Climate change and impacts on family farming in North and Northeast of Brazil

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CLIMATE CHANGE AND IMPACTS ON FAMILY FARMING IN THE NORTH AND NORTHEAST OF BRAZIL

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The starting point for this study was the consideration of future climate change scenarios and their uncertainties. The paper presents the global projections from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) and compares them with regional scenarios (downscaling) developed by the Brazilian National Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais*—INPE), with a focus on two main IPCC scenarios (RCP4.5 and RCP8.5) and two main global models (MIROC and Hadley Centre) for the periods 2011–2040 and 2041–2070. It aims to identify the main trends in terms of changes in temperature and precipitation for the North and Northeast regions of Brazil (more specifically, in the Amazon, semi-arid and cerrado biomes).

In assessing the possible climate change scenarios and related impacts on family farming across Brazil's North and Northeast regions, the main conclusion is that smallholder farmers will have to adapt to a world of increasing climate variability. Despite the lack of literature and more refined studies in Brazil, the paper attempts to present an overview of potential climate change impacts for a specific list of existing crops that are significant for family farming in the North and Northeast of Brazil. Despite the negative future scenarios for many of the crops assessed, the study indicates that with early planning and innovative techniques, it is possible to reduce vulnerabilities and increase resilience, now and in the future.

The study assesses current problems affecting family rural producers in the selected regions—through the lens of the three dimensions of sustainable development: social, economic, and environmental—which could be intensified with climate change and/or extreme weather events, and indicates potential options for family farming to respond to the adverse impacts of climate change, including techniques and technologies.

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Among the options, the study highlights that by means of agro-ecological and other sustainable approaches to agriculture, smallholder and small-scale family farmers could play an important role in offsetting elements of the present environmental crisis, as well as of those related to the threat of climate change.

As far as governance is concerned, regarding the existing institutions and public policies in the context of climate change in Brazil, it was found that the space for issues related to agriculture is quite limited, especially for family farming. Thus, to ensure that the interests of the sector are reflected in potential policies and regulations, including fundraising, the increased awareness and participation of the stakeholders in this sector are fundamental. Mindsets need to change, so that investments can be channelled to people in rural areas, who happen to be the poorest and most vulnerable, to reduce inequalities, especially by fighting poverty and ending hunger and malnutrition.

1 GLOBAL CLIMATE MODELS AND DOWNSCALING SCENARIOS FOR THE NORTH AND NORTHEAST OF BRAZIL

Anthropogenic greenhouse gas (GHG) emissions have increased since the pre-industrial era, largely driven by economic and population growth, and are now higher than ever. Between 1750 and 2013, carbon dioxide (CO_2) concentration rose from 280 parts per million (ppm) to 400 ppm. Consequently, the last three decades have been warmer than any previous decade since 1850, while land and ocean surface temperatures combined increased around 0.85ºC between 1880 and 2012 (IPCC 2013).

If the current trend of GHG emissions continues, it will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts on people and ecosystems. Thus, limiting climate change would require substantial and sustained reductions in GHG emissions—itigation—which, together with adaptation, can limit climate change risks.

To maintain temperature increases below the 2°C target, considered a level that would prevent dangerous anthropogenic interference with the climate system,[2] there is a general understanding that concentrations ought to be stabilised between 450 and 550 ppm CO_2 equivalent relative to pre-industrial levels. The higher global emissions peak, the greater the cut in emissions needed.

To provide guidance for adaptation and mitigation policies, several scenarios aim to predict future alterations to the global climate. However, those scenarios have limitations due to uncertainties, such as emissions pathways, feedback loops and non-linear systemic consequences of increasing global average temperatures.

For its Fifth Assessment Report—AR5 (2013)—the Intergovernmental Panel on Climate Change (IPCC) selected four Representative Concentration Pathways (RCPs) on which to base its scenarios. RCPs present different pathways for total radiative forcing[3] by 2100, and are identified by their total radiative forcing levels: RCP2.6 = 2.6 W/m^2, RCP4.5 = 4.5 W/m^2, RCP6.0 = 6.0 W/m^2, and RCP8.5 = 8.5 W/m^2. Each RCP reflects different pathways for GHG emissions, from a mitigation scenario (RCP 2.6) to a high-emission scenario (RCP8.5). There are also two in-between stabilisation pathways: the RCP4.5, which estimates stabilisation of GHG by 2100; and the RCP6.0, which considers that radiative forcing will peak after 2100.

By the end of the 21st century, global surface temperature change[4] is expected to exceed 1.5°C for all RCP scenarios, with the exception of RCP2.6 (low-emission scenario: 1.0ºC); therefore, likely or more likely than not to exceed 2°C for all higher-emission scenarios: 1.8ºC for RCP4.5, 2.2ºC for RCP6.0, and 3.7 ºC for RCP8.5. This warming is also projected to continue beyond 2100 under all scenarios but RCP2.6 (IPCC 2013a). However, it is hard to determine future emissions pathways.

In the Fourth Assessment Report (AR4), released in 2007, the IPCC used another technique to present its scenarios, known as Special Report on Emissions Scenarios (SRES). SRES scenarios consider different pathways for GHG and aerosol concentrations, based on social and economic assumptions, such as population growth and technological change over time. The SRES approach comprises four main scenario families: (1) A1: rapid and globalised economic growth with population growth peaking by mid-century; (2) A2: regionally focused economic growth with high population growth; (3) B1: same population as A1, but with higher technological improvements; and (4) B2: a focus on local solutions, lower economic growth and an increasing population (IPCC 2014).

In a brief attempt to compare the scenarios from AR4 and AR5, it could be pointed out that the radiative forcing of the RCP8.5 scenario of AR5 resembles the radiative forcing of the A2 scenario of AR4; the A1B lies between RCP8.5 and RCP6.0; and RCP4.5 approaches the B1 scenario of AR4, toward the end of the 21st century.

Climate change scenario projections for the 21st century have been derived from the global climate models used by the IPCC. Despite their importance, they may not provide adequate information for developing public policies, given that global scenarios are based on time-frames larger than those needed for policymaking, and global scenarios have spatial scales that are much larger than those needed to understand the impacts at local level (Baethgen 2010).

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).

The Brazilian National Institute for Space Research (INPE) has been evaluating the different climate change scenarios proposed by the global coupled models of the IPCC AR4 and AR5 and has been developing downscaling[5] methods for Brazil, which are applied to climate change projections from regional climate change models to obtain more detailed climate projections, with improved spatial resolution from regional models. These projections can be used in studies of climate change impacts on several socio-economic sectors (agriculture, energy, health, water resources etc.), indicating vulnerability to risks in the form of probabilities.

For this purpose, INPE has developed the Eta-CPTEC regional climate model (RCM) for South America, which is run on supercomputers, given the need for huge processing in real time. The initial results of the RCM derived from the global climate model by the Hadley Centre (UK) were made available in 2007. More recently, Eta RCM simulations driven by three global models—HadGEM2-ES, BESM and MIROC5—were used for assessing climate change projections in South America, Central America and the Caribbean, with a resolution of 20 km.

In addition, four sets of downscaling simulations based on the Eta RCM forced by two global climate models, the HadGEM2-ES and the MIROC5 (which have shown more consistent results), and two RCP scenarios (4.5 and 8.5) have been carried out to assess the climate change over South America based on the Eta simulations. The future changes were assessed in 30-year periods: 2011–2040, 2041–2070 and 2071–2100.

This section will assess two main IPCC scenarios (RCP4.5 and RCP8.5) and downscaling scenarios for the North and Northeast regions of Brazil, which are the focus areas of the study, based on two main global models (MIROC and Hadley Centre) for 2011–2040 and 2041–2070.

IPCC global scenarios (RCP4.5 and RCP8.5) suggested a warming of 0.5–2°C for the North and Northeast regions of Brazil between 2016 and 2035. For a similar time-frame (2011–2040), downscaling scenarios using the Eta RCM show a similar range of temperature increase using RCP4.5 assumptions: 0.5–1.5°C. However, it is possible to highlight local differences, such as, for example, the fact that the coastal areas are expected to be affected less than the interior. This is of particular concern, given that the Northeast's interior is already becoming drier. It is also the area where family farming is concentrated and already faces more challenges regarding poverty eradication. Similar trends can be observed in downscaling projections based on RCP8.5 scenarios: 0.5–2.0°C.

Between 2041 and 2070, climate change impacts in the region are projected to be greater, but within a range of temperature increase that is similar to the IPCC projections. For the RCP4.5 downscaling scenario, changes are smaller during winter (JJA) and larger during autumn (MAM) and spring (SON). Differences are also larger for the maximum temperature levels both in the RCP4.5 and RCP8.5 downscaling scenarios. Estimates made by INPE for the RCP8.5 downscaling scenarios show a small increase in the maximum temperature change compared with global scenarios used by the IPCC, up to an increase of 4.5°C. Similarly to RCP4.5, RCP8.5 downscaling projections also show larger temperature increases in the interior of the region.

Figures 1 to 5 address two time periods (2011–2040 and 2041–2070), which are the most relevant for this study, since it focuses on the expected changes in temperature and precipitation patterns across Brazil's North and Northeast regions over the next 50 years. The information is presented in such a way that interannual variations in every quarter of the year can be observed (data for December, January and February (DJF); March, April and May (MAM); June, July and Auggust (JJA); and September, October and November (SON)), with particular relevance for crop yields.

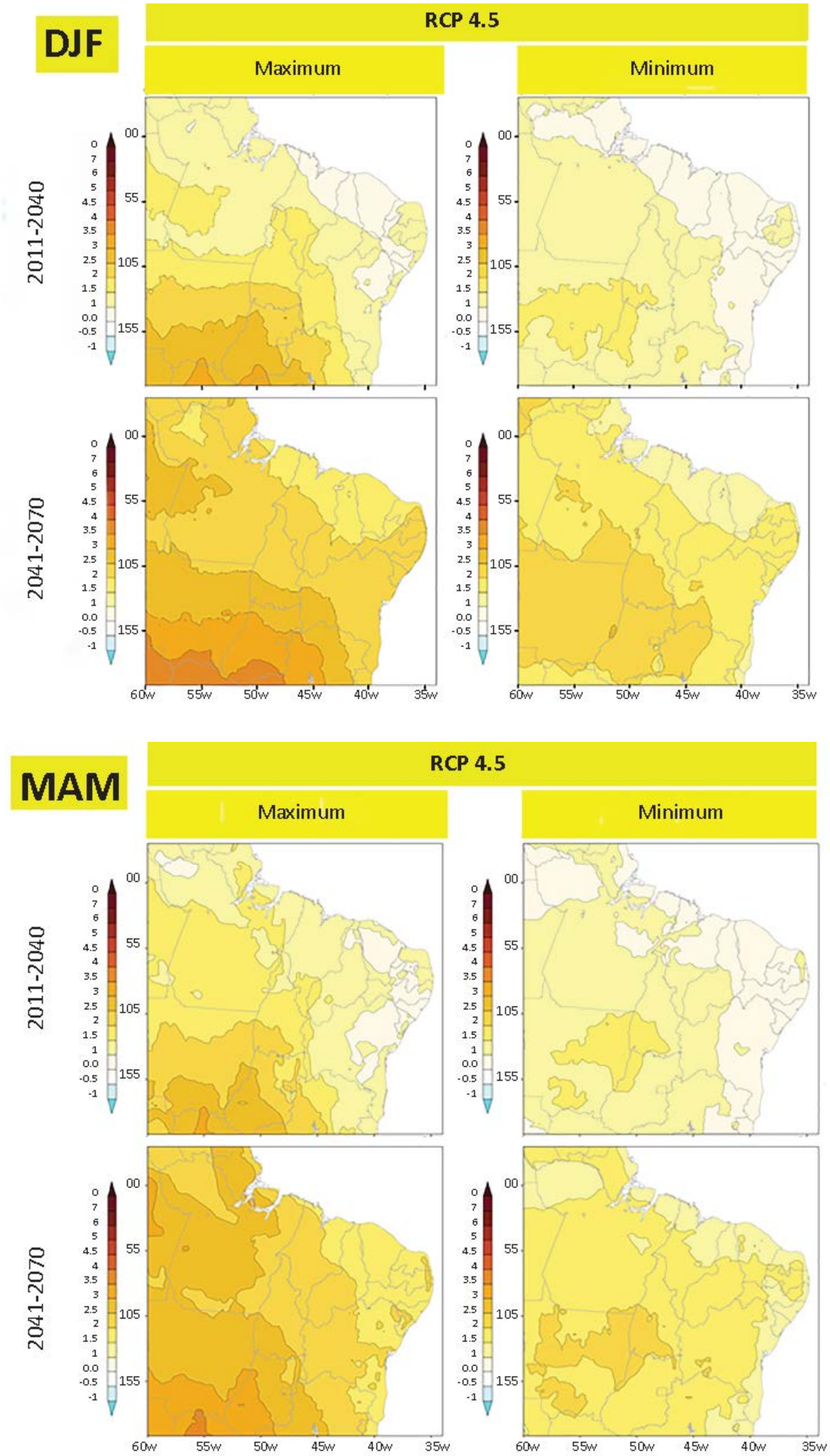
It is worth mentioning that the figures have been prepared especially for this study by INPE,[6] with an emphasis on Brazil's North (in particular, the states of Pará) and Northeast regions.

Rainfall projections in general are even less certain than those for temperature increases. RCP4.5 estimates a change of -10 to 20 per cent in rainfall patterns between 2016 and 2035 for the North and Northeast regions of Brazil, and a similar range of change (-20 to 20 per cent), with a slightly different spatial distribution for 2046–2065. The presence of 'hatching' areas shows that changes are relatively small if compared with existing variability, with variability among models higher than normal (INPE 2015). RCP8.5 estimates have the same range of change in rainfall patterns as RCP4.5, but a change of -20 per cent would be more likely (25 per cent multi-model distribution).

For rainfall patterns, downscaling scenarios provide more detail than global models. It is possible to see different patterns for specific regions and compare them with current trends. For example, in the north of the Brazilian Northeast region, the rainy season occurs during February, March, April and May (FMAM), and the downscaling projections for MAM show reductions in rainfall patterns, together with more rainfall during the summer (DJF). The southern part of Bahia experiences more rainfall during summer (DJF), and the downscaling scenarios show a reduction in rainfall for that region during its rainy season. Finally, the Northeast's east coast rainy season happens during winter (JJA), and no major changes are shown in the downscaling scenarios. Reductions in rainfall during the rainy seasons, as predicted in the two first cases, are of particularly concern if not offset by rainfall at other times of the year.

FIGURE 1

Maximum and minimum temperatures (four seasons):
ET HADGEM2-ES, Eta HADGEM2-ES and Eta MIROC5 scenarios downscaling RCP4.5



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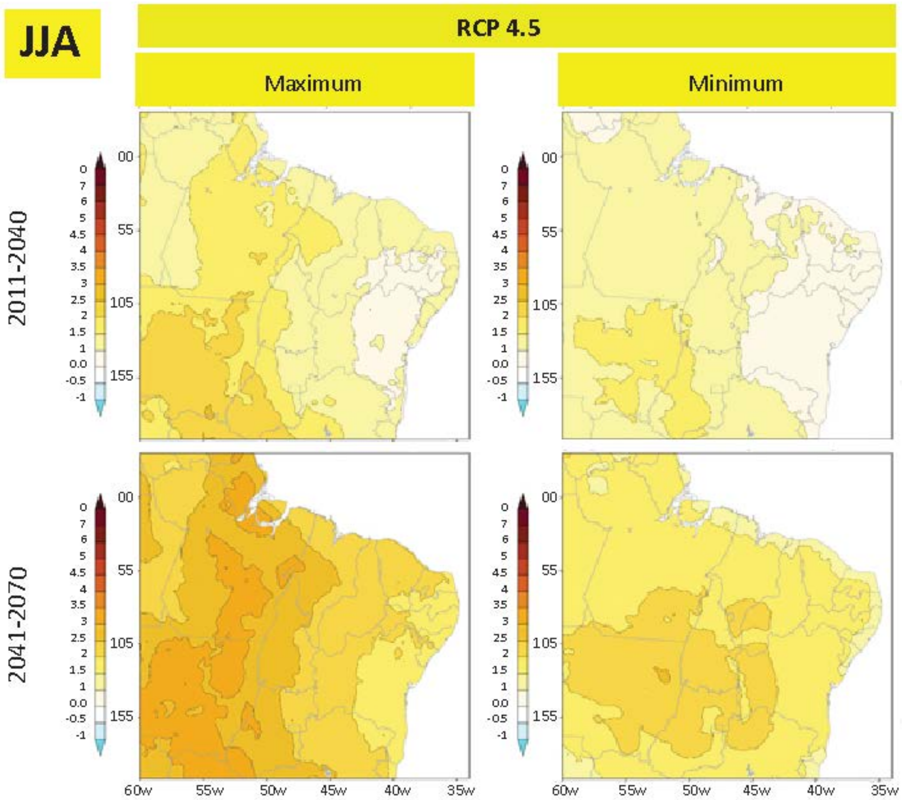
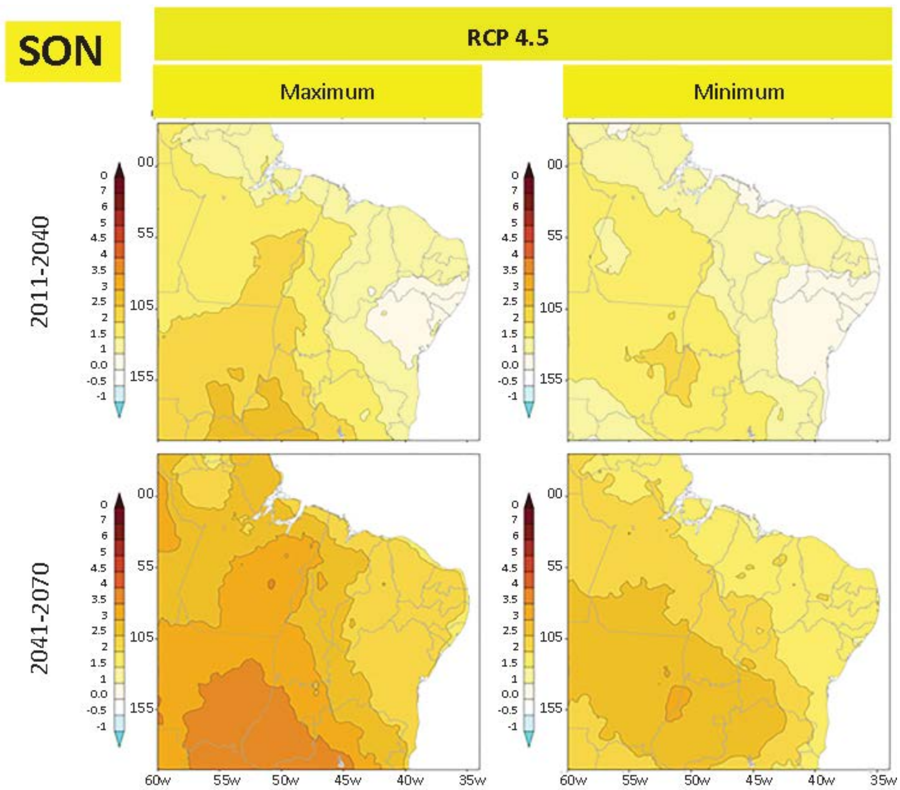
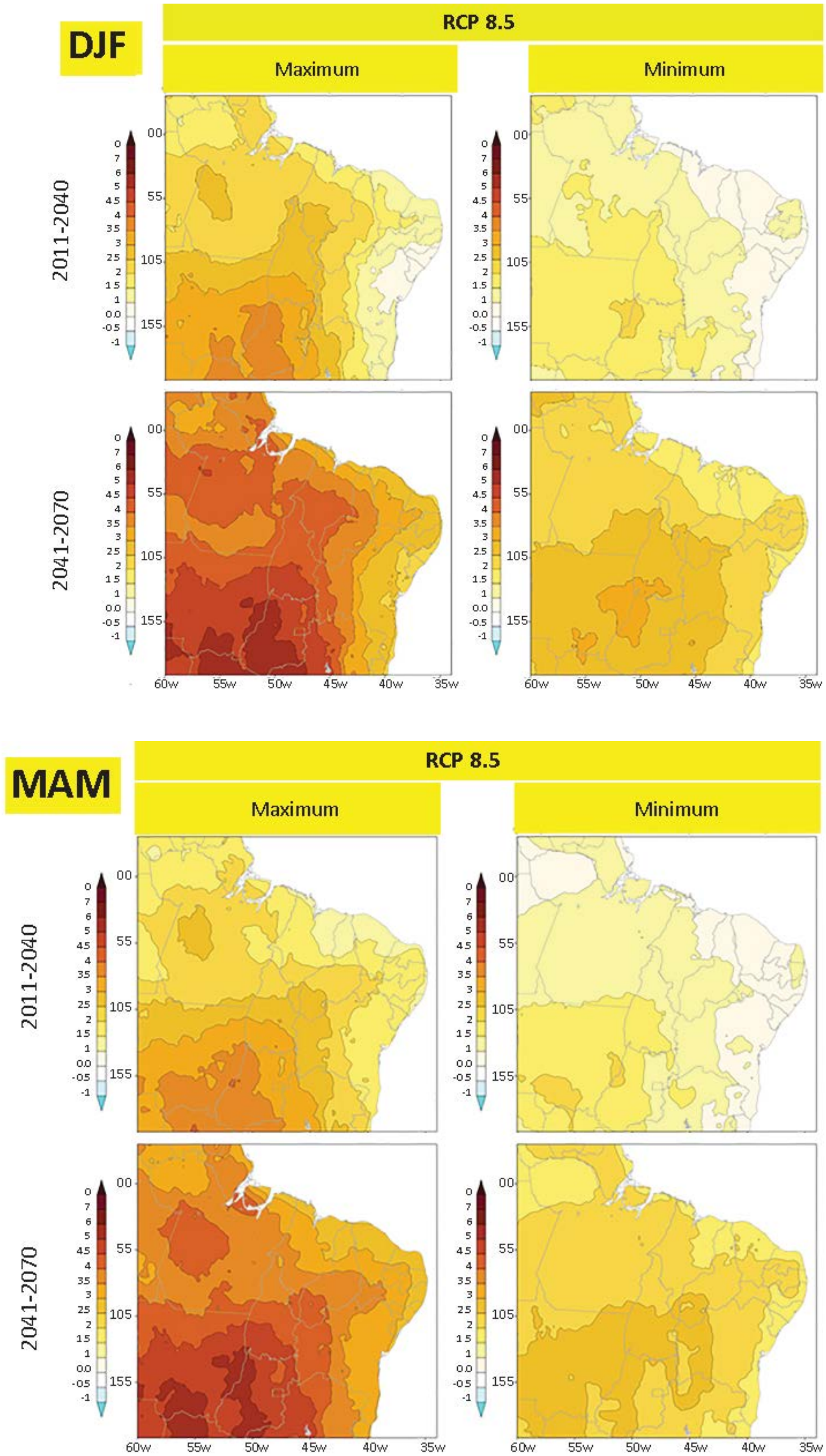




Source: INPE (2015).

