Impacts of extreme climate events on Brazilian agricultural production

Impactos da ocorrência de eventos climáticos extremos na produção agrícola brasileira

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ABSTRACT
Brazilian agricultural production stands out in world food security, accounting for a large part of the food produced worldwide. However, occurrence of extreme climate events is a challenge for the sector across the country. Thus, this study aims to assess extreme climate events impacts on Brazilian

agricultural production. The loss index was calculated using crop data made available by the IBGE from 2005 to 2017, while data on the occurrence of extreme climate events (2002-2017) was obtained from literature. Data related to PROAGRO (2010-2018) and the Crop Assurance Program (2002-2016) were obtained from reports made available by the relevant agencies. Results showed high drought-induced production losses, mainly maize and beans produced in the Caatinga biome, and soybean and wheat in the Southeastern and Southern regions of the country. Hail and frost events also caused reductions in soybean and rice production in the Southeastern and Southern regions. Those impacts on the Brazilian agricultural production, in different regions, might have serious consequences on the availability and access of food to the population in the country.

Keywords: Food security. Climate extremes. Biomes. Crops.

RESUMO

A produção agrícola brasileira se destaca na segurança alimentar mundial, sendo responsável por grande parte dos alimentos produzidos. Porém, a ocorrência de eventos climáticos extremos torna-se um desafio para o setor em todo o País. Assim, o estudo tem o objetivo de analisar os impactos da ocorrência de eventos climáticos extremos na produção agrícola brasileira. O índice de perdas foi calculado com dados das culturas de 2005 a 2017 disponibilizados pelo IBGE, enquanto a ocorrência de eventos climáticos extremos (2002-2017) foi obtida em publicações de literatura. Dados referentes ao Proagro (2010-2018) e Garantia-Safra (2002-2016) foram obtidos em relatórios disponibilizados pelos órgãos responsáveis. Os resultados mostraram elevadas perdas de produção devido à seca, principalmente milho e feijão produzidos no bioma Caatinga, e soja e trigo nas regiões Sudeste e Sul do País. Eventos de granizo e geada também provocaram reduções na produção de soja e arroz nas regiões Sudeste e Sul. Esses impactos sobre a produção agrícola brasileira, nas diferentes regiões, poderão trazer sérias consequências em relação à disponibilização e ao acesso dos alimentos à população no País.

Palavras-chave: Segurança Alimentar. Extremos climáticos. Biomas. Culturas agrícolas.

1 INTRODUCTION

Brazil's food production is based mainly on agriculture and livestock, particularly grain production (maize, soybeans, beans, etc.) and meat (beef, pork and chicken) (CASTRO, 2016; FERREIRA and VIEIRA FILHO, 2019). Between the 2010/2011 and 2017/2018 crops year grain production grew by 40%, going from 163 million tons to 228.3 million tons, with emphasis on soybean (CONAB, 2019). Meat production grew by 27.7% between 2009 and 2017, going from 19.5 million tons to 24.9 million tons (FERREIRA and VIEIRA FILHO, 2019). In addition to the growing domestic demand for food, the growth of the external commodities market made Brazil the world's 3rd largest exporter of agricultural products, responsible for 5.7% of the global market in 2016 (FAO, 2018).

The evolution of Brazilian agricultural production in recent decades has been benefited by favorable climate conditions, by the large extension of its territory, and mainly by the increase in productivity, due to technological and management advances (MATOS and PESSÔA, 2012). However, the country's agricultural production has been facing constant losses due to the occurrence of increasingly frequent and intense extreme climate events (excessive rainfalls, drought, dry spell, frost and hail), which strongly affect farmers and the local economy (EMBRAPA, 2008; CEPED UFSC, 2013). Those events represent extremes of climate variability.

Some regions are more vulnerable to the impacts of extreme climate events, such as, the Brazilian semiarid region, which has been suffering from prolonged droughts and major reductions in its agricultural production in recent years (ASSAD et al., 2013; ARAUJO et al., 2014; ALVES, 2016; MARENGO et al., 2017; MARENGO et al., 2020;). Losses caused by the effects of drought on agricultural production in the Northeastern region of Brazil amounted to US$ 6 billion between 2010 and 2015 (MARENGO et al., 2016).

