606	0.7%
2010	2,341,601	14,189	0.6%	3,863,533	16,138	0.4%
2011	2,535,372	38,512	1.5%	4,211,980	57,207	1.4%
2012	1,890,351	266,868	14.1%	3,734,783	425,419	11.4%
2013	1,780,029	56,499	3.2%	3,550,285	81,884	2.3%
2014	2,126,658	85,654	4.0%	4,145,317	132,554	3.2%
2015	1,975,571	149,792	7.6%	3,969,420	263,819	6.6%
2016	1,795,881	137,107	7.6%	3,678,403	251,110	6.8%

Table A.IV. Agricultural production value per hectare by year, 1990-2016.

Year	Average Agricultural Value (thousand R$/hectare)	Average Agricultural Value - Bean (thousand R$/hectare)	Average Agricultural Value - Corn (thousand R$/hectare)
1990	1.732	0.887	0.495
1991	1.590	0.722	0.643
1992	1.725	0.838	0.682
1993	2.117	1.234	0.917
1994	1.988	0.922	0.634
1995	2.084	0.807	0.674
1996	2.485	0.959	0.886
1997	2.465	0.963	0.826
1998	3.036	1.560	0.980
1999	2.968	1.216	1.120
2000	2.759	1.048	1.245
2001	3.139	1.232	1.086
2002	3.236	1.320	1.444
2003	3.357	1.521	1.676
2004	3.245	1.054	1.313
2005	3.139	1.372	1.402
2006	3.317	1.239	1.254
2007	3.314	1.574	1.576
2008	3.546	1.922	1.697
2009	3.322	1.082	1.479
2010	3.683	1.526	1.547
2011	3.783	1.319	1.712
2012	4.075	1.970	1.997
2013	4.200	2.073	2.107
2014	4.051	1.142	1.852
2015	4.259	1.574	1.892
2016	4.355	2.320	2.147

Table A.V. Agricultural production value and agricultural value lost due to drought by year, 1990-2016.

Year	Agricultural Production Value (thousand R$)	Agricultural Value Lost due Drought (thousand R$)	Agricultural Value Lost due Drought (%)
1990	28,029,820	939,226.44	3.4%
1991	27,979,262	216,375.74	0.8%
1992	29,481,472	41,558.80	0.1%
1993	29,045,514	2,415,216.85	8.3%
1994	34,617,424	368,529.38	1.1%
1995	35,923,337	477,236.36	1.3%
1996	34,973,004	362,903.71	1.0%
1997	36,401,370	223,559.23	0.6%
1998	38,767,027	1,376,960.92	3.6%
1999	40,981,977	613,734.29	1.5%
2000	42,100,879	64,191.09	0.2%
2001	43,860,936	1,052,055.57	2.4%
2002	49,113,476	381,310.29	0.8%
2003	52,801,465	1,165,797.55	2.2%
2004	54,150,259	3,759.37	0.0%
2005	53,306,545	365,981.83	0.7%
2006	55,963,131	386,670.38	0.7%
2007	56,149,641	779,190.84	1.4%
2008	61,582,549	307,310.23	0.5%
2009	57,922,612	225,230.88	0.4%
2010	61,728,666	217,898.36	0.4%
2011	67,134,210	522,734.91	0.8%
2012	63,882,883	3,264,085.01	5.1%
2013	66,924,762	766,262.63	1.1%
2014	69,875,914	1,054,494.72	1.5%
2015	71,901,395	1,920,863.90	2.7%
2016	69,212,324	1,809,210.03	2.6%

Table A.VI. Bean production value and bean production value lost due to droght by year, 1990-2016.

Year	Agricultural Production Value - Bean (thousand R$)	Agricultural Value Lost due Drought - Bean (thousand R$)	Agricultural Value Lost due Drought - Bean (%)
1990	2,233,420	146,869	6.6%
1991	2,364,998	39,367	1.7%
1992	2,550,506	6,728	0.3%
1993	2,333,435	626,833	26.9%
1994	3,134,202	74,964	2.4%
1995	2,564,685	86,522	3.4%
1996	2,588,495	57,960	2.2%
1997	2,690,800	33,280	1.2%
1998	2,704,090	285,534	10.6%
1999	2,855,870	112,908	4.0%
2000	2,927,078	12,062	0.4%
2001	2,608,247	172,354	6.6%
2002	3,574,691	63,570	1.8%
2003	3,951,530	232,857	5.9%
2004	2,761,753	730	0.0%
2005	3,470,901	55,360	1.6%
2006	3,195,950	54,356	1.7%
2007	3,839,373	128,365	3.3%
2008	4,831,021	42,921	0.9%
2009	2,782,875	30,768	1.1%
2010	3,247,831	21,656	0.7%
2011	3,048,168	50,814	1.7%
2012	2,817,063	525,722	18.7%
2013	3,252,828	117,102	3.6%
2014	2,189,672	97,794	4.5%
2015	2,702,781	235,845	8.7%
2016	3,412,630	318,089	9.3%

Table A.VII. Corn production value and corn production value lost due to droght by year, 1990-2016.

Year	Agricultural Production Value - Corn (thousand R$)	Agricultural Value Lost due Drought - Corn (thousand R$)	Agricultural Value Lost due Drought - Corn (%)
1990	1,756,847	90,171	5.1%
1991	2,834,715	34,414	1.2%
1992	2,793,135	7,126	0.3%
1993	2,682,522	468,457	17.5%
1994	2,975,459	68,805	2.3%
1995	3,068,906	83,433	2.7%
1996	3,289,093	46,474	1.4%
1997	3,141,505	37,435	1.2%
1998	2,724,085	216,048	7.9%
1999	3,655,022	111,486	3.1%
2000	4,675,729	20,095	0.4%
2001	3,504,554	180,925	5.2%
2002	5,143,169	86,696	1.7%
2003	6,388,426	299,038	4.7%
2004	5,215,808	635	0.0%
2005	5,564,965	80,112	1.4%
2006	4,950,555	78,484	1.6%
2007	6,450,733	201,207	3.1%
2008	6,998,273	56,611	0.8%
2009	6,171,373	48,238	0.8%
2010	5,575,929	24,965	0.4%
2011	6,740,110	97,938	1.5%
2012	6,007,091	849,456	14.1%
2013	6,712,824	172,526	2.6%
2014	6,980,796	245,517	3.5%
2015	6,716,446	499,172	7.4%
2016	6,529,842	539,114	8.3%