FIGURE 2

Maximum and minimum temperatures (four seasons):
Eta HADGEM2-ES and Eta MIROC5 scenarios downscaling RCP8.5



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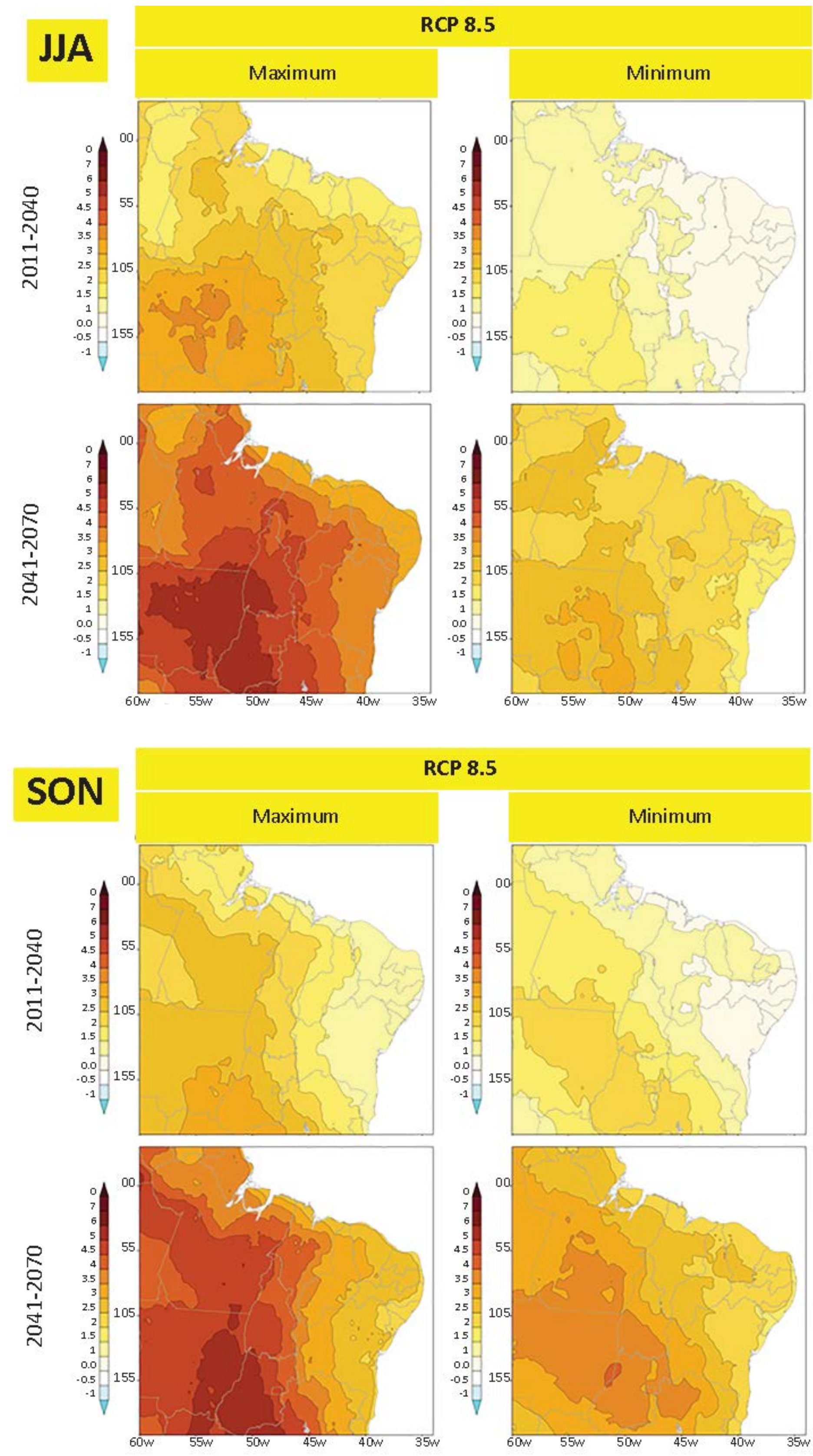
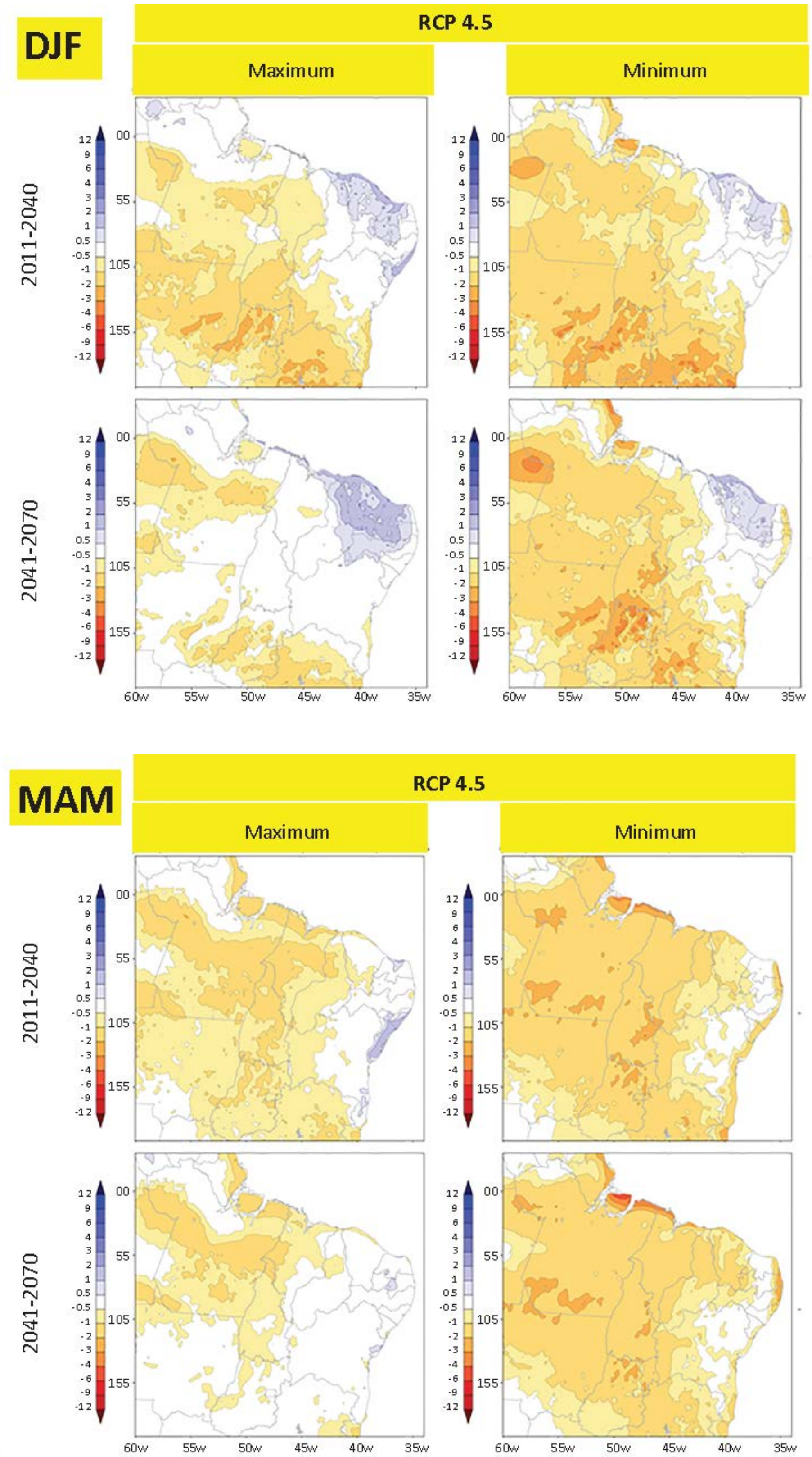


Source: INPE (2015).

FIGURE 3

Maximum and minimum rainfall (four seasons):
Eta HADGEM2-ES and Eta MIROC5 scenarios downscaling RCP4.5



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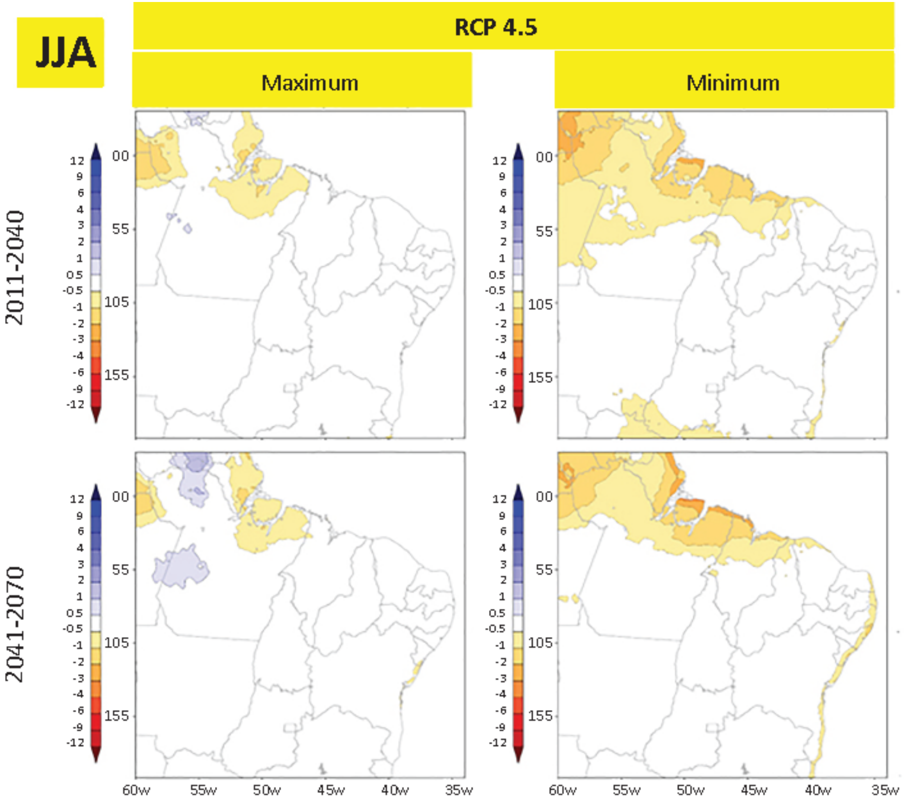
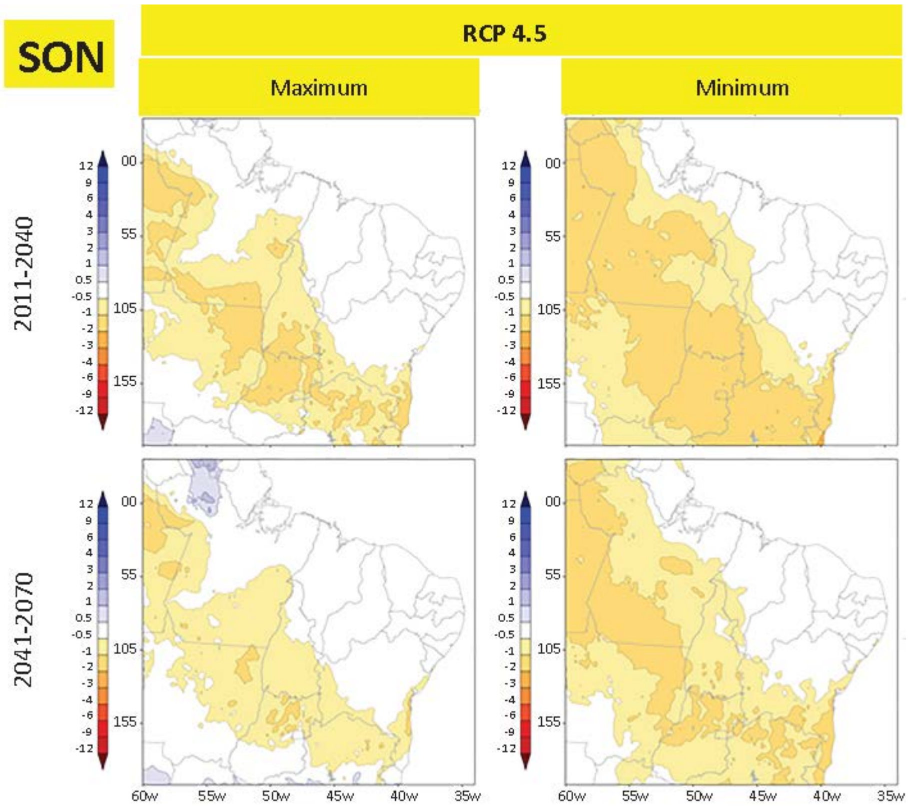
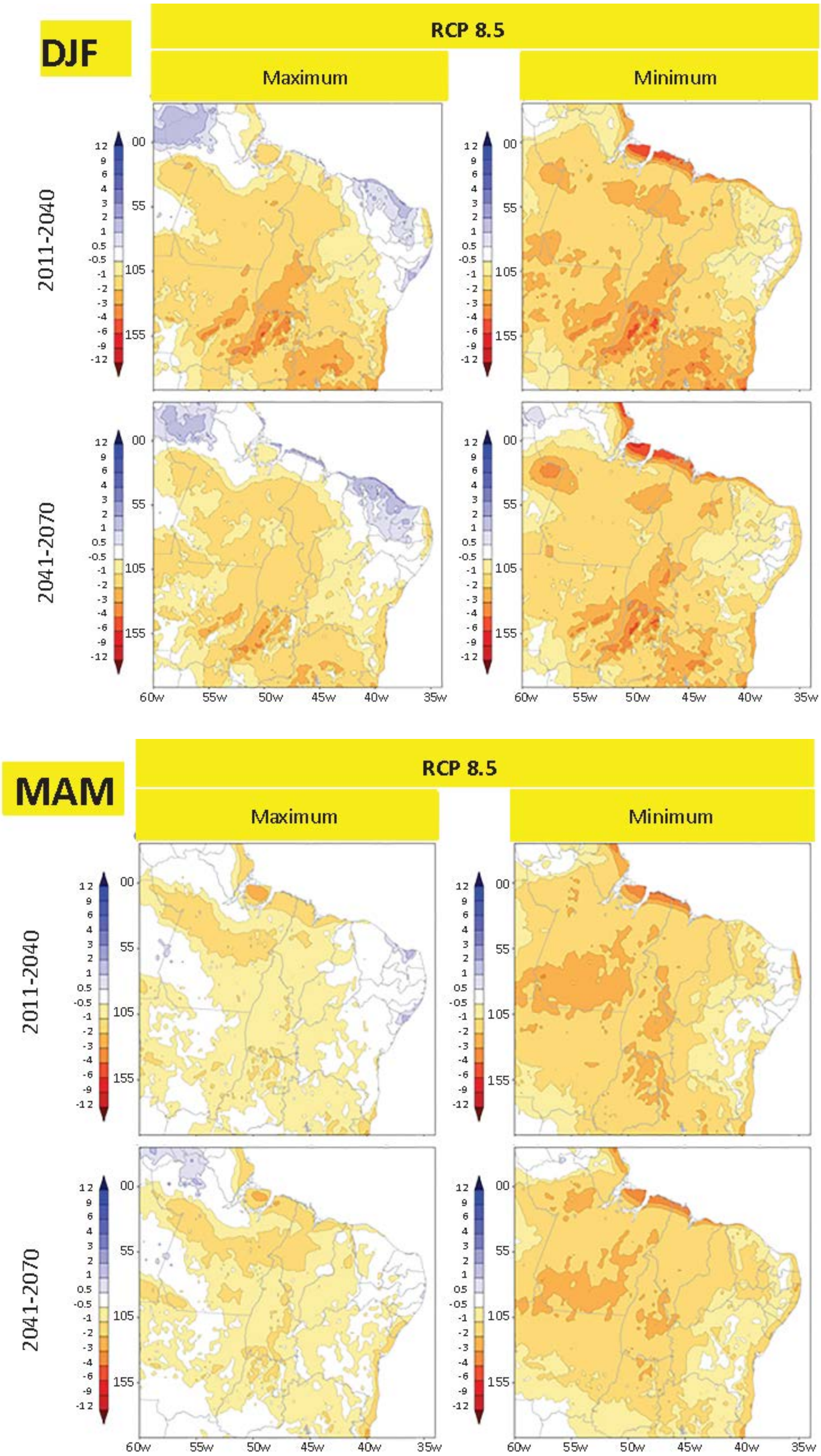




Source: INPE (2015).