In 2015-2016, the total of affected areas used for agricultural activities in the semiarid region, taking into account only the municipalities where the Office for the Development of the Northeast (SUDENE, for its acronym in Portuguese) operates, was 53 million hectares (ALVALÁ et al., 2017). Dry spells also strongly affect agricultural production in several regions of Brazil, mainly grain production in the Center-West region. According to the Brazilian Atlas of Natural Disasters, droughts and dry spells are the disasters that affect the Brazilian population the most (mostly the population in the Northeastern region of the country) for being more recurrent (CEPED UFSC, 2013).

On the other hand, excessive rainfalls have become heavier and more frequent, causing surface water floods, floods and flash floods throughout the country (PBMC, 2016). Lastly, hail and frost events also represent significant damage to agricultural production, occurring more frequently in the country's Southeastern and Southern regions (BERGAMASCHI e MATZENAUER, 2014; BRAZ, 2015). In addition, hail and frost events cause deaths and population displacements (CEPED UFSC, 2013).

Projected aggravation of extreme climate events and climate change impacts may represent real challenges to food production in the country, due to the increase in temperature and changes in the rainfall regime that could cause significant losses in grain crops and alter the geography of Brazilian production (EMBRAPA, 2008; CUNHA et al., 2013). The occurrence of extreme events will become more frequent and intense with climate change, causing major reductions in crop production and changing both food production and consumption patterns in the country (EMBRAPA, 2008; CGEE, 2019; MARENGO et al., 2020).

Extreme climate events may also impact on other factors related to the country's food production. Production costs are increased in an attempt to compensate for losses caused by the impacts, and food prices go up because of their lower availability to the population, becoming a worrying factor for the country's needy families. Thus, the intensification of agricultural losses caused by climate change may further increase food costs and prices.

An analysis of the main factors that relate Brazilian agricultural production to the occurrence of extreme climate events is essential for the development of measures to minimize crop losses and, consequently, impacts on the availability and access to food by the population. Thus, this study aims to assess the main extreme climate events impacts on Brazilian agricultural production between 2002 and 2018.

2 MATERIAL AND METHODS

This study is composed of an analysis of extreme climate events impacts on agricultural production, and the losses index and agricultural credit, covering the period from 2002 to 2018, in the Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa and Pantanal biomes, and also the Coastal Zone (Figure 1). The Coastal Zone represents the coastline (from the Northern to the Southern regions), which is 8.5 thousand km long, and also includes the maritime strip formed by territorial sea, with a width of 12 nautical miles from the coastline (MMA, 2020).