FIGURE 4

Maximum and minimum rainfall (four seasons):
ETA HADGEM2-ES and Eta MIROC5 scenarios downscaling RCP8.5



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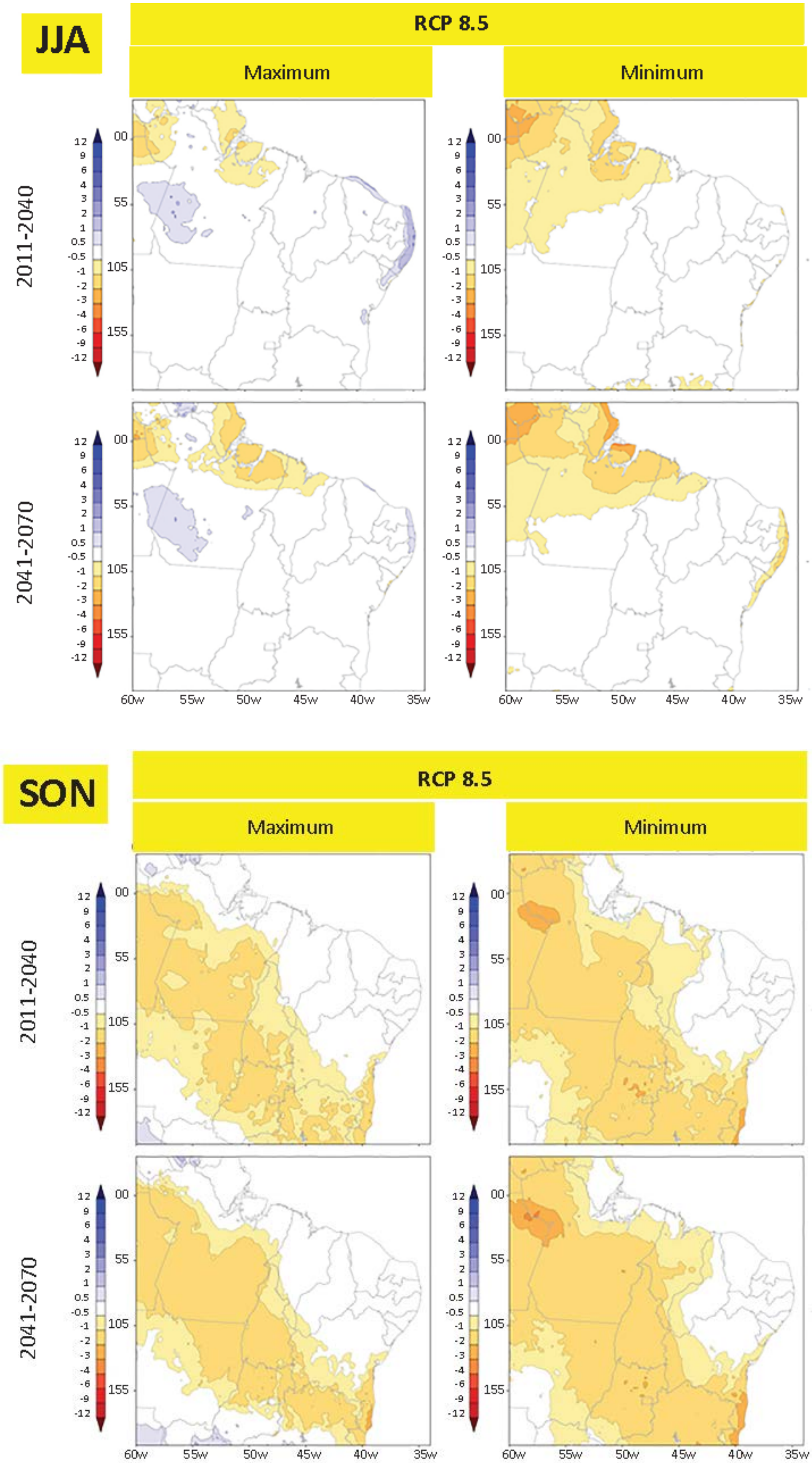


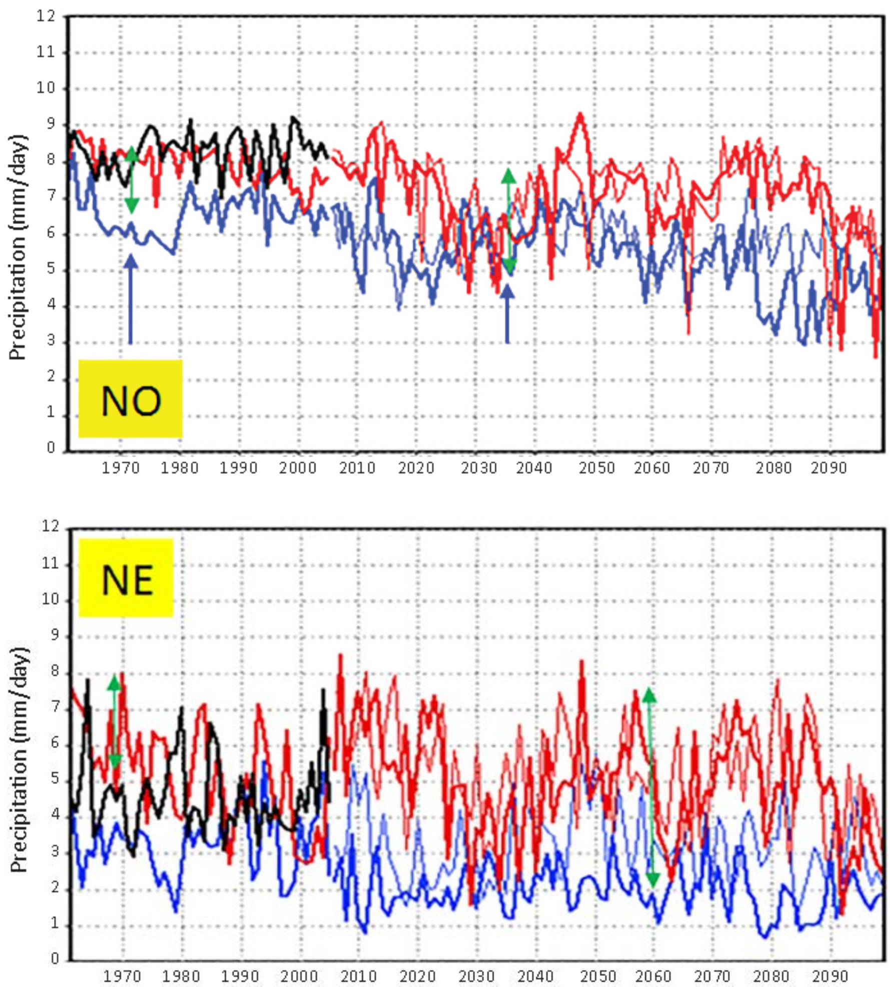
Source: (INPE 2015).

Given that short-term variability has a greater impact on agriculture, and that estimates show the possibility of both increasing and decreasing rainfall trends, policymakers should look for initiatives that make crops and farmers more resilient to a greater variability in rainfall patterns (Baethgen 2010). The variability of rainfall between different years is also expected to increase in these regions, as shown in Figure 5.

In summary, a 0.5ºC increase in global average temperatures since 1950 may not look like much, but it is already affecting the complex climate system, increasing the frequency of and the area covered by extreme weather. An unusually hotter summer is 10 times more common now than it was between 1951 and 1980—just few decades ago (Hansen et al. 2012a).

FIGURE 5

Precipitation (mm/day), yearly values simulated from 1961 until 2100, averaged over the states of North (NO) and Northeast (NE) regions of Brazil and over the December-January-February season



Source: Authors' elaboration, adapted from Chou et al., 2014.

Note: The black lines refer to actual observations, the blue lines refer to Eta downscaling simulation driven by HadGEM2-ES, and the red lines refer to Eta downscaling driven by MIROC5, for both RCP4.5 (thin lines) and RCP8.5 (thick lines) emission scenarios. The graph shows the increase of variability (size of green arrows) toward the end of the century.

BOX 1

Main highlights of temperature and rainfall patterns for the North and Northeast regions of Brazil

In Brazil, the region with the largest predicted increase in average temperatures in the next few decades is the Centre-West. However, up to the end of the century, this trend will also apply to the North and Northeast regions, mostly in their central areas. There is also a general trend for Brazil of less rainfall in the rainy season (summer), although this trend is more pronounced in the Southeast and Centre-West regions of the country. The regions should also experience more interannual variability of rainfall during the rainy season (December to February).

North	Northeast
• Expansion of the trend of increasing temperatures to the North, mostly in the region's central areas. • For the summer, projections estimate, by the end of the century, an increase in mean temperatures of about 3°C to 8°C in the North region. • The North region will also experience an increase in interannual variability. • The North region should experience less rainfall in autumn, and the north of the region will also have less rainfall in the winter. • Most of the reduction in rainfall is projected to occur in the North.	• Expansion of the trend of increasing temperatures to the Northeast, mostly in the region's central areas. • For the summer, projections estimate a moderate increase in mean temperatures of about 2°C to 6°C in the Northeast region. • The northeastern part of the Northeast region is expected to have an increase in precipitation rates in summer.

Source: (INPE 2015).

Given that extreme events are expected to grow both in quantity and intensity, adaption policies tailored to smallholder farmers must take into consideration risks of an increase in climate variability. Expected consequences of this new climatic pattern are more constant droughts, as well as increased rainfall, sometimes in the same region during different years. Public agricultural policies should also account for the intensification of local temperature anomalies, which can result in more extreme heat waves in the region (Hansen et al. 2012b). If targeted public policies are not applied, such phenomena will have serious consequences for the rural population in the North and Northeast of Brazil.

In addition to heat waves and extreme weather events, the *El Niño* and the Southern Oscillation (ENSO) phenomenon also reinforces seasonal climate fluctuations, with serious consequences for the natural environment and local populations. Variations in ENSO events have a global impact because they create alterations in heating patterns of the tropical atmosphere, thereby changing the global atmospheric circulation (Cane 2005).

Although it is still difficult to say how climate change will impact ENSO patterns, it is possible to expect climate change to intensify the effects of this phenomenon. Events such as severe droughts can have even worse outcomes in light of the temperature and rainfall projections previously discussed for the Northeast region.

2 POSSIBLE CLIMATE CHANGE SCENARIOS AND RELATED IMPACTS ON FAMILY FARMING ACROSS BRAZIL'S NORTH AND NORTHEAST REGIONS

The previous section presented the main uncertainties and scenarios of climate change in the North and Northeast regions of Brazil, including features that are important to agriculture, such as changes in temperature and precipitation. In short, the main message from that exercise is that smallholder farmers will have to adapt to a world of increasing climate variability.

Although agriculture is one of the main sources of GHG emissions,[7] it is also highly vulnerable to climate change, due to projected consequences such as increasing global average temperatures and variability in rainfall patterns. The Brazilian Agricultural Research Corporation (Embrapa) (2008) states that significant change in the agricultural landscape should be expected in Brazil over the coming decades, including in the north and northeast of the country.

Although the agricultureal sector as a whole will be affected by these changes, smallholder farmers are more vulnerable and will need more support to adapt. Brazil is a country with high land concentration, but family farming is responsible for producing a large share of food consumed nationally. For this reason, any losses in family farming production will not only affect the food security of these farmers but will also have consequences for the national communities that depend on them.

The study of vulnerability and adaptation to climate change in Brazil is still at a preliminary stage. Efforts were made in the context of the preparation of the Second National Communication of Brazil to the United Nations Framework Convention on Climate Change (UNFCCC), published in 2010, for which some research teams were mobilised to assess specific climate change impacts and their implications for certain areas, including agriculture. As part of this mobilisation process, a team of researchers from Empresa Brasileira de Pesquisa Agropecuária (Embrapa), in collaboration with researchers from the University of Campinas (Unicamp), prepared a flagship report entitled *Aquecimento Global e a nova Geografia da Produção agrícola no Brasil* (*Climate Change and the New Geography of Agriculture Production in Brazil*) (Assad et al. 2008), which is, so far,[8] the most comprehensive study on the potential impacts of climate change on the country's agricultural production.

In this report, researchers considered two main scenarios: A2 (pessimist) estimates an increase in global average temperatures of 2ºC to 5.4ºC by 2100; and B2 (optimistic) estimates an increase in global average temperatures of 1.4ºC to 3.8ºC by 2100.

In the Embrapa study, the assessment of climate change impacts used Climate Risk Zoning (ZARC) technology[9] for the following crops: cotton, rice, coffee, sugarcane, beans, sunflowers, manioc, corn and soybeans, along with pasture and beef cattle. Based on the zoning of crops in 2007, Brazilian agricultural scenarios were simulated for 2020, 2050 and 2070, taking into account predicted climate change.

However, the main focus of this 2008 study was on agribusiness, with very few references to smallholder farmers, who were only mentioned when projections for corn, beans, sunflowers and cassava were analysed. A literature review shows that most of the existing studies on the effects of climate change on agriculture usually only considered big crops and producers, with limited references to family farming. This is not only observed in Brazil but, rather, a global trend.[10] A review of the existing literature allows some general considerations presented in Box 2.

This section will present an overview of potential climate change impacts on a specific list of crops[11] present in the North and Northeast of Brazil. The selection of these crops was not only driven by commercial interests but also followed two main assumptions: (i) the products are among the most relevant for smallholder farmers in the selected regions; and (ii) impacts on their production are expected to have detrimental outcomes in terms of food security, mostly for poor rural communities.

Given that more in-depth research on simulations of ZARC crops in light of the new AR5 scenarios—or preferably based on the downscaled scenarios produced by INPE—has not been conducted yet, the following considerations are an attempt to review the little literature available on the potential impacts of climate change on the yields of selected crops (primarily using the results of AR4 scenarios).

A preliminary assessment of the downscaled scenarios produced by INPE was also considered, to estimate different responses of plants to expected changes in temperature and precipitation. The result of this exploratory research is summed up in Table 1.

Table 2 is an attempt at assessing the projections of downscaled scenarios for the North and Northeast regions of Brazil in terms of the impacts of changes in temperature and precipitation, and taking as references two main AR5 scenarios (RCP4.5 and 8.5). The four 'simplified scenarios' are thus based on a combination of possible changes in temperature and precipitation, which may happen both as long-term trends and as short-term climatic variability. Considering the uncertainties of climate change models, as well as an increase in extreme weather events and variability over time, the table attempts to offer a simplified framework to assess crop vulnerability.

More research is needed to increase the resilience of family farming in the north and northeast of Brazil to climate change pressures. However, this preliminary assessment presents a few important considerations. First, future manioc production is a main concern, mainly in the Northeast region, where the crop is a fundamental staple and an important part of regional culture. The worse scenario seems to be a greater increase in temperature (RCP8.5) together with a decrease in precipitation. Additional pressure is also expected from an increase in extreme weather events, since several crops analysed are vulnerable to dramatic oscillations in temperature and rainfall. On the other hand, traditional crops may offer alternatives to offset losses from other agriculture.

Climate change impacts are likely to pose a significant threat to food security in rural communities. Nevertheless, it is important to clarify that this study attempted to assess the potential impacts of climate change on selected crops in the 'Business-as-Usual' (BAU) scenarios, which is usually the methodology used when making an assessment from the perspective of climate change. With early planning and innovative techniques, it is possible to reduce vulnerabilities and increase resilience, now and in the future. Other adaptive options, including innovative techniques and technologies, will be presented in Section 4.

BOX 2

General considerations of the impact of extreme weather events and climate variability on family farming

Literature review

- Ninety-five per cent of all losses in Brazilian agriculture were due to either floods or droughts (Assad et al. 2008). Such events are projected to become more frequent in the future.
- Considering the relative magnitude of rainfall variability in three temporal scales, interannual, decadal and long-term (last 100 years): "The proportion of total variance explained by the short-term (interannual) variability is three times greater than that corresponding to the long-term variability (climate change) and two times greater than that of the decadal variability" (Baethgen 2010).
- The general trend indicates a reduction in rainfall over time for the Northeast and North regions (INPE 2015).
- The main losses in yields projected by Embrapa indicate the loss of suitable land as one of the main factors.
- The Northeast's semi-arid regions will get even drier, whereas the eastern part of the Amazon may become more similar to a savanna biome.
- For agriculture, the dry trend can lead to detrimental outcomes regarding food security, bringing additional concerns for smallholder farmers. A clear-cut example of how this could happen is the estimate that manioc may disappear from semi-arid regions of the Northeast. Corn production is also expected to be severely impacted in the Northeastern Agreste (Assad et al. 2008).
- Several crops adapted to tropical climates may migrate to the south of Brazil or higher regions to offset increases in temperature (ibid.). This could result in competition from other areas, as well as migration of rural labour to more favourable regions.
- Other predicted factors of future stress in agricultural systems are reduced water flows and irrigation potential, increased incidence of pests and diseases, changes in biomes, and decreased biodiversity of plants and animals (World Bank 2013).

Literature considerations

- Adaptation efforts targeting future climate change impacts would also benefit from increasing resiliency to current climate variability.
- Policymakers should consider investing in crops that are more resilient to drier weather.
- Future strategic planning for rural development, including smallholder farmers, must take into consideration this changing landscape when deciding in which crops to invest.

TABLE 1

Impacts on the productivity of crops relevant to family farming in Brazil, as well as in its Northeast and North regions

Crop	Brazil	Northeast region	North region
Manioc/Cassava *(Manihot esculenta)*	(↑)	(↓)	(↑)
Cotton *(Gossypium hirsutum)*	(↓)	(↓)	(↓)
Coffee *(Coffea arabica)*	(↓)	(↓)	(↓)
Bean *(Phaseolus vulgaris)*	(↓)	(↓)	(↓)
Cowpea bean *(Vigna unguiculata)*	(↓)	(↓)	-
Corn *(Zea mays)*	(↓)	(↓)	(↑)
Pineapple *(Ananas comosus)*	(↓)	(↓)	(↓)
Banana *(Musa spp)*	?	(↓)	(↓)
Cocoa *(Theobroma cacao)*	?	?	?
Cashew *(Anacardium occidentale)*	?	?	?
Coconut *(Cocos nucifera)*	?	?	?
Palm *(Elaeais guineensis)*	(↓)	(↓)	?
Açai berry *(Euterpe oleracea)*	?	?	-
Cupuaçu *(Theobroma grandiflorum)*	(↓)	(↓)	-

TABLE 2

Most vulnerable traditional crops within different temperature and precipitation scenarios

	Warming trend — **Temperature (RCP4.5)**	Extreme temperature — **Temperature (RCP8.5)**
(+) Rainfall Extreme precipitation	• Manioc • Coffee	• Manioc • Cotton • Coffee • Bean • Corn • Pineapple • Palm
(-) Rainfall Drying trend	• Cotton • Coffee • Corn • Cowpea Bean • Pineapple • Banana • Palm	• Manioc • Palm • Cotton • Coffee • Bean • Corn • Cowpea Bean • Pineapple • Banana • Cocoa

3 MAIN PROBLEMS AFFECTING FAMILY RURAL PRODUCERS ACROSS BRAZIL'S NORTH AND NORTHEAST REGIONS

Before presenting the options for family farming to respond to the adverse impacts of climate change, including techniques and technologies, it is fundamental to better understand the problems already affecting the producers that could be aggravated by changes in temperature and precipitation.

This section will focus on current multidimensional problems affecting family rural producers in the North and Northeast regions. The problems will be addressed in general terms for all the regions and biomes (semi-arid, cerrado and Amazon), but any specific circumstances related to these regions and biomes will be clearly singled out.

Family farmers in the North and Northeast regions of Brazil already face many problems, especially related to poverty and its effects. The current social vulnerabilities of these populations are likely to increase if the expected impacts of climate change occur in these regions. Thus, a comprehensive understanding of the main social drivers that affect the lives of family farmers is important so that actions can be taken to increase their resilience.

For the most vulnerable groups, even minor changes in climate can have disastrous impacts on their lives and livelihoods. Most climate change models predict that damage will be disproportionately borne by small-scale farmers, particularly those practising rain-fed farming in developing countries (Alteri and Koohakkan 2008).

In Brazil, family farmers occupy an area of 80.25 million hectares, which represents 24.3 per cent of the area occupied by Brazilian agricultural establishments (IBGE 2006). As in other regions of the world, the majority of the rural poor population also lives in areas that are resource-poor, highly heterogeneous and risk-prone. In the Northern region of Brazil are located 413,101 family farming establishments, representing a total of 16,647,328 hectares. Half of the total number of such establishments are concentrated in the Northeast region: 2,187,295 establishments, with an area of 28,332,599 hectares.

Most poor farmers in the northeastern semi-arid biome have insufficient land, the allocation of capital is negligible, the human capital is low, the level of productive organisation is incipient, and technological progress indicators reveal a backwards trend (Silva and Costa 2014). In the North region, although land is usually not the problem, the other problems are very similar, and, in general, farmers face difficulties in accessing markets for their production.

According to the agriculture and livestock census (IBGE 2006), increases in land productivity and workforce did not manage to prevent family farmers' households from living in conditions of extreme poverty, and over 50 per cent of them have a monthly income equivalent to half the minimum wage.

This scenario occurs, moreover, in a permanent context of inequality in land ownership. Of the 4.3 million family farming establishments, 3.2 million farmers had access to land as owners, representing 74.7 per cent of the number of family farms and 87.7 per cent of their area. Approximately 170,000 producers declared their access to the land as 'settlement without formal rights to the land'. However, 691,000 producers had temporary or precarious access to land, either as tenants (196,000 producers), partners (126,000 producers) or occupants (368,000 producers) (IBGE, 2006).

Poverty is essentially a multidimensional phenomenon that not only manifests itself in insufficient income but also in hunger, illiteracy, a lack of housing and a lack of access to electricity and water. The rural context also features a low quality of rural education, limited access to health care services, poor working conditions and localised shortages. However, regardless of the specific characteristics of poverty in rural areas, there is an initial correlation between poverty, the fragility of family farming and high land concentration (Soares 2003). Thus, many people advocate that land reform is essential for safety and food sovereignty.