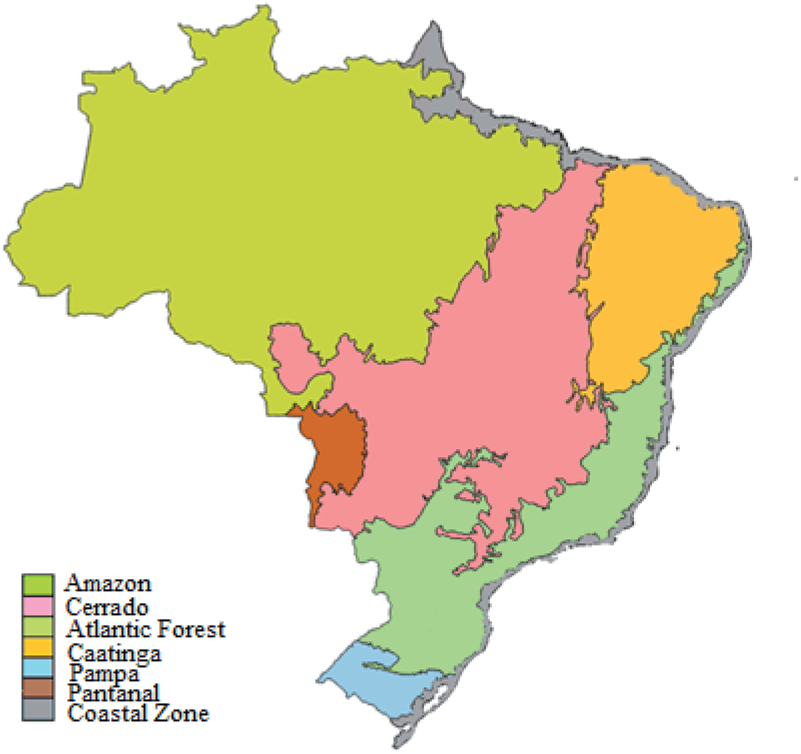


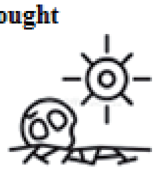
Figure 1 | Brazilian biomes and Coastal zone.

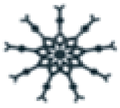
Source: IBGE (modified by the authors).

2.1 EXTREME CLIMATE EVENTS

The occurrence of extreme climate events (drought, excessive rainfall, dry spells, frost and hail), between 2002 and 2017, was collected based on information provided by the Federal Government's National Plan of Disaster Risk Management and Response of and by the National Center for Monitoring and Early Warnings of Natural Disasters (CEMADEN, for its acronym in Portuguese), which encompasses the monitoring of 958 Brazilian municipalities (MIKOSZ, 2017; CEMADEN, 2020) and records obtained in the Brazilian Atlas of Natural Disasters (CEPED UFSC, 2013). Information about occurrence of extreme events may be seen in Box 1. This information was analyzed together with agricultural production in several municipalities, in order to obtain those events impacts on local production.

Box 1 | Occurrence of extreme climate events in Brazil

Events	*Definitions*	*Occurrences**
Excessive Rainfall 	Continuous and frequent rainfall with large volume of precipitated water (Monteiro, 2009).	Excessive rainfalls have occurred mainly in the Northern and Southern regions, particularly 2012-2013 and 2015. In those years, an increase in annual rainfall was observed, which varied from 28.6 to 66.7% in the Northern Region, and 40.0 to 53.0% in the South.
Drought 	Low rainfall in a certain region, for a prolonged time, causing a sustained reduction in water reserves (Grigoletto et al., 2016).	Droughts have occurred in all regions of the country in recent years, particularly in 2010 to 2014 and 2017. In those years, a decrease in annual rainfall was observed, which varied from 42.9 to 66.7% in the North, 25.0 to 33.0% in the South, 15.0 to 70.0% in the Northeast, 15.0 to 20,0% in the Southeast, and 30.0 to 60.0% in the Center-West region**.

Events	Definitions	Occurrences*
Dry Spell 	Period of low (or absence of) rainfall, when the loss of soil moisture is greater than its replacement (Grigoletto et al., 2016).	Dry spells have occurred in all regions of the country in recent years, mainly in the Northeastern and Center-West regions, particularly in 2010 and 2013. In those years, a decrease in annual rainfall was observed, which varied from 25.0 a 50.0% in the Center-West region and 15.0 to 60% in the Northeastern region.
Frost 	It occurs when temperature reaches 0°C on exposed surfaces, transforming the water vapor directly to the solid state after the dew freezes and the temperature continues to fall (EMBRAPA, 2020a).	Frost has occurred mainly in the Southeastern and Southern regions, particularly in 2014 and 2016. In those years, a decrease in average temperature was observed, which varied from 6.0 to 7.5% in the Southeastern region, and 4.8 to 5.9% in the Southern region.
Hail 	Rain in the form of ice crystals, which may be round or irregular, but with more than 5 mm in diameter (UFES, 2020).	Hail has occurred mainly in the Southeastern and Southern regions, particularly in 2011 and 2014. In those years, an increase in annual rainfall was observed, which varied from 25.0 to 50.0% in the Southeastern region, and 30.0 to 60.0% in the Southern region.

*Source: based on MIKOSZ (2017); XAVIER et al. (2016) and CEPED UFSC, 2013; **INMET (2018).*

2.2 AGRICULTURAL PRODUCTION

Rice, coffee, beans, cassava, maize, wheat and soybeans production data per municipality were obtained from the database of the Brazilian Institute of Geography and Statistics (IBGE, for its acronym in Portuguese), available in the IBGE Automatic Recovery System (SIDRA, for its acronym in Portuguese), for the 2002-2017 period. Production was calculated for the biomes and the Coastal Zone, by selecting the municipalities in each of these territorial sections, according to the information obtained in the most current Brazilian municipalities *shapefile*, which is available by the IBGE.