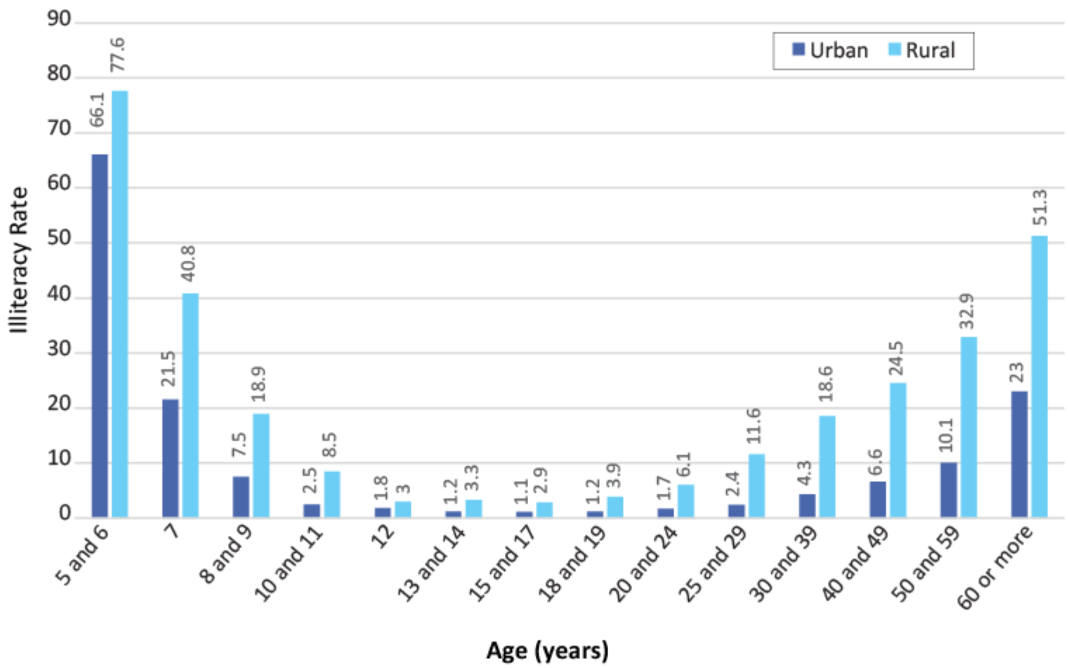
The old poverty is concentrated in the Northeast region, with the determining factors the occurrence of drought and deprivation of access to water and land. In the Amazon, poverty is related to a lack of access to land and the precariousness of labour relations. Thus, agribusiness, associated with other processes such as the expansion of mineral extraction, can reproduce poverty and in some instances actually reinforce its fundamental causes, such as the expropriation and land concentration by large landowners, as well as the exploitation of the rural labour force (Romano, Soares, and Menezes 2013).

Illiteracy rates can be three times higher in rural areas than in urban areas, and the low literacy rate among family farmers jeopardises the real potential of agricultural production. According to research by the Instituto de Pesquisa Econômica Aplicada (Ipea), only 5.2 per cent of rural households are responsible for 63.5 per cent of total family farming production. On the other hand, two thirds (66.4 per cent) of the households generate just 10 per cent of the total value of production.

Vieira Filho, researcher at Ipea, argues that this is due to the concentration of technological resources: just 16 per cent of the households have a high level of technological know-how. It is believed that if technology and access to education increased in just 5 per cent of the households with technological gaps, the present level of production could double (Vieira and Silveira 2012).

FIGURE 6

Illiteracy rate* by age and residence, Brazil, 2009 (percentage)



Source: IBGE, PNAD; table by DIEESE.

Note: * Share of illiterate people by age in relation to the total number of people in each age group.

Universities and local agricultural institutions can help to build people's capacity and work towards minimising the inequalities in production and income among Brazilian regions. The lack of opportunities in rural areas is one of the main reasons for population movements, especially the growing migration from rural to urban areas. In 1950, 63.8 per cent of Brazilians lived in rural areas, while only 36.2 per cent in urban areas. In 2010, the proportion of the population living in urban areas had jumped to 84.3 per cent, while only 15.7 per cent lived in rural areas. (IBGE, 2010)

The semi-arid region of northeastern Brazil is one the regions most affected by population movements. The massive expansion of commercial monocultures, soil degradation and potential desertification, together with the growing climate instability, have provoked a situation of social and economic instability, forcing millions of the dryland inhabitants to migrate to urban centres (Marsha 2000).

In many situations, the migrants are not the poorest or most vulnerable, but exactly those who were able to overcome illiteracy and are looking for new opportunities. Usually, when people are able to become better educated or acquire certain knowledge in poor and remote areas, they migrate to other regions in search of better opportunities, which results in a disruption of knowledge transmission in poor rural areas.

In many circumstances, poverty can be one of the main causes of environmental degradation, which is usually aggravated by institutional and market failure. Small-scale farmers are usually considered one of the main agents responsible for unsustainable deforestation activities in Brazil's Amazon (Southgate and Pierce 1988, quoted by Duraiappah 1996). Unfortunately, deforestation by small-scale farmers is not only observed in the North region. In the northeast of Brazil, the biodiversity of Caatinga is also suffering negative effects, given that approximately 33 per cent of the energy supply in rural areas is derived from firewood obtained through unsustainable exploitation of its vegetation.

Moreover, as pointed out by Hawkes and Ruel (2006), in agricultural communities, poor health reduces income and productivity, further decreasing people's ability to address poor health and inhibiting economic development. Leishmaniasis, tuberculosis, malaria, dengue fever and leprosy are present over almost the entire Brazilian territory. As in other countries, the North and Northeast regions of Brazil with the lowest Human Development Index (HDI) also have the highest rates of tropical diseases. Another public health concern in Brazil associated with agriculture is the use of pesticides. Currently, the country is the largest consumer market for pesticides in the world. However, there are still few studies on the risk factors associated with pesticide use.

The latest IPCC report (2014) highlighted that climate change will act mainly, at least until the middle of this century, by exacerbating health problems that already exist, and the largest risks will apply in populations that are currently most affected by climate-related diseases.

In addition to social problems, there are many environmental and natural resources management problems. Temperature and precipitation are the main climatic factors that directly influence the growth and development of plants, since they affect all biochemical reactions of photosynthesis. Thus, temperature increases and changes in precipitation patterns may affect the duration of cultivation cycles, the final retention of pods, and fruit quality through the accumulation of sugars and colouring, and trigger the abortion of flowers, among other impacts (INSA 2011). Certainly, some crops are more vulnerable than others to these changes.

The previous section already provided a list of significant crops in family farming in the North and Northeast regions of Brazil that may be affected by the adverse effects of climate change. However, there are other fragile crops and livestock activities that were not previously considered—cotton, rice, coffee, sugarcane, beans, sunflowers, corn and soybeans, along with pasture and beef cattle—which are usually associated with commercial agricultural activities.

According to the 2008 Embrapa study previously mentioned, one of the main expected impacts of increasing temperatures is the reduction in the number of municipalities with agricultural potential in 2020, 2050 and 2070, compared with the current situation, for almost all crops (except sugarcane and manioc). Even if rising temperatures reduce the frost risk in the south of the country, enabling areas now restricted to tropical plant cultivation to become more favourable in the future, they will not compensate for the damage caused by warmer weather (Assad et al. 2008).

The impacts of global warming can be minimised if the production system is able to use more intensively the areas most suitable for cultivation identified in the Embrapa study. Part of the response must come from the rotation of grazing areas with crops, thus shortening the period of use of pasture and planting a cycle of three to five years of intensive crops.

One of the main agribusiness crops, soybean, is also one of the crops expected to be most affected by climate change in the next few decades. Soybeans are highly vulnerable to increases in temperature, and soybean plantations in the Northeastern region's cerrado biome are expected to be badly affected (ibid.).

Given that soybean is currently Brazil's main agricultural commodity, such losses account for half of all national agricultural losses projected for the country (ibid.). There are two potential outcomes resulting from this scenario: a decrease in soybean production in the Northeast region may also decrease agrobusiness pressures on family farming; and a decrease in the land available for soybean production may intensify the expansion of agribusiness on lands currently occupied by smallholder farmers.

In addition to fragile crops, there are many other environmental problems that affect family farming in the regions: processes affecting animals, monocultures or subsistence farming, wild plant gathering, soil degradation, pest, disease and weed manifestation, water resources, drought and other precipitation problems, and desertification faced by family farmers in the cerrado, semi-arid and Amazonia regions.

Unsustainable methods of land use, such as repeatedly planting cash crops on the same land, excessive irrigation which can cause salinisation, excessive grazing by domestic livestock, and inappropriate disposal of waste, are practices attributed to a lack of education and technical knowledge that may lead to environmental degradation by poor or small-scale farmers.

Biodiversity loss is another significant concern because species and habitats are the building blocks on which human livelihoods depend, the foundation for production from forests, fisheries and agricultural crops. Enhanced protection and management of biological resources will also contribute to solutions as nations and communities strive to adapt to climate change (World Bank 2008).

Brazil has unique ecosystems, the greatest biodiversity on the planet and a variety of eco-climatic gradients. Unfortunately, this natural wealth is threatened by advancing agricultural frontiers resulting from rapidly growing agricultural and cattle production.

According to the IPCC AR5, there are a number of major impacts of climate change on biodiversity in Brazil, as shown in Box 3.

Considering such a threat, understanding the biodiversity of the semi-arid, cerrado and Amazon regions, including the biotic and abiotic processes that affect their biota, is the first step to ensuring that their resources can be used sustainably, reducing environmental degradation and improving the quality of life of their inhabitants (INSA 2011). Knowing in detail how these biomes and agricultural activities may counteract the negative effects of climate change in Brazilian climatic conditions is an effective way to reconcile food production with environmental quality.

BOX 3

Main impacts of climate change on biodiversity in Brazil

• Rising sea levels and increasing weather and climatic variability and extremes modified by global warming are very likely to have impacts on mangroves. • Over a third (38–45 per cent) of the plants in the cerrado (central Brazilian savannas) face extinction with a temperature increase of 1.7°C above pre- industrial levels. • Endemic cerrado bird species (Marini et al. 2009) and plant species (by 2055, scenarios HHGSDX50 and HHGGAX50; Siqueira and Peterson 2003) will relocate towards the south and southeast—precisely where fragmentation and habitat loss are worse.	
North	**Northeast**
• Replacement of tropical forest by savannas. • In non-fragmented Amazon forests, direct effects of CO_2 on photosynthesis, as well as faster forest turnover rates, may have caused a substantial increase in the density of lianas over the last two decades. • Estimates of the risk of extinction of plant species in the Amazon—not taking into account possible climate change impacts—range from 5 per cent to 9 per cent by 2050 with a habitat reduction of 12–24 per cent (Feeley and Silman 2009) to 33 per cent by 2030 (Hubbell et al. 2008). • Increases in temperature and decreases in soil water would lead to the replacement of tropical forest by savanna in eastern Amazonia.	• Reductions in precipitation and increases in evapotranspiration are expected. • Decline in water resources due to climate change.

Some economic activities (large-scale agribusiness, large-scale animal rearing, mining activities) that have gained ground at the expenses of family farming, and the implications they could have in terms of the sustainable management (prices of some agricultural crops rising significantly, difficulties in accessing seed markets and trade difficulties) of the semi-arid, cerrado and Amazon regions in the context of climate change scenarios, must be carefully considered.

Family farmers' contribution to some of the supply chains of Brazil's livestock and agriculture is extremely important. According to data from the 2006 agriculture and livestock census, family farming is responsible for about 70 per cent of the food produced in Brazil. Family farming constitutes 90 per cent of the economic income in some small Brazilian municipalities; it accounts for approximately 10 per cent of national GDP, with funding resources for rural credit growing to BRL24.1 billion in 2015/2016 (Safra Plan for Family Farming 2015/2016). In Brazil, family farming produces a significant proportion of daily food crops, such as approximately 87 per cent of manioc, 70 per cent of beans, 46 per cent of maize and 34 per cent of rice. It is also responsible for approximately 60 per cent of milk yield, 59 per cent of the pig herd and 50 per cent of poultry meat in the country.

TABLE 3

Agricultural production by type of farming, Brazil, 2006 (percentage)

Product	Family farming	Non-family farming	Total
Vegetable production	**40.0**	**60.0**	**100.0**
Rice	33.9	66.1	100.0
Black beans	76.8	23.2	100.0
Coloured beans	53.9	46.1	100.0
Black-eyed beans	83.8	16.2	100.0
Manioc	86.7	13.3	100.0
Corn in grain	45.9	54.1	100.0
Soybeans	15.7	84.3	100.0
Wheat	21.2	78.8	100.0
Arabic coffee in grain (green)	34.2	65.8	100.0
Canephora coffee in grain (green)	55.0	45.0	100.0
Livestock*			
Cattle	30.3	69.7	100.0
Cows' milk	58.1	41.9	100.0
Goats' milk	67.1	32.9	100.0
Poultry	50.0	50.0	100.0
Pigs	59.0	41.0	100.0

Source: IBGE (2006); table by DIEESE.

Note: * It was not possible to calculate the sum of livestock products, in view of the different units of measure for these products.

Although the importance of this sector in the context of the Brazilian economy and food security is clear, there are many economic factors that limit or prevent the development of family farming.

According Buainain and Garcia (2013), the availability of infrastructure influences the conditions of production and the competitiveness of producers, as they determine the insertion opportunities in local markets and the development of innovations. The infrastructure deficit tends to penalise small-scale producers and favour large-scale production. The precariousness of the Brazilian secondary road network illustrates the difficulty for smallholder farmers to access local markets for daily products.

The problem of deficient infrastructure is not restricted to the Northeast region; it is also an obstacle to national economic growth. But what makes the Northeast challenge harder is the abyss of social inequality. In addition to these socio-economic factors, the economic viability of the family farmers' establishments also faces the challenge of scale, dispersion and spatial isolation (Buainain and Garcia 2013), which are even more challenging for establishments in the north of the country.

Many rural technologies—particularly innovations associated with equipment and machines—require relatively large production scales, which presents another difficulty for small units to use them effectively. The geographic dispersion and the spatial isolation also hinder communication between small-scale producers and their access to different local markets. The difficulty of trade faced by family farmers is perceived from access to good-quality seeds, through the process of harvesting and storage of crops, until unloading.

The issue of waste permeates every stage of trading. According to a researcher at Embrapa Food Technology, Brazilian agriculture wastes, on average, 10 per cent of production. In some specific cases, such as fruits and vegetables, such losses reach 30 per cent and 35 per cent, respectively (Portal Ecodesenvolvimento 2015).

Regarding harvesting and storing crops, it is necessary to enable smallholder farmers to improve handling during harvest and storage, so that the product can be better protected from adverse conditions. Farmers need sufficient infrastructure to allow the movement and flow of their production. A major obstacle to the competitiveness of agriculture in Brazil, mainly in the northeast of the country, is the cost of freight.

Some of these factors addressed in this section show the difficulty of separating social and environmental factors from purely economic ones. The issues mentioned above attempt to address remaining elements or add an economic perspective to those considered in the previous sections.

Regardless of the nature of the problems, they have the potential to be amplified in the context of climate change scenarios.

4 RESPONSE OPTIONS FOR FAMILY AGRICULTURAL PRODUCERS

Through the lens of the three dimensions of sustainable development, this section will focus on the potential solutions to address problems affecting family agricultural producers in the North and Northeast regions that could be intensified by climate change and/or extreme weather events.

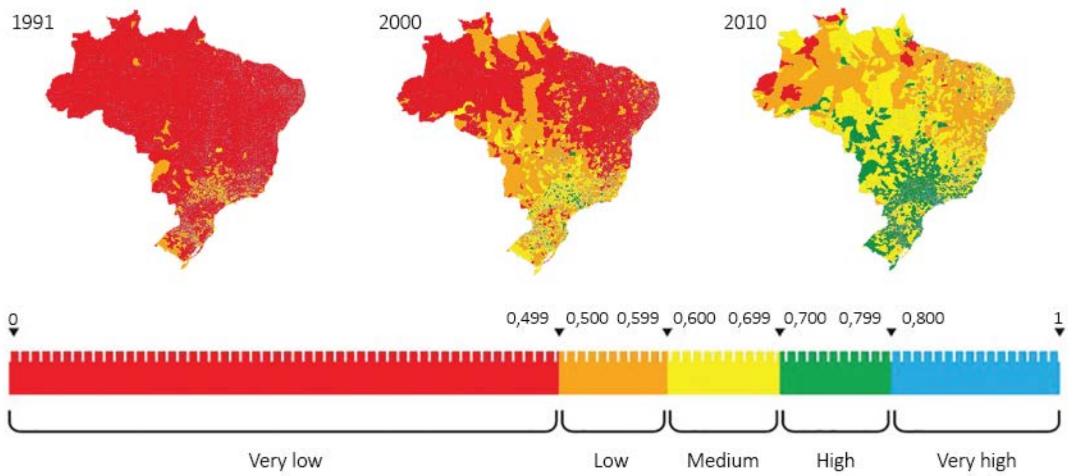
The response options will be addressed in general terms for all the regions and biomes (semi-arid, cerrado and Amazon), but any specific circumstances related to the specific regions and biomes will be clearly singled out.

Brazil is often cited as a successful example of a country that has implemented effective policies for reducing vulnerability and building resilience through active policies to reduce inequality and eradicate poverty and extreme poverty. To illustrate this progress, Figure 7 shows the evolution of the HDI between 1991 and 2010.

The figures reveal that, although still facing challenges, Brazil has advanced greatly in terms of human development over the past 20 years. Between 1991 and 2010, the HDI in the country grew 47.5 per cent, rising from the category of 'Very Low' to 'High' human development. The advance was accompanied by a reduction in regional disparities due to the marked improvement of the poorest municipalities, which have the worst indicators.

FIGURE 7

Evolution of Brazil's HDI from 1991 to 2010



Source: UNDP, Ipea and Fundação João Pinheiro (2013).

The *Human Development Report* cites the *Bolsa Família* (Family Allowance)[12] programme as an example of social policy that has helped in the creation of a social protection floor. It was responsible for a 16 per cent reduction in poverty and a 20–25 per cent reduction in inequality in the country in recent years, with an investment of 0.5 per cent of GDP in 2006 and 0.3 per cent of GDP in 2008–2009.

Brazil is also notable for the growing consumption of the poorest households. Consumption by the poorest 40 per cent of the population has grown faster than for the population as a whole. It has a high rate of employment, with a decreasing rate of informality, although sustaining this trend may be a challenge in light of the recent economic and fiscal crisis.

In short, three determinants are linked to the sharp decline in poverty and extreme poverty in Brazil: an increase in the number of formal jobs, income growth (especially for households with a low income) and the effects of cash transfers.

Thus, it is important to highlight the significance of policies and interventions aimed at addressing social vulnerabilities, such as programmes related to eradicating poverty in rural areas, to increasing security in relation to land tenure, to combating illiteracy and providing technical assistance, capacity-building and training, as well as to ensuring healthy lives. Nevertheless, despite the efforts that have been made in the last decade, great regional disparities still exist within the country, especially in the rural areas of the North and Northeast regions, as can be seen in the most recent HDI map from 2010. These areas have the lowest HDI in the country.

Moreover, it is also worth considering that if the adverse impacts of climate change are verified in the near future, they have the potential to offset recent social gains, given that a changing climate and rapidly growing exposure to disaster risk present a threat to social development, mainly to income growth and employment. Thus, it is important to include resilience considerations in policies and response options.

In the most optimistic part of this study, many strategies of adaptation to environmental and natural resource management problems are assessed, also taking into account the perspective that they could increase the resilience of family farmers to face the adverse effects of climate change. In this regard, adaptive response options, including other economic alternatives for the families, must be explored, including the feasibility of adopting agro-ecological technologies, managing practices and other technologies that improve natural resource management in the semi-arid, cerrado and Amazon biomes. Options are considered in such a way to combine adaptation and mitigation aspects of the activities assessed.

An important consideration is that through agro-ecological and other sustainable approaches to agriculture (e.g. multiple cropping and polyculture systems; agroforestry systems; home gardening; wild plant gathering; use of local genetic diversity; soil enhancement, including organic matter; preventing pest, disease and weed manifestation; genetic improvement; managing water; drought-resilient plants; biomass-producing plants), smallholder and small-scale family farmers could offset elements of the present environmental and economic crisis, as well as of those related to the future threat of climate change.[13] These approaches commonly involve the maintenance or enhancement of biodiversity, and represent a viable long-term strategy to improve agro-ecosystem resilience to the effects of climate change.