2.3 LOSSES IN AGRICULTURAL PRODUCTION

Production losses (from planting to pre-harvest) were calculated using the loss index, according to the methodology applied by the IBGE (IBGE, 2004). Production, planted area, harvested area and average crop yield data between 2010 and 2017 (provided by the IBGE Automatic Recovery System - SIDRA) were used to calculate the index of agricultural losses by biome. According to the IBGE (2004), the sum of actual production (Pr) plus harvest losses (Pn) represents an approximation of production potential up to pre-harvest (PR = Pr + Pn), in a baseline year, with the quotient of the division of Pn by PR represented by the loss index, of each crop (Pe = (Pn / PR) * 100). Harvest loss is the difference between the planted are and the area actually harvested for a given crop, and corresponds to the area lost. The difference between the area planted and actual harvested area was used in the calculation of harvest loss due to loss of area.

2.4 FARM SUBSIDIES AND CREDIT PROGRAMS

Data related to farm subsidies and credit programs, such as the Agricultural Activity Guarantee Program (PROAGRO, for its acronym in Portuguese) and the Crop Assurance Program in the period 2002-2018 were obtained through published reports and historical records of the relevant public agencies. For PROAGRO, variables such as deferred coverage and amounts paid for the period 2010-2018 were used (CENTRAL BANK OF BRAZIL, 2019). Data referring to the Crop Assurance Program consisted of the variable adhesions and payments made during the period 2002-2016 (MDA, 2019).

3 RESULTS AND DISCUSSION

Agricultural losses proved to be quite variable among the biomes and over the years (Table 1). Among the crops analyzed, beans and maize showed higher loss rates, especially in regions that were more vulnerable to extreme climate events, such as the semiarid region. The maximum values of the agricultural loss index taking into consideration the major producing regions were: beans (62.4%), wheat (60.9%), maize (46.6%), soybeans (38.1%), cassava (34.3%), coffee (17.2%) and rice (10.1%).

The Caatinga showed the highest values in the loss index upon analyzing the specific results for the biomes. The high losses that occasionally occur for crops in this biome may be explained by the drought that has hit the region in recent years. The length and intensity of the drought, which has been occurring since 2012, has affected the semiarid region of the Northeast's economy in several municipalities, creating problems in urban and rural areas (MARENGO et al., 2017; MARENGO et al., 2020). Production losses caused by drought events were observed with greater intensity in 2012 and 2016, mainly for bean crops with a production drop by 62.4% and 48.2%, maize by 46.6% and 42.3%, and cassava by 34.3% and 15.6%, respectively.

In the Cerrado biome, agricultural losses were also significant, despite the lower values when compared to the Caatinga biome. Crops such as wheat, rice and maize were the most affected by dry spells events, with losses by 18.5% (2013), 10.1% (2016) and 8.7% (2016), respectively. It is worth mentioning that production of these crops in the Cerrado biome is high and losses of this magnitude may represent significant impacts for farmers and consumers. In the Federal District and surrounding areas, some 70% of drought events start in the middle of the rainy season, and are responsible for the fall in agricultural production (CUNHA et al., 2018). According to these authors, the occurrence of drought has been recurrent in the region of the Federal District in recent decades and future climate projections indicate rainfall reductions all year-round, which may further affect agricultural production.

In other biomes, the occurrence of drought and dry spells also caused a fall in agricultural production, with losses of soybeans (18.6%) in the Atlantic Forest in 2012; wheat (60.9%) and coffee (16.7%) in the Coastal Zone, in 2015 and 2016, respectively.

In the Southern region, the Pampa biome also showed declines in the harvests of several crops, with production losses for the soybean crop (38.1%) caused by frost/hail in 2012; wheat (28.2%) caused by drought/dry spells, in 2015; and rice (7.0%) caused by excessive rainfall/hail, in 2016.