As stated by the Food and Agriculture Organization of the United Nations (FAO), the main challenge to achieving a wider spread of agro-ecology is not technical but political. It involves the need to overcome the political, economic and ideological power of agribusiness and governments that drives the continued expansion of the industrial farming model. In contrast, family farming holds the promise of developing productive, sustainable, responsive, innovative and dynamic agricultural systems and contributing to resolving the food, finance, fuel and climate crises prevailing in the world today (FAO 2014).

The National Programme on the Sustainable Development of Rural Territories (*Programa Nacional de Desenvolvimento Sustentável de Territórios Rurais*—PROINF), managed by the Territorial Development Secretariat at the Ministry of Agrarian Development (Ministério do Desenvolvimento Agrário—MDA), has contributed to qualifying economic and productive processes for family farming in rural territories. Partnership with states, municipalities and civil society has supported the acquisition of equipment and the growth of infrastructure for the production and trading of family farming products. PROINF is an important tool for inclusion processes, income generation and economic self-sufficiency of family farmers and family farming establishments in rural territories.

Another relevant tool that may contribute to the success of public policies for family farming is the Rural Environmental Registration (*Cadastro Ambiental Rural*—CAR).[14] CAR is an electronic register with the overall objective of integrating environmental information on the legal situation of Permanent Preservation areas (*Área de Preservação Permanente*—APP), Legal Reserve areas, areas of forests and remnants of native vegetation, Restricted Use areas and consolidated areas in rural properties and settlements across the country. Registration with CAR is compulsory for all rural establishments.

The Safra Family Farming Plan 2015/16 has allocated a considerable amount of resources to CAR and to agro-ecological production. Due to the low rate of registration with the CAR programme, only 53.6 per cent of the rural population had registered up to 31 May 2015 – it is still pending the registration of 184.6 hectares. The Southern region has the fewest registrations: only 17.5 per cent of the total properties. The North region has the highest percentage of registered areas (75.3 per cent), and the states of Acre, Amazonas and Rondônia have already completed the process.

Interventions in poor and vulnerable regions are the major priorities for reducing the risks of production and guaranteeing access to knowledge and credit for family farmers. The 2006 census already identified the vulnerabilities of the drylands of the semi-arid region, where 47 per cent of the country's rural population live.

The main task is to increase substantially the average productivity in the drylands of the semi-arid region and, therefore, connect them to markets. Strategies to support organic food production in this region have to be developed and managed for all levels of production, including smaller rural economic establishments. This could enable smaller-scale farmers to practise sustainable production in the Northeastern semi-arid region, which could help to improve food security at all levels for this population.

Rural poverty in Brazil should be reduced by altering the structural causes of social exclusion and inequalities through activities such as: (i) those already implemented, such as income transfers, productive inclusion, improved access to services, in combination with effective and comprehensive land reform; and (ii) the government's prioritisation of sustainable rural and solidarity development, to support family farmers and indigenous populations through all of its activities (credit, extension, research, investment in infrastructure etc.) (Romano, Soares, and Menezes 2013). In this sense, family farming is, in itself, a way of minimising acute social problems, despite the many other challenges mentioed above. The strengthening of family farming depends on the implementation of specific tools and appropriate public policy and on the capacity of representative organisations to have effective control over implementation of the tools and to resist the interests of large-scale farmers.

To increase security of land tenure, a new, inclusive and sustainable type of rural development must be designed that contributes to guarantee food security and food sovereignty, along with income generation and job opportunities. Such a strategy depends largely on addressing land reform, which some scholars consider one of the priorities of Brazilian politics.[15]

Regarding the North and Northeast regions of Brazil, there are still major gaps that need to be radically modified. Reis (2015) advocates that Brazil, mainly because it is a country of continental dimensions and has one of the highest levels of socio-economic inequality and concentration of wealth in the hands of very few, needs to immediately revamp its land distribution process, providing effective opportunities for smallholder farmers to join the market and generate sufficient income to ensure sustainable conditions for life, form families and climb out of poverty.

In this regard, means must be sought to eliminate land fraud, a common practice in the North and Northeast regions, where laws are created by landowners themselves to protect those most interested in land concentration. The North and Northeast regions, due to their historical and social context, have in fact made the least progress on land reform; therefore, there is greater urgency for the fair redistribution of unproductive and idle lands (Reis 2015).

For the second half of 2015, President Roussef announced in June of that year the development of a new plan for land reform, under the responsibility of the Instituto Nacional de Colonização e Reforma Agrária (INCRA) and the MDA. This measure is seen as a response to the criticisms made to the federal government about the small number of people settled in the last four years: 54 per cent less than in the previous period.[16]

It is important to remember that, according to Brazilian law, land ownership fulfils its social function when it simultaneously: (i) promotes the welfare of the owners and workers, as well as their families; (ii) maintains satisfactory levels of productivity; (iii) ensures conservation of natural resources; and (iv) observes the laws governing fair working relationships between those who own it and those who cultivate it. (Presidência da República, 2016) The importance of property for environmental preservation as well as increased productivity is evident.

Regarding technical assistance, capacity-building and training focused on family farming, the Technical Assistance and Rural Extension Service (*Assistência Técnica e Extensão Rural*—ATER), founded in 1948, plays an important role (Peixoto 2014). ATER is a public service tailored to small-scale family farmers, based on informal education and promoting management, production, milling and trade for agriculture and livestock services/activities, including activities in forestry management, gathering and artisanal crafts. It has been recognised as enabling a considerable acquisition of knowledge and technology, yet its major impacts are among professionals and institutions that have a network allowing the implementation and development of public policies. ATER has 27 state entities with 16,671 rural extension staff in 4,596 towns covering 2.8 million farming families.

In 2010, the National Policy for Technical Assistance and Rural Extension for Family Farming and Land Reform (*Programa Nacional de Assistência Técnica e Extensão Rural*—PNATER) was established. The policy was guided by the National Programme for Technical Assistance and Rural Extension (Pronater), which is based on sustainable development, including different categories and activities of family farming, and taking into account elements such as gender, income generation and ethnicity, as well as the role of governmental and non-governmental organisations.

There are many programmes and activities which are substantially supported by ATER policies, such as the National Programme to Strengthen Family Farming (Pronaf) Food Acquisition Programme (*Programa de Aquisição de Alimentos*—PAA), the National School Food Programme (*Programa Nacional de Alimentação Escolar*—PNAE) and the Biofuels Programme (*Programa de Biocombustíveis)*. Support for ATER must be one of the priorities of Brazilian agricultural policy, since it is the sole body with the real capacity to guarantee better use of Pronaf credit to minimise the risks of default and the benefits of agricultural production.

To build resilience, including regarding the challenges related to climate vulnerability and climate change, ATER policies should exclusively target family farming and indigenous populations. It is also essential to establish educational institutions and rural extension schools to equip small-scale farmers with the necessary scientific knowledge.

The focus of this section is on providing adaptive response options for family farming, including the feasibility of adopting agro-ecological technologies, management practices and other technologies that improve natural resource management in the semi-arid, cerrado and Amazon biomes. In this sense, practices of agroforestry and integrated crop-livestock-forestry (CLF) systems result in the integration of economic and ecological interactions between components (Lundgren 1982; Nair 1993; Young 1997). Agroforestry systems are agricultural systems that use trees and shrubs for land management. An estimated 30 per cent of the global rural population practise crop and/or animal production (Lasco et al. 2014).

Agroforestry systems offer compelling synergies between adaptation and mitigation to climate change, given that they improve the resilience of farmers with smallholdings through more efficient water use, improved microclimate, control of pests and diseases, improved farm productivity, maintaining sustainable productivity, and diversified and increased farm income, while at the same time sequestering carbon (ibid.). The potential to sequester carbon in agroforestry systems in tropical and temperate regions is promising, but little information is available to date.

BOX 4

Agro-ecological and integrated crop–livestock–forestry systems

Agro-ecological and integrated crop–livestock–forestry systems:

- minimise dependency on energy-intensive (external) inputs, enhance the recycling of biomass, and optimise nutrient availability;
- have minimal negative effects on the environment and release insignificant amounts of toxic or damaging substances into the atmosphere, soil, surface water or groundwater;
- minimise the production of greenhouse gases, and work to mitigate climate change—for example, by increasing the ability of managed systems to store fixed carbon;
- work to value and conserve biological and genetic diversity of plants and animals, both in the wild and in domesticated landscapes; and
- eliminate hunger, ensure food security in a culturally appropriate manner, empower, especially women and smallholder farmers, and guarantee every human being a right to adequate food.

Source: IFOAM/Biovision/Millennium Institute (2015).

As a production system, agroforestry is interesting for family farming in the North and Northeast regions of Brazil, as it combines economic and environmental advantages. It features the sustainable use of natural resources and less dependence on external inputs, and results in greater food security and economic inputs, both for farmers and consumers. It should be noted that there is no single implementation 'formula'; that is, for each region—Amazon, cerrado and semi-arid[17]—the choice of components of the agroforestry systems will vary. Use of the integrated CLF system is an alternative to conventional crops, as this promotes more sustainable use of soil and water resources, resulting in increased productivity.

The use of agroforestry is very important for the semi-arid region, which suffers from intense processes of erosion and water shortages. The productivity of the agricultural systems in this region is mainly limited by the availability of water and nutrients; thus, all management techniques that increase the soil water content can enhance productivity. Agroforestry presents an alternative to traditional agricultural systems, as it effectively provides soil coverage and improves the amount and quality of soil organic matter.

On the other hand, trees in agroforestry systems have another important function. They can also be used to provide certain services—for example, they serve as hedges and windbreaks, support beekeeping and provide greater thermal comfort for animals, among various other uses on a property (Ribaski 1994).

Also according to Ribaski (1994), exploratory testing of tree species to identify potential material for use in agroforestry systems had interesting results. For *Eucalyptus*, over 25 species and 160 varieties were tested, covering the states of Pernambuco, Paraiba, Rio Grande do Norte, Ceará, and Bahia. Noteworthy are also the good performance and resistance to drought of a species of *Prosopis* genus (carob), *Leucaene* (leucaena), *Mimosa* (thrush) and *Gliricidia* (gliricidia) in the same region, with the great advantage of being multi-purpose trees (for firewood, charcoal, poles, fodder, hedges, windbreaks, nitrogen fixation, shading etc.). More then 10 species of *Prosopis* were studied in the semi-arid region. The best results were found for *P. juliflora, P. pallida, P. affinis, P. Cineraria* and *P. velutina*, considered to have a potential to contribute to increased wood production, energy, and food for the regional herd.

Rearing livestock is very important for the survival of farmers, whose livelihood depends on breeding cattle, goats and sheep, and it has been responsible in large part for keeping people in rural areas (Holanda and Araújo 2004). Therefore, livestock represents the main axis of family production systems in the semi-arid region, as it is structured as a food support system (Lima 2006).

However, the challenge of raising livestock on a large scale in the semi-arid region is how to use the natural resources of Caatinga and preserve their sustainability (Andrade et al. 2006). To date, almost all the alternatives proposed have limitations because of the difficulty of biomass accumulation, which depends on rainfall in the region. According to Campanha and Holanda Júnior (2005), the degradation process that this region has experienced has been caused mainly by poor practices of exploitation of the physical and biological resources, highlighting the predatory management of the farming systems, overgrazing of the savanna, and predatory extraction, which is gradually depleting the productive potential of the region and rendering family properties technically and economically unviable. This situation will worsen in the future scenario of climate change, with higher temperatures and less rainfall.

According to Carvalho (2003), agroforestry systems developed for the semi-arid region help in an agricultural setting in several ways: increasing organic matter by eliminating burning and deforestation; improving pastoral management by adjusting stock rates; improving the management of native vegetation; and causing the rationalisation of logging through selective logging and the management of regrowth and the redistribution of nutrients in the agro-ecosystem. It also diversifies production, increases the productivity of the land and improves farmers' income and quality of life (Araújo Filho et al. 2006).

In addition to the favourable economic and financial impacts, the agrosilvopastoral system represents a better way for the family productive unit to cope with climate instabilities in the Brazilian semi-arid region. It allows the family to increase and stabilise its food supply (maize, beans, cassava, goats' milk and animal protein), and increases the stock of fodder for the animals throughout the year (sustainable use of Caatinga natural resources, strategic reserve of drought-tolerant forage, protein bank, grain and stubble crop, grass silage). With regard to water security, the system works for the protection of springs (riparian) and the reduction of water loss through the ground (Coutinho et al. 2013).

The use of agroforestry is also a sustainable and cost-effective alternative for the farmers of the Brazilian cerrado. Agricultural expansion, especially monoculture and intensive farming, has caused the degradation of this ecosystem. The use of native cerrado species is an important way to enable the degraded areas to recover. The high level of biological diversity found in the region offers numerous choices of species that can be used in agroforestry systems, adding more value to their products. Several species with multiple uses are considered commercially valuable in the cerrado, including the Barú or Cumbaru (*Dipteryx alata*) (Ribeiro, Duboc and de Melo 2004).

BOX 5

Agroforestry options for the semi-arid biome

Integrated crops, livestock and forest as an alternative for the semi-arid region

Management systems such as integrated CLF, polycultures and agroforestry are important adaptation strategies that can be used as a response to climate change.

For the semi-arid region, such management systems may be an alternative for small-scale farmers to increase their resilience in light of environmental adversity caused by climate change. They contribute to improving the physical and chemical characteristics of the soil; increase soil biota; reduce soil loss and nutrient leaching; increase soil moisture; reduce soil compaction; and emit fewer GHGs.

In addition to improving the soil, these types of agriculture allow diversification of production; increase productivity, especially when animals are raised for meat; and also add greater value to the products and property.

These technologies can also be used for the recovery of degraded pastures and in legal reserve areas and permanent protection areas.

To optimise results and reduce costs, the species used for the implementation of these technologies should be native to the semi-arid region or exotic species that are adapted to the climate.

Riachos do Velho Chico project

The Riachos do Velho Chico project aims to use community action to revitalise the Frazão and Queimada streams, which are vital water sources for farmers in this semi-arid region of Pernambuco. The project uses agroforestry to enable the recovery of riparian vegetation by supporting and conserving water resources in the region.

These streams are important because they are part of important watersheds that supply the São Francisco River or 'Velho Chico', as it is called by the Northeastern population. The species selected for this project are mostly native species and, in some cases, exotic species adapted to the climatic conditions of the region.

Source: Caatinga (2016).

In addition, species of palms, such as buriti, palm fibre and gueroba, have been used traditionally and marketed by communities in central Brazil. The babaçu, for example, produces oils used in the national and international cosmetics industries. International companies acquire this extractive product only from sustainable producers with values that are compatible with this strategy (ibid.).

On account of the high level of biodiversity and favourable conditions for the development of trees and shrub species in the cerrado, there are numerous useful species that can be used in agroforestry and permaculture, as shown in Table 4.

In the Amazon biome, family farming has developed using agroforestry systems which were and are deployed by the indigenous *mestizo* and riverside communities. Agroforestry systems were rescued from ancient cultures and updated to meet the evolving needs of land use, especially in tropical regions. Today they exist virtually in all regions where it is possible to have agricultural and forestry crops (Daniel et al. 1999).

The traditional people from the Amazon have a vast knowledge of agroforestry and have developed production techniques that guarantee and ensure the ecological balance of natural resources. In the search for alternative land uses in the region, agroforestry has grown in importance, as has the demand for species with multiple uses.

A study in Pará (Vieira et al. 2007) identified 38 species (seven temporary and 31 permanent) grown in agroforestry systems by farmers in the study area (see Table 5). The preference of farmers in the study area for annual crops and permanent fruit species is probably related to household food security and the demands of the local market (sale of fruit for the livelihood of local families).

Among the temporary annual species cultivated, cassava (*Manihot esculenta*) is the one that stands out most in the agroforestry systems studied, as does bean (*Vigna* sp.), which is quite widely cultivated and plays an important role in farmers' food security. (Vieira et al., 2007)

In a survey conducted by Bright et al. (2004) in the state of Acre, it was found that peach palm, coffee (*Coffea arabica*) and cupuassu were the most frequently used species in agroforestry. According to these authors, the preference for these species was because the farmers had high expectations of being able to market such products.

Smallholder farmers in the Amazon biome have used agroforestry systems with native fruit species in the region for the production of fibre and oils, along with cassava, rice, bean and other crops, for their livelihood. Many cosmetics companies now use this type of system to produce oils, essences and pulp from the Amazon forest and cerrado.

TABLE 4

Useful species for agroforestry and permaculture in the Brazilian cerrado

Common name	Scientific name	Common name	Scientific name
Unha-de-vaca	*Bauhinia spp*	Pequi	*Caryocar brasiliensis*
Guatambú	*Aspidosperma sp*	Banana	*Musa sp*
Cabeça-de-negro	*Ouratea hexasperma*	Mogno	*Swietenia macrophylla*
Jacarandá-muchiba	*Macherium acutifolium*	Andiroba	*Carapa guianensis*
Tabebuia	*Tabebuia ochracea*	Castanha-do-brasil	*Bertholletia excelsa*
Chumbinho	*Trema micrantha*	Cupuaçu	*Theobroma grandiflorum*
Pau-terra	*Vochysia tucanorum*	Ingá	*Inga sp*
Pau-terra-da-folha-larga	*Qualea grandiflora*	Côco	*Cocos nucifera*
Canela-de-ema	*Vellozia squamata*	Babaçu	*Orbygnia speciosa*
Abacaxi	*Ananas sp*	Pupunha	*Bactris gasipaeas*
Assa-peixe	*Vernonia ferruginea*	Pimenta-do-reino	*Piper nigrum*
Goiaba	*Psidium guajava*	Café	*Coffea arabica*
Amendoim-do-campo	*Platypodium elegans*	Faveira	*Parkia pendula*
Sapuva	*Machaerium acutifolium*	Sobrasil	*Colubrina glandulosa*
Pitanga	*Eugenia uniflora*	Erytrina	*Erythrina speciosa*
Faveira	*Dimorphandra mollis*	Seringueira	*Hevea brasiliense*
Baru	*Dipterix alata*	Dendê	*Elaeis guineensis*
Cajuí	*Anacardium humile*	Araticum	*Annonna montana*
Carne-de-vaca	*Roupala montana*	Bacuri	*Platonia insigns*
Quaresmeira	*Tibouchina sp*	Baunilha	*Vanilla sp*
Fruta-de-ema	*Couepia grandiflora*	Cacau	*Theobroma cacao*
Araticum	*Araticum crassiflora*	Cedro vermelho	*Cedrela odorata*
Bacupari	*Rheedia gardnerina*	Copaiba	*Copaiba sp*
Banha-de-galinha	*Swartzia langsdorfii*	Fruta-pão	*Artocarpus altilis*
Buriti	*Mauritia vinifera*	Genipapo	*Genipa americana*
Caju-de-árvore-do-cerrado	*Anacardium othonianum*	Pau-rosa	*Aniba rosoedora*
Guariroba	*Syagrus oleraceae*	Carnaúba	*Copernicia cerifera*
Curriola	*Pouteria ramiflora*	Buriti	*Mauritia flexuosa*
Fruto-do-tatu	*Chrysophyllum soboliferum*	Tucumã	*Astrocarymum vulgare*
Gariroba	*Compomanesia cambessedeana*	Gliciridia	*Gliciridia sp*
Gravatá	*Bromelia balansae*	Estacas	*Gliciridia sepium*
Jaracatiá	*Jaracatia heptaphyla*	Pinhão-do-paraguai, estacas	*Jatropha curcas*
Jatobá-do-cerrado	*Hymenaea stigonocarpa*	Sete-capotes	*Guazuma ulmifolia*
Jatobá-da-mata	*Hymenaea stilbocarpa*	Munguba	*Pachira aquatica*
Macaúba	*Acrocomia aculeata*	Açaí	*Euterpe oleraceae*
Mama-cadela	*Brosimum gaudichaudii*	Mamão	*Caryca papaya*
Mangaba	*Hancornia speciosa*	Maracujá	*Passiflora sp*
Marmelada-nativa	*Alibertia edulis*	Canela	*Nectandra myriantha*
Pêra-do-cerrado	*Eugenia klostzchiana*	Guaraná	*Paullinia cupana*
Pitomba	*Talisia esculenta*	Murici	*Byrsonima verbacifolia*
Eucalipto	*Eucalyptus sp*	Sombreiro	*Clitoria racemosa*
Pinus	*Pinus sp*	Pau-santo	*Kielmeyera coriacea*
Leucena	*Leucaena leucocephala*	Vinhático	*Plathymenia reticulata*
Leucena	*Leucaena diversifolia*	Caliandra	*Calliandra sp*
Leucena	*Leucaena shannoni*	Ipê-roxo	*Tecoma curialisa*
Albizia	*Albizzia sp*	Barbatimão	*Stryphonodendron adstringens*
Caliandra	*Calliandra callotrysurs*	Embiruçu	*Eriotheca pubescens*
Acioa	*Acioa sp*	Ipê-amarelo	*Tabebuia sp*
Sesbania	*Sesbaniasp*	Eritrina	*Erythrina edulis*
Fleminga	*Flemingia congesta*	Ritrina	*Erythrina poepigiana*

Source: Ratter et al. (1998).