Table 1 - Agricultural loss index (%) of crops (from planting to pre-harvest) in Brazilian biomes and Coastal Zone and extreme climate events.

Crops	*Biomes*	*Loss index (%)*	*Year*	*Associated extreme events*
Rice	Cerrado	10.1	2016	Dry spell
	Pampa	7.0		Excessive rainfall/Hail
Coffee	Caatinga	17.2	2012	Drought
	Coastal zone	16.7	2016	Dry spell
Beans	Caatinga	62.4	2012	Drought
		48.2	2016	
	Pantanal	23.5	2012	Dry spell
Cassava	Caatinga	34.3	2012	Drought
		15.6	2016	
	Pantanal	12.4	2012	Dry spell

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Crops	Biomes	Loss index (%)	Year	Associated extreme events
Maize	Caatinga	46.6	2012	Drought
		42.3	2016	
	Cerrado	8.7	2016	Dry spell
Soybeans	Atlantic Forest	18.6	2012	Dry spell/Drought
	Pampa	38.1	2012	Frost/Hail
	Coastal zone	16.2	2016	Dry spell
Wheat	Cerrado	18.5	2013	Dry spell
	Pampa	28.2	2015	Dry spell/Drought
	Coastal zone	60.9	2015	Dry spell/Drought

Source: based on IBGE, 2004; MIKOSZ (2017).

Climate-related impacts represent a major role of extreme climate variability events on food production, which may already be observed, and are of concern, since they have affected agricultural production, with consequences in supply, costs and prices, and thus, making the challenge of promoting food security in the country even more difficult. Food security is referred to herein as the "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (Universal Declaration on Eradication of Hunger and Malnutrition, 1975).

A more specific analysis of extreme events allowed for the identification, for example, that drought led to large reductions in national agricultural production, especially in more vulnerable biomes such as the Caatinga. Bean production in Araripina, in the Pernambuco countryside, dropped by 99.4% in 2012 compared to the average of the past ten years (Figure 2).

That year, the average annual rainfall in Araripina was 400 mm, some 43% less than the climatological average rainfall in the region (CLIMATE-DATA.ORG, 2020). That same year, drought was responsible for the 41.3% decline in soybean production in the municipality of Tupanciretã, in the state of Rio Grande do Sul. Impacts of the occurrence of drought were also responsible for the decline in temporary crops production in the state of Rio Grande do Norte between 2012 and 2016: oilseeds (91% to 100%), fiber (52% to 87%) and vegetables (77% to 86%) (SOUZA and AQUINO, 2018).

According to Souza and Aquino (2018), grains were most affected by the drought in the state of Rio Grande do Norte, with losses by 72.6% to 92.9% between 2012 and 2016. The authors also show that the most affected crops were maize and beans, with percentage decrease varying between 72.5% to 94.8% and 70.1% to 94.7% between 2012 and 2016, respectively. According to Alvalá et al. (2017) and CONAB (2017), grain production in the Northeastern region fell by 40%, and sugarcane production fell by 19%, between 2014/2015 and 2015/2016 crop years.

Dry spells have also been affecting the agricultural production in several regions of Brazil. In 2012, the state of Rio Grande do Sul suffered an intense drought, which affected local agriculture, reducing wheat production by 38.8% in the municipality of Ibirubá (MIKOSZ, 2017; IBGE, 2019c). According to Silva (2013), the 2011-2012 crop year had below-average rainfall in Ibirubá/RS, with a 46.4% decrease. In 2019, the dry spell caused a decline in the production of crops such as rice (683.8 thousand tons), maize (30.5 thousand tons) and soybeans (1.04 million tons), generating a loss of some 2 billion reais (RURAL CANAL, 2020). Dry spells also caused a 49.1% decline in cassava production in the municipality of Oriximiná, in the state of Pará. In the state of Paraná, soybean production, for example, fell by 30% in the 2018/2019 crop year due to dry spell, ceasing to produce some 6 million tons (COOPADAP SEMENTES, 2020; EMBRAPA 2020b).