TABLE 5
Species grown in agroforestry systems in Pará

Common name	Scientific name	Fr (%)	Finality
	Temporary		
Mandioca	*Manihot esculenta Crantz*	28,1	A,C
Feijão caupi	*Vigna sp*	25	A,C
Abacaxi	*Ananás comosus L.*	3,1	C
Batata doce	*Ipomea batatas (L.LAM).*	3,1	A
Jerimum	*Curcubita sp.*	3,1	A
Pimenta-de-cheiro	*Capsicum sp.*	3,1	A
	Permanent		
Pimenta-do-reino	*Piper nigrum L.*	50	C
Cupuaçu	*Theobroma grandiflorum*	34,4	A,C
Caju	*Anacardium occidentale L.*	21,9	A,C
Açaí	*Euterpe oleracea Mart.*	18,8	A
Maracujá	*Passiflora sp*	18,8	C
Mogno	*Swietenia macrophylla King.*	18,8	C
Pupunha	*Bactris gasipaes H.B.K*	18,8	A,C
Coco	*Coccus nucifera L.*	15,6	C
Nim Indiano	*Azadirachta indica A. Juss*	15,6	C
Graviola	*Annona muricata L.*	12,5	C
Urucum	*Bixa orella L.*	12,5	C
Andiroba	*Carapa guianensis Aubl*	9,4	C
Muruci	*Byrsonima carssifolia H.B.K*	9,4	C
Teça	*Tectona grandis Lf.*	9,4	C
Acacia mangium	*Acacia mangium WILLD*	6,3	C
Banana	*Musa sp*	6,3	A,C
Laranja	*Citrus sinensis (L.) Osb.*	6,3	A,C
Limão	*Citrus sp.*	6,3	C
Mamão	*Carica papaya L.*	3,1	A
Abacate	*Persea americana Mill*	3,1	A
Bacabi	*Oenocarpus minor Mart*	3,1	A
Cacau	*Theobroma cacao L.*	3,1	C
Cedro	*Cedrela odorata L.*	3,1	C
Cumaru	*Dipterix odorata (Aubl.) Wild*	3,1	C
Ingá	*Inga edulis Mart.*	3,1	A
Ipê	*Tabebuia serratifolia Rolfe*	3,1	C
Manga	*Mangifera indica L.*	3,1	C
Paricá	*Schizolobium amazonicum (Huber) Ducke*	3,1	C
Quaruba	*Vochysia sp.*	3,1	C
Sumaúma	*Ceiba pentandra (L.) Gaertn*	3,1	C
Tachi	*Triplaris surinamensis Cham.*	3,1	C

Source: Vieira et al. (2007).

Notes: Fr (%) - Relative frequency expressed in percentage. A: Own consumption. C: Commercialization.

The adoption of agroforestry—agrosilvopastoral and silvopastoral systems—with annual crops, forest and pasture can also reduce the negative effects of the rigours imposed by the tropical climate on animals, and improves the use of natural resources, with a subsequent increase in productivity and lower costs. Thus, agroforestry makes agriculture a more intensive and sustainable activity, with profitability on the sale of products and derivatives, adding value to the property, in addition to landscaping, allowing ecotourism (Castro et al. 2008).

Cattle ranching on the cultivated pastures of the Amazon has been stigmatised as being responsible for the low efficiency of land use. The profitability of livestock production depends on the effectiveness of the operation, rational pasture management, the breeding herd, intensive production of meat and/or milk, high productivity, economy, and preservation of the environment (Veiga et al. 1996).

In recent years, an alternative that has been used successfully is 'integrated pasture'—using the productive potential of the forage floodplain in the dry season and the pastures on the land—of the genera *Brachiaria* (*Brachiaria humidicola, Brachiaria brizantha*). This system has not caused significant environmental damage by using smaller and different areas (Castro 2008).

Agrosilvopastoral systems may also be relevant to buffalo production in the Amazon. The use of land altered by inappropriate use can add value to the land, via tree components, providing better nutrient cycling and improved animal comfort. It may also, for example, qualify as a low-carbon technology for funding from the ABC Plan (see Section 5). These systems represent attractive alternatives for sustainability maximising land use (ibid.).

The adoption of integrated management systems, such as agrofrestry and CLF, also plays an important role in increasing carbon stocks in the short and medium term through the assimilation of CO_2 from the atmosphere, because of carbon incorporation into the biomass and above ground. Another advantage of these systems is the possibility of inclusion in the Payment for Ecosystem Services (PES) and Clean Development Mechanism (CDM) programmes, which represent a source of supplementary income for farming families, in addition to improvements in environmental conditions.

The main issue regarding integrating agroforestry systems is the importance of soil as one of the essential components of the Earth's natural ecosystems. In recent decades, agricultural productivity and quality have grown to such an extent that their intensive use has caused a decrease in their ability to maintain sustainable production (Karlen and Stott 1994).

In recent decades, large areas of Brazil's semi-arid region have been degraded by traditional agricultural practices (Sousa et al. 2012). Studies of such systems describe the deleterious changes in the chemical and physical properties of the soil through erosion, a decrease in carbon stocks, the depletion of water reserves, and a reduction in the available soil nutrients, especially nitrogen (N) and phosphorus (P) (Aguiar et al. 2010; Maia et al. 2007; Silva et al. 2011). Agroforestry systems represent an efficient way to provide soil coverage and improve soil organic matter levels (Breman and Kessler 1997) through the maintenance and management of organic residues provided by trees, crops and animals (Altieri 2004). Trees are expected to improve soil fertility and benefit crops and pastures through their capacity for rooting depth, nitrogen fixation in some cases, and soil retention (Breman and Kessler 1997).

Farmers play an important role in the maintenance of the physical, chemical and biological properties of soil. The use of sustainable agricultural practices such as agroforestry, CLF, polycultures and organic agriculture promotes the maintenance of soil quality, as these practices increase the acumulation of soil organic matter, maintain soil moisture, decrease soil erosion and leaching, and also ensure clean and safe water.

According to Embrapa Semiarido, the use of green manures—single plants or vegetable cocktails—may be a viable management strategy for increasing soil fertility in the semi-arid cerrado and the Amazon regions. A vegetable cocktail consists of planting a mixture of seeds of various species and families, including legumes, grasses or oilseeds, among others, to promote improvement in the chemical, physical and biological properties of soil. The supply of organic material provided by the species planted in the cocktail also provides better exploitation of the soil, recycling nutrients more efficiently than a monoculture, thus favouring the diversification of species in the production systems (including increasing and diversifying the microbial population present in the rhizosphere) and providing organic material with a richer nutrient composition. The use of interim plants in the form of green manure enables the use of high amounts of organic waste, which helps in increasing the soil's carbon content and cation exchange capacity (CEC), as well as in reducing the leaching of cations and water. Furthermore, the production of plant material *in situ*, and its use as mulch, reduces the evaporation of water applied, minimising the risk of salinisation of the crop areas.

In general, to increase the soil organic matter, it is important to use fast-growing species capable of depositing plant residues in the soil and recycling nutrients. Leguminous trees are a good option, as they have a vast root system and the potential for nodulation and symbiotic fixation of atmospheric nitrogen, and are multipurpose trees.

For centuries the small-scale agricultures of developing countries were built on the local land, water and other resources, as well as local varieties and indigenous knowledge. These have been robustly nurtured by biologically and genetically diverse smallholder farms, and a built-in resilience has helped them to adjust to rapidly changing climates, pests and diseases (Denevan 1995). The persistence of millions of agricultural hectares under traditional management, in the form of raised fields, terraces, polycultures (with a number of crops growing in the same field), agroforestry systems etc., documents a successful indigenous agricultural strategy and pay a tribute to the 'creativity' of traditional farmers.

Many family farmers in the semi-arid, Amazon and cerrado regions have a vast amount of knowledge about the varieties they produce. According to Neto et al. (2012), in the Paraíba semi-arid regions some producers have 11 cultivars, especially maize and beans. In the communities studied, a possible facilitator of productive development is the appreciation of the local grain seeds (maize and beans)—a total of six varieties of beans and five of corn—which are the main income-generating crops.Table 6 presents the strategies of adaptation to environmental and natural resource management problems.

In addition to vulnerability to climate change, people living in rural areas already face constraints regarding their economic participation. The food and agriculture sector lies at the heart of the development process and is both a main cause of, and solution to, the world's environmental (e.g. climate) and social (e.g. unsatisfied basic needs) problems. Small-scale food producers around the world face enormous challenges meeting their food needs and contributing to the food security of their communities and countries. These challenges are compounded by climate change. Without efforts to address and adapt to climate change, more erratic weather will result in lower yields for basic staple grains (FAO 2014).

The lack of job creation and income policies, unemployment, concentration of income, and low wages are factors that can result in a drop in food consumption, and may cause hunger. On the other hand, when there is a lack of agricultural policies, high interest rates, falls in agricultural prices, and agricultural crisis, there is a reduction in food supply, which can also cause food insecurity and hunger. Added to these elements, the lack of agricultural research, technology transfer, technical assistance and rural extension also contributes to food insecurity (MDA 2010). All these components together create a negative feedback process. Especially in recent decades, the Government of Brazil has adopted many financing instruments which, when combined with social protection policies, have helped to reduce poverty and social vulnerabilities and have also helped to improve the income and quality of life of small-scale farmers and family farming.

TABLE 6

Strategies of adaptation to environmental and natural resource management problems

Technology	Advantages
Agroforestry and integrated crop-livestock-forestry (CLF) systems	Can be applied to small-, medium- and large-scale farmers; more efficient control of insects, diseases and weeds, leading to lower pesticide use; improved microclimatic conditions thanks to the tree component reducing thermal amplitude, increasing air humidity and lowering wind intensity (huge adaptive characteristics to climate change); increased animal well-being due to improved thermal comfort; possibility of reducing pressure for deforestation; possibility of using the most suitable species for each region; great potential for carbon sequestration and mitigation of greenhouse gas emissions; increased regional production of grains, beef, milk, fibres, timber and energy; higher turnover for several segments of the local economy; diversification of farm activities, improving year-round labour demand; lower costs for afforestation through cultivation of pasture and/or annual crops.
Multiple cropping and polyculture systems	This type of management, with different crops at the same time, favours the replacement of minerals in the soil, unlike monoculture, which makes them scarce; productivity in terms of harvestable products per unit area of a polyculture developed by small landholders is higher than under a single crop with the same level of management; by managing fewer resources more intensively, small-scale farmers are able to make more profit per unit of output and, thus, make more total profits—even if production of each commodity is lower; diversified farms produce much more food; less vulnerable to catastrophic losses because they grow a wide variety of crops and varieties, in various spatial and temporal arrangements; increased resilience of producers to climate change; this type of management should use the species local to each region (North, Northeast and semi-arid).
Organic production	No use of synthetic fertilisers, pesticides, growth regulators or synthetic additives for animal feed; minimal use of tillage ensures structure and soil fertility, avoiding erosion and degradation; allows considerable cost savings for small-scale producers and adds value to the products that go to the market with respect to ecological seals with quality assurance; great climate change adaptation strategy.
Home gardening	Urban agriculture can help supply food to undernourished populations in cities; home gardeners can be an important part of the solution to climate change by using climate-friendly practices in gardens and landscapes; practising sustainable gardening and landscaping techniques can dramatically reduce carbon emissions and slow warming by increasing carbon storage in the soil and landscape; urban agriculture can be one of the solutions to water shortages, erosion, greenhouse gas emissions and an important tool to promote food security in the north and northeast of Brazil. Moreover, the use of agricultural gardens in towns also contributes to the scenic beauty of the large urban centres; home gardens can be important spaces for improving the income of farming families, as they offer an important addition to food and other essential items needed for their livelihood.
Wild plant gathering	Provides a second source of income for many farmers, also helps the family's livelihood; when well managed allows the sustainable use of renewable resources for various uses (pharmaceutical industry, cosmetics and the furniture industry, among others) and allows maintenance of the Brazilian socio-biodiversity and traditional knowledge of certain communities; employment and income from extractive activities are of great importance to the rural economy, particularly for poor households and women.

→

Preventing pest, disease and weed manifestation	The use of biocontrol with small animals such as chickens, ducks, quail and others is an important tool for disease prevention and control in family farming; this type of management has many advantages, since it represents a new alternative livelihood for the family, with the use of meat and eggs (if the animals produce eggs); it is cheaper than the use of insecticides and does not harm the environment nor endanger the health of workers and consumers.
Genetic breeding	The fundamental strategy in genetic engineering is to modify the plants to allow them to be productive in adverse conditions that are caused by pests, pathogens, drought, saline environments and unfertile soils; or to design plants for new objectives such as plants with altered nutritional content.
Managing water	Cisterns: The cisterns, with a normal accumulation capacity of between 7 and 15 cubic metres, represent a supply of 50 litres of water daily for 140 to 300 days after being filled by the end of the rainy season and without being refilled during the period. The tank-use technique is relatively easy for small-scale farmers to incorporate and has growth potential compared to other countries that adopt this strategy. Underground Dam: The underground dam is a very low-cost intervention, simple in construction and operation, and may be implemented on a large scale, as this is natural under such conditions.
Biomass-producing plants	Biofuels present a possible alternative to non-renewable energy sources; the increasing employment levels in the biofuel agroindustry have contributed to a reduction in rural–urban migration and avoided adding to the growth of populations in large cities, especially in developing countries; Brazil could become a major international player in this process, as the country has the potential to explore various forms of biomass.

The main policies and interventions for food security in Brazil are Zero Hunger (*Fome Zero*), the Food and Nutrition Surveillance System (SISVAN), the Food Acquisition Programme (PAA), the National School Feeding Programme (PNAE), the Family Agriculture Price Guarantee Programme (PGPAF), the Workers' Food Programme (PAT), the National Programme for Strengthening Family Agriculture (Pronaf) and rural micro-credit (Pronaf Group B). Nevertheless, these instruments are not able to tackle the issue of hunger alone, much less ensure food security for the population (ibid.). Apart from government action, it is worth pointing out that the implementation of this set of measures depends on the commitment of several institutions, such as international organisations, non-governmental organisations (NGOs) and research institutions, among others. The Brazilian government's key policymaking actions will be presented in the following section.

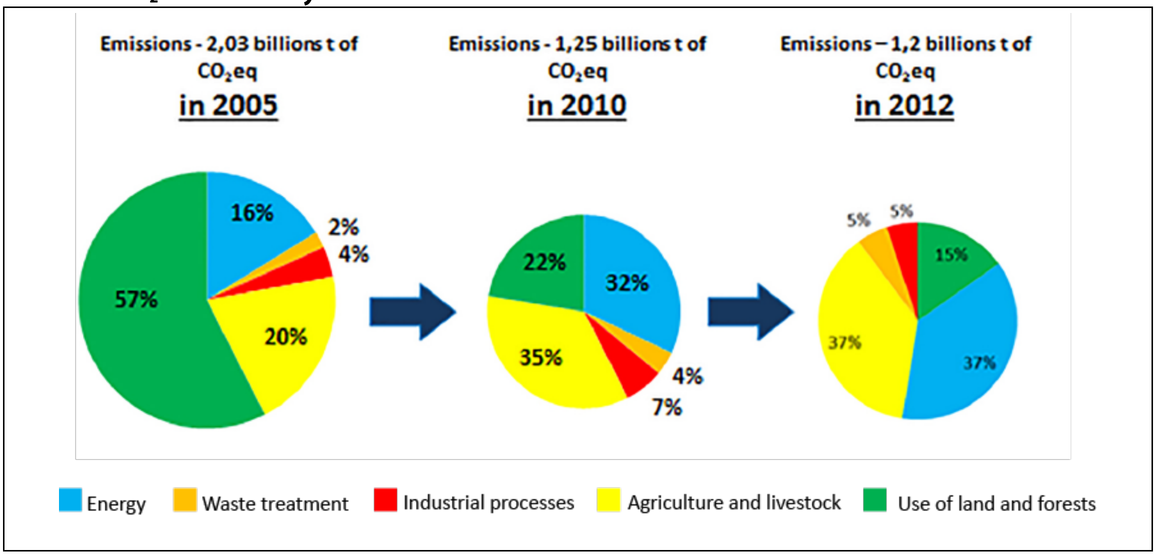
Regarding access to the benefits of the policies, technicians should advise families to choose activities that generate income and ensure food security; ensure forms of insertion in local and regional markets, including institutional markets; and provide technical assistance and guidance for the appropriate implementation and development of projects that give positive returns. To reduce the vulnerabilities and increase the resilience of family farming to the expected adverse impacts of climate change, it is essential to train technicians in relevant strategies, including those mentioned above.

5 MAIN INSTITUTIONS AND PUBLIC POLICIES IN THE CONTEXT OF CLIMATE CHANGE

In addition to the fact that the total amount of GHG emissions in Brazil has significantly decreased in recent years, the composition of its emissions has changed rapidly in the last decade. As can be seen in Figure 8, Brazil emitted approximately 2.03 billion tons of CO_2 equivalent in 2005, 1.25 billion in 2010 and 1.2 billion in 2012. These estimates are being refined and should be reflected in the national inventory to be contained in the Third National Communication of Brazil to the UNFCCC, which is expected to be published in early 2016.
As far as this study is concerned, it is worth highlighting that the proportion of GHG emissions from the land use, land-use change and forestry (LULUCF) sector decreased from 57 per cent in 2005 to 15 per cent in 2012, and the proportion of emissions from the agricultural sector increased from 20 per cent in 2005 to 37 per cent in 2012.

FIGURE 8

Brazilian CO_2 emissions by sector



Source: MCTI (2014).

It is worth noting that the final figures from the third Brazilian inventory on GHG are not yet available, so we cannot verify whether the absolute figures for the agricultural sector have increased or not. However, it should also be mentioned that the main shift shown in Figure 8 is due to the relative success in reducing deforestation in Brazil, more specifically in the Amazon region, in the last decade, according to data from the Project for Estimating Gross Deforestation of the Brazilian Amazon (PRODES).

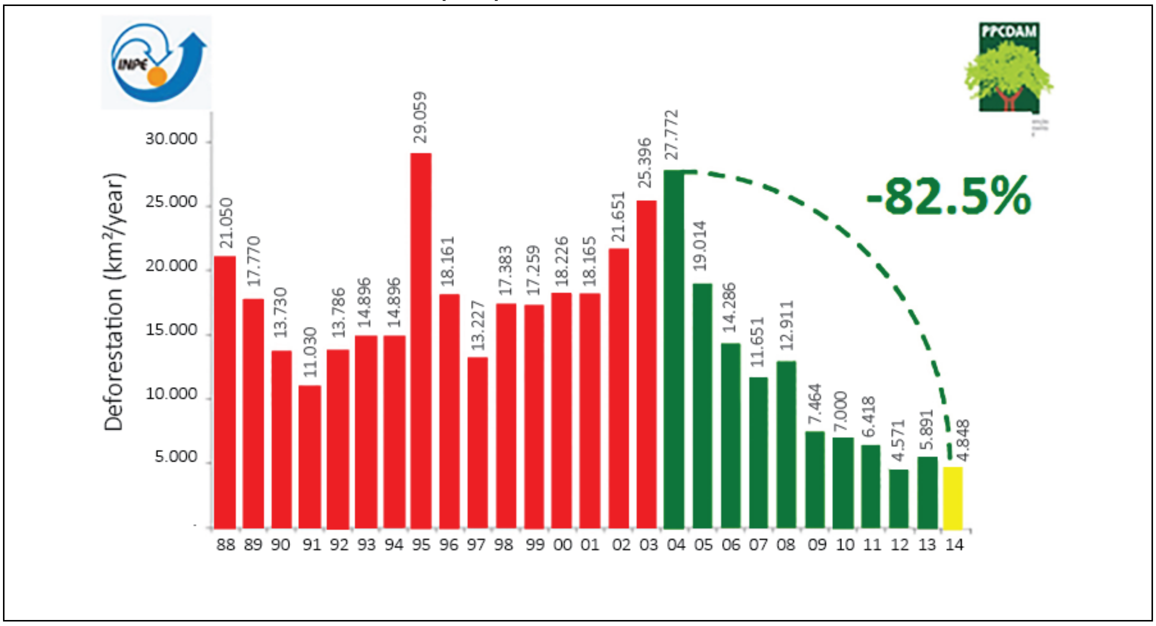
Although a considerable reduction in total GHG emissions can be observed, the increased significance of agricultural activities in GHG emissions may have a major impact in terms of public policies related to agricultural activities in the context of climate change in the near and medium term. However, it is yet to be seen how (and if) the special context of family farming will be reflected in present and future public policies to be adopted.

The National Plan on Climate Change, which was launched on 1 December 2008, was a significant step towards a more structured and organised set of mitigation actions with the aim of collaborating with international efforts to combat climate change. The National Plan must be guided by the National Policy on Climate Change (PNMC), which emerged later. With the adoption of the National Policy, the National Plan has been reviewed and updated in light of this more comprehensive legal instrument.

As far as the main topic of this study is concerned, it is worth noting that the MDA is part of the broad Interministerial Committee, but it has not been included in the Executive Group on Climate Change (GEx). Since the MDA is the main ministry (and secretariats) responsible for family farming issues, its absence from the main institution in charge of coordinating the creation and implementation of the national and sectoral plans might impose some constraints on the direct consideration of issues related to family farming in climate change policies and regulations. However, it is worth pointing out that the Ministry of Agriculture, Livestock and Supply (MAPA), which is usually more associated with larger commercial agricultural sectors, is part of the GEx. Given the need to coordinate efforts to improve the resilience of family farmers in the face of challenges related to climate change, closer cooperation between the MDA and the MAPA on these issues will be fundamental.

FIGURE 9

Brazilian deforestation 1988–20194 (km²)



Source: INPE (2015).

The PNMC, enacted by Law No. 12,187, of 29 December 2009, established its own principles, objectives, guidelines and instruments. It aims, among other things, to harmonise social and economic development while protecting the climate system; reduce anthropogenic GHG emissions in relation to their various sources; strengthen GHG sinks in the country; and implement measures to promote adaptation to climate change by the three levels of government (federal, state and local), with the participation and collaboration of economic and social stakeholders, particularly those especially vulnerable to its adverse effects (Machado Filho 2013).

As announced at the 15th session of the Conference of the Parties (COP 15) and COP/MOP-5, the text of the law provides that, to achieve the goals of the PNMC, the country will adopt, as a voluntary commitment at national level, actions to mitigate GHG emissions with a view to reducing its projected emissions by between 36.1 per cent and 38.9 per cent by 2020. Accordingly, in January 2010 the Government of Brazil informed the Secretariat of the Framework Convention of the nationally appropriate mitigation actions that it intends to undertake. These actions are shown in Box 6.

BOX 6

Mitigation actions proposed by the Brazilian government

- Reduction in the deforestation of the Amazon (range of estimated reduction: 564 million tons of CO_2 eq. by 2020);
- Reduction in cerrado deforestation (range of estimated reduction: 104 million tons of CO_2 eq. by 2020);
- Restoration of grazing land (range of estimated reduction: 83 to 104 million tons of CO_2 eq. by 2020);
- Integrated system of crops and livestock (range of estimated reduction: 18 to 22 million tons of CO_2 eq. by 2020);
- No-till farming (range of estimated reduction: 16 to 20 million tons of of CO_2 eq. by 2020);
- Biological nitrogen fixation (range of estimated reduction: 16 to 20 million tons of CO_2 eq. by 2020);
- Energy efficiency (range of estimated reduction: 12 to 15 million tons of CO_2 eq. by 2020);
- Increase in the use of biofuels (range of estimated reduction: 48 to 60 million tons of CO_2 eq. by 2020);
- Increase in energy supply by hydroelectric power plants (range of estimated reduction: 79 to 99 million tons of CO_2 eq. by 2020);
- Alternative energy sources (range of estimated reduction: 26 to 33 million tons of CO_2 eq. by 2020);
- Iron and steel (replace coal from deforestation with coal from planted forests) (range of estimated reduction: 8 to 10 million tons of CO_2 eq by 2020).

In 2010, the work to implement the PNMC started, with a view to establishing priority sectoral plans to achieve its mitigation goals. This included an Action Plan to Prevent and Control Deforestation in the Legal Amazon (PPCDAM); an Action Plan to Prevent and Control Deforestation in the Cerrado (PPCerrado); and a Mitigation and Adaptation Plan for a Low Carbon Agriculture and Livestock Sectors, known as the ABC Plan (*Agricultura de Baixo Carbono*).

The National ABC Plan was originally established by the MAPA/MDA Interministerial Ordinance No. 984/13. It aims to promote the mitigation of GHG emissions in agriculture; improve the efficient use of natural resources; increase the resilience of the systems of production and rural communities; and enable the adaptation of the crops and livestock business sector to climate change.

At the national level, the ABC Plan follows the directions of the PNMC. It is coordinated jointly by the MAPA and the MDA. From the operational point of view, State Management Groups are being created, which will be in charge of promoting coordination and articulation of the Sector

Plan for Agriculture in the states. These groups include representatives of civil society (the productive sector, workers, universities, research, cooperatives, agriculture federations, NGOs etc.), which is essential so that the claims of family farmers can be taken into consideration.

The consolidation of public–private partnerships is also essential to enhance the Plan's activities and replicate them at the state and municipal levels. Such activities could be made more efficient through the dissemination and adoption of sustainable practices aimed at reducing GHG emissions in agriculture and thus minimising the possible negative impacts of climate change through adaptive practices.

As part of the PNMC, there is also the National Adaptation Plan to Climate Change (*Plano Nacional de Adaptação à Mudança do Clima*—PNA), which has been coordinated by the Ministry of Environment.[18] The PNA is an instrument developed by the federal government in collaboration with the Brazilian Forum on Climate Change, civil society, the private sector and state governments that aims to promote the reduction of national vulnerability to climate change and risk management associated with this phenomenon.

The sectors covered by the PNA include agriculture, water resources, food security and nutrition, which are issues closely related to family farming. The PNA elaboration process is still ongoing, and public consultations have been held. The participation of all family farming stakeholders in the public consultation process is fundamental to ensure that their interests will be reflected in this important planning instrument.

The National Fund on Climate Change (Fundo Nacional de Mudança do Clima— FNMC) was created by Law No. 12,114, published in December 2009. It is an accounting-based fund under the Ministry of Environment aimed at ensuring resources to support projects and studies and to finance undertakings that aim at mitigating climate change and adapting to climate change and its effects.

FNMC funds are used to provide reimbursable financial support through the granting of loans by the operator agent, and non-reimbursable financial support for projects related to the mitigation of climate change or adaptation to climate change and its effects, approved by the FNMC Managing Committee, as per the guidelines previously established by the Committee. The definition of resources to be invested in each of the modalities is up to the Committee, and this application may be used in projects that address, *inter alia*: GHG emission reduction projects; adaptation of society and of ecosystems to global climate change impacts; reduction of carbon emissions from deforestation and forest degradation, with priority given to natural areas threatened with destruction and important for biodiversity conservation strategies; sustainable production chains; payments for environmental services to communities and individuals whose activities verifiably contribute towards carbon storage; agroforestry systems that contribute towards a reduction in deforestation and the absorption of carbon by sinks and towards income generation; and the recovery of degraded areas and forest restoration.

The FNMC's financial agent is the Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social—BNDES), which can also enable Banco do Brasil, Caixa Econômica Federal and other public finance agents to conduct financial operations using FNMC resources. Nevertheless, the FNMC has been criticised for being excessively bureaucratic and with interest rates higher than other funds.[19]

There is also the Amazon Fund, created by means of Decree No. 6,527, of 1 August 2008. It aims to attract donations for non-reimbursable investments in activities that can contribute to preventing, monitoring and combating deforestation, as well as initiatives that promote the conservation and sustainable use of the Amazon biome, as per the terms of the decree. The BNDES manages the Amazon Fund through a Steering Committee.

The Amazon Fund[20] supports projects in areas including management of public forests and protected areas; sustainable forest management; economic activities carried out from sustainable use of the forest; ecological and economic zoning, land planning and land compliance; and recovery of degraded areas. Similar to the FNMC, the Amazon Fund has been criticised for being excessively bureaucratic and with interest rates higher than other funds.

In the last decade, given the growing awareness of issues related to climate change in the country, and also thanks to the work done by the Brazilian Forum on Climate Change, many climate change fora at state level have been established, although the levels of institutionalisation and active engagement differ considerably.

In the North and Northeast regions of the country, which is the focus of this study, many fora have also been established by state decrees, but their implementation is at different stages. The most active state fora in the Northeast are in the states of Pernambuco and Ceará. There is also evidence of these kinds of fora in Piauí, Bahia and, more recently, Maranhão. The states of Alagoas, Sergipe and Rio Grande do Norte have not yet established any. As for the states in the North region, there are state fora on climate change in Amazonas, Para and Rondonia. In theory, they can help to set up and implement the major national policies on climate change at state level, and bring together many relevant actors and institutions. Nevertheless, the lack of information on existing activities, the lack of institutional structure and staff, and the discontinuity of activities and difficulties in funding are significant, and make it difficult to assess their impact.

More recently, in preparation for COP 21, countries have agreed to publicly outline what post-2020 climate actions they intend to take under a “legal instrument or an agreed outcome with legal force under the Convention”, known as their Intended Nationally Determined Contributions (INDCs). The INDCs will largely determine whether the world will be able to achieve an ambitious 2015 agreement and is put on a path toward a low-carbon and climate-resilient future.

Among the actions under its INDCs related to the agricultural sector, Brazil announced the intention to strengthen the ABC Plan as the main strategy for sustainable agricultural development, including by restoring an additional 15 million hectares of degraded pasturelands by 2030 and enhancing 5 million hectares of integrated CLF systems by 2030. In the land-use change and forestry sector, efforts include strengthening and enforcing the implementation of the Forest Code, at federal, state and municipal levels; strengthening policies and measures with a view to achieving zero illegal deforestation in the Brazilian Amazon by 2030 and compensating for GHG emissions from the legal suppression of vegetation by 2030; and restoring and reforesting 12 million hectares of forests for multiple purposes by 2030.

Despite the uncertainties of the successful implementation of the plans and policies adopted at state and national levels, it should be recognised that in recent years there has been an increasing number of initiatives at various stages of implementation that are contributing and/or will contribute to the inflection in the growth rate of the GHG emissions curve in the country, which reflects the commitment by many stakeholders to combat climate change.

Nevertheless, in most of the existing institutions and public policies in the context of climate change in Brazil, the space for issues related to agriculture is limited. As far as the issue of family farming is concerned, such a role is marginal or virtually non-existent. The fact that agricultural activities are responsible for an increasing proportion of GHG emissions may have a significantly impact in terms of public policies related to agricultural activities in the context of climate change in the near and medium term. However, if this is in fact verified it is likely to address issues related more to commercial farming, especially as far as mitigation aspects are concerned. It is yet to be seen how (and if) the special context of family farming will be reflected in the public policies and programmes to be adopted, especially if adaptation is to be taken into consideration. Hence, the mobilisation of stakeholders in the sector is fundamental to reflecting their interests in future policies and regulations, including the mobilisation of funding.

6 CONCLUSIONS

Climate change has been increasingly recognised as the main challenge that humanity will face in the coming decades. This study started by considering future climate change scenarios and their uncertainties. First, global projections from AR5 were presented. Second, they were compared with regional scenarios developed by the INPE, with a focus on two main IPCC scenarios (RCP4.5 and RCP8.5) and two main global models (MIROC and Hadley Centre) for 2011–2040 and 2041–2070.

In this context, the main conclusions on future climate scenarios for the North and Northeast regions of Brazil were identified. In Brazil, the region with the higher increase in average temperatures in the next few decades will be the Centre-West. However, until the end of the century, there will be also an expansion of this trend to the North and Northeast regions, mostly in their central areas.[21]

The North and Northeast regions should also experience more interannual variability of rainfall during the rain season of December to February. There is a general trend for Brazil of less rainfall in the rainy season (summer), although this trend is more evident in the Southeast and Centre-West regions of the country. On the other hand, the northeastern part of the Northeast region is expected to have an increase in precipitation rates for the summer. The North region should also experience less rainfall during autumn, and the north of the region will also have less rainfall in the winter. Overall, most of the reduction in rainfall is projected to occur in the North region.

In assessing the possible climate change scenarios and their related impacts on family farming across Brazil's North and Northeast regions, the main conclusion is that smallholder farmers will have to adapt to a world of increasing climate variability. The challenge is to understand, with a certain level of confidence, how the main crops of the region are expected to be affected by climate change, as well as to provide recommendations on how to increase the resilience of family farming in the region.

Regarding the impacts on selected crops,[22] the study considered the most relevant related products for smallholder farmers in the regions and the impacts on their production that are expected to have detrimental outcomes in terms of food security, mostly for poor rural communities. Unfortunately, the main findings were not encouraging. The areas cultivated with most of the crops will suffer a significant reduction in the Northeast and North regions, with a significant loss of production. The whole area of the Northeast semi-arid region, and the region of northeastern savannas—southern Maranhão, southern Piauí and western Bahia—will be the worst affected. Soybeans and coffee may experience the heaviest losses, whereas sugarcane and manioc will suffer less than other crops (Assad et al. 2008).

Therefore, the impacts of climate change are likely to pose a major threat to food security in rural communities. Nevertheless, it is important to clarify that this study attempted to assess the potential impacts of climate change on selected crops in BAU scenarios, which is usually the methodology used when assessing the effects of climate change. With early planning and innovative techniques, it is possible to reduce vulnerabilities and increase resilience, now and in the future.

Before exploring ways in which family farming might respond to the adverse impacts of climate change, including techniques and technologies, it is fundamental to better understand the problems already affecting the producers that could be aggravated by changes in temperature and precipitation. Family farmers in the Northeast and North regions of Brazil already face many problems, especially related to poverty and its effects. The current social vulnerabilities of these populations are likely to increase if the expected impacts of climate change occur. Thus, a comprehensive understanding of the main social drivers that affect the lives of family farmers is important so that actions can be taken to increase their resilience.

In addition to social problems, family farmers in the cerrado, semi-arid and Amazon regions also face many environmental and natural resources management problems. Thus, developing an in-depth understanding of the biodiversity of the regions and how these biomes and agricultural activity may counteract the negative effects of climate change are the firsts steps to identifying how its resources can be used sustainably, reducing environmental degradation and improving the quality of life of its inhabitants (INSA 2011). Such a strategy could represent an effective way to reconcile food production and environmental quality.

In the regions examined in this study, some economic activities (large-scale agrobussiness, large-scale animal rearing, mining activities) have gained ground at the expense of family farming, with implications for the sustainable management of the semi-arid, cerrado and Amazon regions (prices of some agricultural crops rising significantly, restricted access to seed markets, and trade difficulties). The negative effects of these practices have the potential to be amplified in the context of climate change.

In terms of the potential options for family farming to respond to the adverse impacts of climate change, initially the policies and interventions aimed at addressing social vulnerabilities were explored (e.g. programmes related to eradicating poverty in rural areas and others). Despite the efforts made in the last decade, large regional disparities still exist in the country, especially in the rural areas of the North and Northeast regions, which have the lowest HDI in Brazil.

The study assessed many strategies of adaptation to environmental and natural resource management problems, also considering that they could increase the resilience of family farmers to the adverse effects of climate change. In this regard, adaptive response options (including other economic alternatives for the families) were explored, including the feasibility of adopting agro-ecological technologies, management practices, and other technologies that improve natural resource management. The options considered combined adaptation and mitigation aspects of the activities assessed.

One important conclusion was that, through agro-ecological and other sustainable approaches to agriculture,[23] smallholder and small-scale family farmers could play an important role in offsetting elements of the present environmental crisis, as well as of those related to the future threat of climate change. These approaches commonly involve the maintenance or enhancement of biodiversity, and represent a viable long-term strategy to improve the agro-ecosystem's resilience to the effects of climate change.

It is worth highlighting that in Brazil family farming is responsible for producing most of the food consumed domestically. Thus, it is fundamental that producers increase their resilience to adverse effects of climate change, whether through economic instruments (e.g. through food security instruments, innovative financing, labelling, adding value to products etc.) or the dissemination of new technologies and programmes (e.g. genetic improvement, biomass-producing plants etc.) in the private and public sectors. In this regard, the adoption of policies to address market failures is essential.

Regarding the existing institutions and public policies in the context of climate change in Brazil, the space for issues related to agriculture is quite limited, and marginal or virtually non-existent for family farming. Given that agricultural activities have more recently been responsible for a significantly larger proportion of GHG emissions in Brazil, this may have a potential impact in terms of adopting new or refining existing public policies to address issues related to agriculture in the context of climate change. Nevertheless, if this scenario is in fact verified, it is likely to address issues related more to commercial farming, especially as far as mitigation aspects are concerned. It is yet to be seen how (and if) the special context of family farming will be reflected in the public policies and programmes to be adopted, especially if adaptation is to be taken into consideration. Thus, for the interests of the sector to be reflected in such policies and regulations, including the mobilisation of funding, the increased awareness and participation of stakeholders in the sector is essential.

Another main conclusion is that there is a significant lack of literature regarding family farming and climate change, not only at national level but also at global level. A significant example is the fact that the last IPCC report, the most comprehensive literature review on climate change, from its groups on vulnerability and adaptation (Working Group II) and mitigation (Working Group III), has few references to family farming. Usually, when literature regarding climate change and agriculture is found, it is addressing impacts of changes in temperature and precipitation on agricultural commodities. For this reason, there is also a lack of literature in Brazil regarding agriculture in the semi-arid and Amazon regions, since most of the agricultural commodities are produced in the South, Southeast and Centre-West regions of the country. When the element of climate change impacts is added to the equation, available material becomes scarce.

Beyond agribusiness and the export of food products, the national and international communities must realise that millions of people are living on the revenues from family farming or just on subsistence agriculture. They are the true mechanism of development. Thus, investment in people is fundamental. Mindsets should be changed so that investment in people should be the main goal—not investment in infrastructure or energy, where it could make a profit, but investing in particular in places where people who do not have infrastructure and energy live. If inequality in the world is to be reduced, especially by fighting poverty, ending hunger and malnutrition, the national and international communities need to invest in people in rural areas, who happen to be the poorest and most vulnerable.

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ANNEX I

Technologies: Short-term and long-term potential for application in the North, Northeast and Centre-West regions of Brazil

Technology	Potential for application in the North, Northeast and Centre-West regions today and for the next 10 years	Potential for application in the North, Northeast and Centre-West regions in climate change scenarios (2050)
Agroforestry and integrated crop-livestock-forestry (CLF) systems	Medium	High
Multiple cropping and polyculture systems	Medium	High
Organic production	Low	Medium
Home gardening	Low	High
Wild plant gathering	Medium	High
Preventing pest, disease and weed manifestation	Low	High
Genetic breeding	Medium	High
Managing water	Low	High
Biomass-producing plants	Medium	High

Technologies and limiting factors for short-term and long-term implementaion

Technology	Limiting factors for short-term implementation	Limiting factors for long-term implementation
Agroforestry and integrated crop-livestock-forestry (CLF) systems	Lack of capacity of rural assistance technicians and farmers; difficulties of implementation of the ABC Plan, especially in the Northeast region.	Lack of public policies and financing; extreme scenarios of climate change; desertification.
Multiple cropping and polyculture systems	Lack of capacity of rural assistance technicians and farmers; lack of specific finance for these activies.	Lack of public policies and financing; extreme climate change scenarios; desertification.
Organic production	Lack of capacity of rural assistance technicians and farmers; difficulties of implementation of the ABC Plan, especially in the Northeast region; local market.	Lack of public policies and financing; extreme climate change scenarios; desertification.
Home gardening	Lack of interest of the urban population; lack of expertise in the cities.	Lack of interest of the urban population; lack of expertise in the cities.
Wild plant gathering	Lack of organisation of cooperatives; small market for certain products; low-paid workers.	Extreme climate change scenarios; extinction of exploited species; deforestation; desertification.
Preventing pest, disease and weed manifestation	Lack of capacity of rural assistance technicians and farmers; high price and low supply of alternative products.	Unknown negative interactions between alternative products and the environment.
Genetic breeding	Need for large investments in research; dependence on multinational companies; image of genetically modified products in the consumer market.	Need for large investments in research; dependence on multinational companies; image of genetically modified products in the consumer market.
Managing water	Dependency on policies and public programmes to deal with drought (in most cases, palliative and short-term and insufficient to solve the problem).	Need for robust public policies and financing for a concrete solution; extreme climate change scenarios; desertification.
Biomass-producing plants	Dependency on public policies and international trade; reduction of available areas for production.	Dependency on public policies and international trade; reduction of available areas for production (in scenarios of increased food production and preservation of the remaining forests).