However, in some cases extreme climate events might benefit the country's agricultural production. Excessive rainfall events accounted for the 32.0% increase in coffee production in the municipality of Barra do Choça/BA in 2014 and 13.4% in wheat production in Tibagi/PR in 2013 (Figure 2). In the municipality of Barra do Choça/BA, for example, total accumulated rainfall was 65.5% higher than the climatological average in 2013-2014. However, the occurrence of excessive rainfalls may also cause serious damage to agricultural production. In the state of Rio Grande do Sul, floods affected rice, maize and soybeans production, with losses amounting to 1.75 million tons in 2019 (CANAL RURAL, 2020).

Impacts on food production due to frost and hail events were also observed, occurring more frequently in Southeastern and Southern Brazil (Figure 2). The occurrence of frosts, for example, has fallen in the Southeastern region in recent years (SAPUCCI et al., 2018), but more intense events may cause significant damage to agricultural production (CEPED UFSC, 2013). In 2009, cold waves dropped the temperature below 5°C and caused frost events in several cities in the State of São Paulo (CAFEICULTURA, 2019), for example, in the municipality of Cândido, where the average annual temperature was 23,6°C, thus decreasing maize production by 57.9%. Another example occurred in Nova Alvorada do Sul/MS, where rice production dropped by 72.6% with the occurrence of frosts. In the state of Rio Grande do Sul, the occurrence of a hail event in 2005 caused losses in local agricultural production, decreasing soybean production by 88.1% in the municipality of Crissiumal/RS (MIKOSZ, 2017; IBGE, 2019c). In 2014, the occurrence of hail caused a 73.7% drop in wheat production in Lages/SC.