ANNEX II

ASSESSMENT OF FAMILY FARMING ACTIVITIES IN LIGHT OF THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

At the Rio+20 (UN Conference on Sustainable Development), Member States agreed to establish an intergovernmental process, through an open working group, to develop a set of action-oriented, concise and easy to communicate Sustainable Development Goals (SDGs). The SDGs are to be "coherent and integrated into the UN development agenda beyond 2015", as stated in paragraph 246 of the Rio Declaration. These new global Sustainable Development Goals (SDGs) will guide policy and funding for the next 15 years.

In August 2014, the *Ad Hoc* Open Working Group (OWG-SDG), composed of 70 governments (and all others wishing to intervene), drawing on technical inputs from the UN system, launched a proposal for a set of new SDGs to replace the Millennium Development Goals (MDGs) at the end of 2015, encompassing goals to promote sustainable development and poverty eradication. The proposal has 17 goals and 169 targets. More recently, in August 2015, the text of the proposed 17 SDGs was finalised for adoption. The SDGs are expected to be endorsed at the UN Summit to adopt the post-2015 development agenda (25–27 September 2015).

Sustainable agriculture systems aimed at alleviating poverty, such as the examples of family farming organisations, play an important role in development. Moreover, the risk management of climate change related to these systems is an essential component to achieve sustainable, inclusive and resilient human development.

Some of the most obvious linkages among family farming, climate change and the SDGs are listed below:

SUSTAINABLE DEVELOPMENT GOALS (SDGS)

1. End poverty in all its forms everywhere

   With the estimated impacts of climate change on regions and biomes, family farming enterprises, whose vulnerability is more pronounced, risk being more exposed to poverty and extreme poverty in the farming environment. To avoid this scenario, it is fundamental to promote alternative practices of farming and also social and financial protection mechanisms that could increase the resilience of these family farmers.

2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

   Family farming plays a central role in ensuring food security and the right to adequate food, figuring simultaneously as an element of subsistence and, when more developed, to promote better living conditions for families who depend on this activity for living and those who consume what it is produced. Considering the possible threats posed by climate change to the appropriate conditions governing the performance of family farming in certain regions, such as the decrease in precipitation for the production of certain crops, adaptation and mitigation activities described in this report could play a fundamental role in fighting hunger by promoting sustainable agricultural practices.

3. Ensure healthy lives and promote well-being for all at all ages

   Preserving the environment, landscapes and communities is directly related to ensuring the health and well-being of family farmers. The choice of agro-ecological systems and the consequent rejection of practices that degrade the soil and products that offer health risks, such as the use of pesticides, are practical examples of this relationship. Thus, it is necessary to foster agricultural productivity that promotes the health of both small-scale farmers and consumers.

4. Ensure inclusive and equitable high-quality education and promote lifelong learning opportunities for all

   The availability and the quality of education in the field are important factors in generating diverse opportunities for rural populations. The positive effects of school inclusion of this population and the acquisition of technical skills through education can be felt in the economy of rural areas, with the emergence of new services, jobs and supply chains, contributing to social mobility and improved quality of life. In addition, the promotion of environmental education for farming communities encourages the practice of a more sustainable agriculture. In this sense, incentives for education in family agriculture are key to ensuring their resilience to the adversity to which they are exposed in their communities.

5. Achieve gender equality and empower all women and girls

   Gender inequality is a phenomenon that is usually reflected in family farming. In Brazil, women in rural areas suffer gender constraints such as greater involvement in unpaid work in the field and less access to land and technical training than men. The promotion of an economically dynamic environment for family farms that values the role of women as active and central figures in this process is a challenge.

6. Ensure the availability and sustainable management of water and sanitation for all

   Access to water and sanitation is essential to ensure the whole cycle of agricultural production as well as for the maintenance of basic living conditions for rural populations, linked to issues such as hygiene, nutrition and health. In addition, agricultural production free from toxic substances, chemicals and other hazardous materials reduces the chances of water pollution and allows recycling and safe reuse.

7. Ensure access to affordable, reliable, sustainable and modern energy for all

   Among the uncertainties regarding changes in temperature and precipitation driven by climate change, there are the possible effects on watersheds and rivers fundamental for energy supply. Dependency on energy from water resources in certain regions is an increasing concern for sustainable development, and the need to promote other sustainable energy sources that are less susceptible to these variations should be carefully considered. From the perspective of family farming, action could be taken to ensure sustainable access, such as the possibility of investing in crops that require less energy and, in particular, prioritising projects that are less harmful to the environment, such as agro-ecological practices.

8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

   Family farming is an important driver of sustainable economic activity on a large scale, covering millions of people in a traditional and potentially harmonious relationship with the environment, even more so when there are incentives in this regard. Given this situation, it is necessary to promote economic inclusion combined with economic incentives and opportunities to ensure both growth and inclusion that promote the dignity of the workers in rural areas.

9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation

   Given the vulnerability of agricultural activity in general and particularly of family farming, especially with the expected future changes and climatic variations, ensuring durable structures of sustainable economic development seems to be fundamental. In this regard, actions such safer roads, genetic improvement, improvement of water use techniques, investment in production from family farming, expansion of effective access to agricultural credit policies and rural technical assistance emerge as relevant initiatives to achieve desirable and sustainable levels of economic development, industrialisation, innovation and infrastructure.

10. Reduce inequality within and among countries

    The promotion of free trade agreements and other trade agreements, such as tariff preference agreements and public procurement, which promote the commercialisation of products from family agriculture between Brazil and other countries, can foster agricultural activity by small-scale producers and generate economic incentives and social inclusion for these families. Strengthening family farming is an opportunity for sustainable economic development in areas with high income inequality.

11. Make cities and human settlements inclusive, safe, resilient and sustainable

    The relationship between urban and rural areas is evident in the case of agricultural production. The productivity generated by family farming supplies the resident populations of cities. Another important relationship refers to levels of urban pollution and its impacts on the quality of the water, soil and air in rural areas. Moreover, the loss of biodiversity caused by unsustainable urbanisation processes can affect the quality of soil and water in rural areas, as well as the availability of natural resources in areas conducive to planting crops. Thus, it is important to support positive economic, social and environmental relationships between urban and rural areas by strengthening integrated national and regional planning.

12. Ensure sustainable consumption and production patterns

    In this regard, it important to promote investment and training for the implementation of initiatives with reduced impacts, such as organic production. The enhancement of agro-ecological practices contributes to managing this issue by minimising the generation of waste in the environment, encouraging responsible consumption and supporting production through cooperatives.

13. Take urgent action to combat climate change and its impacts

    A true understanding of the climate scenarios favours action targeting specific regions, crops and populations. An understanding of the effects of climate change on specific crops needs to be accompanied by an understanding of alternatives that family farmers may have to cultivate instead. Thus, one major challenge in this context is reaching family farmers with the necessary means—knowledge, technology, financial resources, social protection—to face climate change and its impacts.

14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

    The use of fertilisers in agriculture may affect the quality of sea and ocean waters, as well as biodiversity in these ecosystems. Chemicals are likely to negatively affect the health of seas and oceans, which are often the destination for untreated sewage. Therefore, there should be a preference for agro-ecological systems that are free from toxic substances, to reduce marine pollution arising from land-based activities, such as pollution by nutrients.

15. Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss

    In the regions and biomes considered in this study, desertification, deforestation and land degradation are current realities that may worsen in the coming decades due to climate change and human action. Alternatives presented in this assessment such as agro-ecology and integrated crop, livestock and forestry systems, which are included as productive and sustainable instruments to mitigate and adapt to changes, can significantly contribute to the protection and restoration of the environment.

16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

    Ensuring access to justice and civil registry services for rural populations is essential to guarantee their basic rights, such as access to land, credit or microcredit and public services such as water supply, and formalisation and regularisation of socio-economic activities developed by the farmers and their families, among other factors. All these measures can significantly reduce violence in rural areas.

17. Strengthen the means of implementation and revitalise the global partnership for sustainable development

    Existing initiatives and others to be developed have the potential to build a strong sustainable development and bring resilience to vulnerable populations such as the family farmers of the semi-arid, Amazon and cerrado regions of Brazil. Thus, there is a need to strengthen local, state and national governance structures in this context, in a way that policies, plans and programmes can be closer to target populations. The establishment of public–private–producer partnerships, the strengthening of global networks, financing for development, exchange of data and promotion of technology transfer are important measures for the implementation of sustainable development.

ANNEX III RECOMMENDATIONS

SOCIAL DIMENSION

- Prioritise the selection of areas for the implementation of social protection policies and programmes based on the criteria of lack of opportunities for its population (lowest municipal Human Development Indexes should be used as a tool for ranking priorities) and places that are more vulnerable to climate change.
- Identify alternative income sources to ensure the financial stability of smallholder farmers.
- Develop alert systems and invest in risk management on family farming properties.
- Promote awareness of climate change risks and impacts.
- Establish and implement educational institutions and rural extension schools to inform small-scale farmers about planning, including how to face challenges related to climate vulnerability and climate change.
- Conduct vulnerability studies addressing complex and heterogeneous social realities: fisherfolk, extractive communities, riparian, indigenous people, *quilombolas*, populations in at-risk areas, areas prones to desertification, among others.
- Promote capacity-building and increase existing technical capacity related to organic and sustainable food production systems, including the diffusion of innovative products and techniques that take into consideration economic, social and environmental sustainability.
- Ensure that ATER is oriented exclusively for family farming (including agrarian reform settlers) and for traditional people, giving priority to agro-ecological transition, recognising the diversity of family farming, appreciating the relationship between popular and scientific knowledge, ensuring their autonomy over goods of nature and over seeds, and adapting and collectively building technologies.
- Invest in strengthening the organisational skills of farmers by creating cooperatives.
- Promote knowledge generation and sharing, by means of systematising and disseminating knowledge (including traditional knowledge) based on local initiatives, as well as strengthening the exchange of experience among relevant stakeholders.
- Preserve traditional knowledge on Brazilian biodiversity (e.g. indigenous crops), and increase the resilience of smallholder farmers against climate change.

ENVIRONMENTAL DIMENSION

- Promote new practices and techniques that fully consider not only the adaptation to climate change but also environmental sustainability, with the aimi of ensuring food and nutritional security in Brazil.
- Stimulate research networks and technological centres on agro-ecology, including initiatives by institutes and universities at state and federal levels, as well as other public institutions involved in agro-ecological knowledge.

- Make use of the new Technology Facilitation Mechanisms (launched at the United Nations summit for the adoption of the 2030 Agenda for Sustainable Development) online platform to establish a comprehensive mapping of, and serve as a gateway for, information on the existing science, technology and innovation initiatives, mechanisms and programmes related to family farming, especially related to the impacts of climate change.
- Invest in monitoring tools to assess vulnerabilities of agricultural production systems to economic shocks, biological shocks and/or climate-related impacts, with the aim of ensuring stability and improving current production.
- Create instruments that could help family farmers to comply with the *Cadastro Ambiental Rural* (CAR).
- Develop and refine systems based on geospatial information, especially those related to mapping and monitoring of land use and land-use change, water resources, and the supply and demand of food stocks.

ECONOMIC DIMENSION

- Promote family farms as successful businesses, rather than dismissing them as subsistence activities, by integrating smallholders into domestic markets.
- Encourage family farmers to undertake planning exercises (for the short and medium terms).
- Improve infrastructure for the production, storage and access to markets of family farming production.
- Catalyse private-sector investment, ranging from local microenterprises to global agribusiness companies with which rural people could engage in commercial relations on equitable terms, by means of, but not limited to public–private–producer partnerships (4Ps).
- Promote financial inclusion, by expanding the access of rural people to a variety of financial services, including savings, credit, remittances and insurance, to enable them to invest in productive activities and protect themselves against risk.
- Present options to family farmers (including techniques and technical capacity) related to the production of biofuels, including as an option for energy generation for self-consumption, taking the appropriate measures to ensure that biofuels do not compete for land with cereals and other crops, especially in the case of subsistence agriculture.
- Invest in irrigation and soil recovery techniques, and promote the dissemination of agricultural techniques and training for farmers.

GOVERNANCE DIMENSION

- Advocate for closer interministerial and intersectoral collaboration regarding the interests of family farmers.
- Advocate for the mainstreaming of public policies related to family farming, such as the National Policy on Agro-ecology and Organic Production.

- Advocate for the consideration of issues related to family farming in the context of the National Plan and Policy on Climate Change, and participate in setting it up.
- Encourage the participation of all family farming stakeholders in the public consultation process on the National Plan on Adaptation (PNA), to ensure that their interests are reflected in this important planning instrument.
- Advocate for more active participation by MAPA and MDA representatives in both the Intermenisterial Commission and the Committee on Climate Change by addressing specific issues related to family farming, both from the perspective of mitigation and adaptation to climate change.
- Promote and finance research on the following topics: agro-ecology, family agriculture, integrated production systems, climate modelling, climate change adaptation, mitigation of GHG emissions, and carbon dynamics in the soil.

NOTES

2. Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC) states: "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (United Nations 1992). Although the Convention itself does not establish which would be the level that would prevent dangerous anthropogenic interference with the climate system, decisions taken under the UNFCCC and its Kyoto Protocol have established this temperature increase relative to pre-industrial levels as the maximum safe level.

3. Total radiative forcing is the cumulative measure of human emissions of GHGs from all sources, expressed in Watts per square metre (W/m^2).

4. Relative to the reference period of 1986–2005.

5. The downscaling technique is used to make an 'interpolation' from a sub-grade scale with less resolution to one with greater resolution, adjusted to mesoscale processes, such as those at the watershed level. The downscaling technique consists of projecting large-scale information onto a regional scale. This 'translation' of a global scale to a regional one and of annual time scales to daily ones would also increase the degree of uncertainty regarding climate change projections. For example, although a climate model may be capable of reproducing the field of observed precipitation with some success, it will probably be less successful in reproducing daily variability, especially in relation to high order statistics, such as standard deviation and extreme values. Thus, although it may seem reasonable to adopt a scenario of interpolated temperature starting with the points of a global climate model grade for a specific location, the interpolated time series can be considered inappropriate for current climates and, therefore, generates uncertainty in climate change scenarios.

6. The coordination of this study would like to express its appreciation to Dr. Sin Chan Chou, INPE/CPTEC, and her team for their great contribution to this study.

7. Agriculture is currently responsible for 10–12 per cent of global anthropogenic emissions. The agriculture, forestry and other land use (AFOLU) sector together accounts for about a quarter of all global GHG emissions (IPCC 2013e).

8. New studies have been developed for the Third National Communication of Brazil to the UNFCCC. However, at the closing date of this study, they had not yet been published.

9. Agricultural Zoning Climate Risk (ZARC) is an agricultural policy and risk management instrument. The study has been developed to minimise the risks related to weather phenomena. The climate parameters, soil and cultivars cycles are analysed based on a methodology validated by Embrapa and adopted by the Ministry of Agriculture. This study, reviewed annually, results in a list of municipalities that are most suitable for planting certain crops, with their respective planting schedules. Currently, it already includes 40 cultures, of which 15 are annual and 24 permanent cycles, in addition to zoning associated with Brachiaria, reaching 24 units of the federation. When the abovementioned Embrapa study was published, the states of the Amazon region were excluded from the assessment due to environmental restrictions and the fact that they were not assessed under ZARC. To access Proagro and federal grants for rural insurance, producers must follow the recommendations of this technological package. In addition, some financial authorities are already conditioning the granting of rural credit to the use of agricultural zoning (MAPA 2015).

10. One significant example is the fact that the last IPCC report, the most comprehensive literature review on the subject, has few references to family farming in either its reports on vulnerability and adaptation (Working Group II) or mitigation (Working Group III).

11. The crops detailed in this report were selected from the main list considered by the funds supporting family farming (e.g. *Seguro da Agricultura Familiar* (SEAF); 50 crops ZARC/MAPA): pineapple, acaí berry, cotton, plums, peanuts, rice, oats, bananas, cocoa, coffee (arabica and robusta), cashew nuts, sugarcane, canola, barley, citrus (orange, lemon, lime, tangerine and grapefruit), coconut, palm, eucalyptus, beans (first, second and third harvest), cowpea bean, sesame, sunflower, guava, apple, papaya, castor (mamona), manioc or cassava, mango, passion fruit, watermelon, millet, corn, corn/Brachiaria, nectarine, cactus (palma forrageira), pear, peach, pepper, pine, peach palm (pupunha), rubber, sisal, soybeans, sorghum, wheat and grape (American and European).

12. *Bolsa Família* is a Brazilian government social welfare programme, part of the Zero Hunger (*Fome Zero*) network of federal assistance programmes. It provides financial aid to poor Brazilian families. If they have children, families must ensure that the children attend school and are vaccinated. The programme attempts to both reduce short-term poverty through direct cash transfers and fight long-term poverty by increasing human capital among poor households through conditional cash transfers. It also works to show the importance of education by providing free education to children who cannot afford to go to school.

13. For some concrete examples, see Table 6. See also Annexes.

14. It was created by Law No. 12,651/2012 within the National Information System on the Environment (*Sistema Nacional de Informação sobre Meio Ambiente*—SINIMA). It is a strategic database for the control, monitoring and management of general deforestation, as well as for environmental and economic planning for rural establishments.

15. In addition to the distribution of lands and fundraising, there is a substantial need to increase the supporting mechanisms for production in rural settlements—mainly credit, ATER and access to institutional markets—along with strengthening services such as transport, health and education in the communities (Romano, Soares, and Menezes 2013).

16. This new plan will include a specific credit programme for land acquisition. As a preliminary step, on 24 June 2015 the government announced the allocation of 12.2 million ha of federal lands in the so-called 'Legal Amazon', which covers nine states, to be made available for land tenure and agrarian reform. These areas are located in the states of Acre, Amazonas, Amapá, Mato Grosso, Maranhao, Para, Rondonia, Roraima and Tocantins.

17. Agroforestry presents an alternative to traditional agricultural systems in semi-arid regions as it effectively provides soil coverage and improves the amount and quality of soil organic matter.

18. This adaptation strategy had not been released by the end of this study. The final publication of the PNA is expected in early 2016.

19. It has been recently announced that the BNDES, on a temporary basis, will not accept new applications for funding under the FNMC, except for solar energy projects that were successfully accepted under an auction on 31 October 2014. The suspension is due to the commitment of the BRL560 million budget within the current portfolio and the solar projects coming from the auction. As soon as new resources are available under the FNMC, the BNDES will announce it on its website.

20. As of 1 July 2015, the Amazon Fund had supported 74 projects, involving total financial resources of approximately BRL1.155 billion, of which approximately BRL447 million has been disbursed. Among the projects it has supported are projects related to extractive products and agroforestry, such as the Frutos da Amazonia, Néctar da Amazonia, APL Babaçu and Negócios Agroflorestais projects, among others. For more information, see the Amazon Fund website: <http://www.fundoamazonia.gov.br/FundoAmazonia/fam/site_pt/Esquerdo/Projetos_Apoiados/Projetos_Terceiro_Setor>.

21. For the summer, projections estimate, by the end of the century, an increase in mean temperatures of about 3ºC to 8ºC in the North region, and a more moderate increase of about 2ºC to 6ºC in the Northeast region.

22. Crops assessed in the semi-arid and cerrado regions were cotton, pineapple, banana, cocoa, coffee, cashew, coconut, bean, cowpea bean, manioc, and corn/maize. In addition to these crops, more specifically for the Amazon region, acai berry and cupuassu were also considered.

23. For example, multiple cropping and polyculture systems; agroforestry systems; home gardening; wild plant gathering and use of local genetic diversity; soil enhancement, including organic matter; preventing pest, disease and weed manifestation; genetic improvement; managing water; drought-resilient plants; and biomass-producing plants, among others.

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