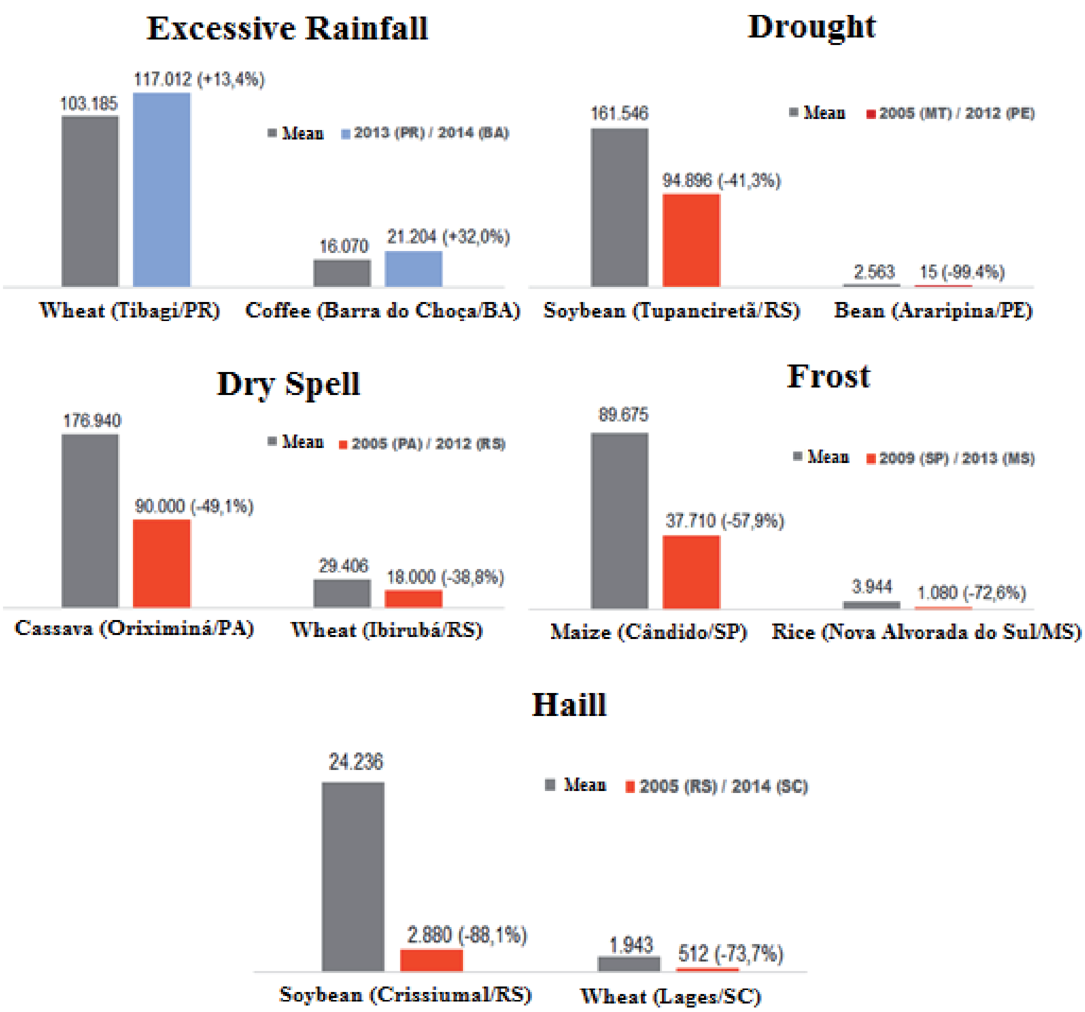

Figure 2 | Occurrence of extreme climate events and agricultural production (average of the past 10 years) in millions of tons in different Brazilian municipalities.

Source: IBGE (Automatic Recovery System/SIDRA, for its acronym in Portuguese); MIKOSZ (2017).

Agricultural losses during the production process in the field have become more frequent and intense, causing immense damage to farmers, despite the fact that food production in the country has shown robust expansion in recent decades (SAATH and FACHINELLO, 2018). Those impacts affect small farmers (who are more vulnerable and who actually end up producing for the local market) and the production of commodities for the foreign market alike. As mentioned above, the occurrence of extreme climate events strongly affects the country's agricultural production, leading to large volumes of production losses and, consequently, impacts on the country's economy (ALVALÁ et al., 2017). Therefore, the occurrence of extreme climate events may also be assessed through their effects on farm subsidies and credit programs, such as PROAGRO and the Crop Assurance Program, which had their actions intensified in the years when extreme climate events occurred.

Table 2 presents data communicating deferred crop losses (quantity and value) per extreme event in relation to PROAGRO (Agricultural Activity Guarantee Program) between 2010 and 2018. Results show that in the years where extreme events were more intense, there was a substantial increase in the amounts paid or the number of beneficiaries. The 2011-2012 crop year, for example, presented the largest number of losses with 110 thousand insurances, which corresponded to 989.45 million reais invested.

Out of this total, 86.3% were drought events, which occurred mainly in the Northeastern and Southern regions, and accounted for 78.8% of the total amount paid (CENTRAL BANK OF BRAZIL, 2019). In the same period, 10,353 frost events were deferred, representing 147.55 million reais paid (14.9% of the total amount paid), and it was also the crop year with the highest number of hail events in the country (3,383), representing approximately 47 million reais (4.8% of the amount paid).

Excessive rainfall events also had a significant share in the communication of losses. In the 2013-2014 crop year, some 30 thousand insurances were deferred for excessive rainfall, and a total of 590 million reais were paid, which represented 67.1% of the total amount paid by PROAGRO in the period. The 2014-2015 crop year had the highest number of frost events, which represented 48.4% of the total amount paid by PROAGRO in the period (338 million reais), with 15 thousand cases deferred. The 2014-2015 crop year was marked by frost events in the Southeastern and Southern regions, with approximately 15 thousand cases, representing a total of 338.8 million reais (48.4% of the total paid).

Table 2 | Deferred insurances* (quantity and value) per extreme event referring to the Agricultural Activity Guarantee Program (PROAGRO), period 2010-2018.

		Excessive Rainfall	*Drought*	*Frost*	*Hail*	*Total*
2010-2011	Deferred	2,331	4,883	9,779	1,427	18,420
	Amount (BRL)**	24,000	39,315	162,697	12,741	238,753
	Average (BRL)***	10,296.0	8,051.4	16,637.4	8,928.5	12,961.6
2011-2012	Deferred	1,332	95,012	10,353	3,383	110,080
	Amount (BRL)**	14,597	780,008	147,545	47,296	989,446
	Average (BRL)***	10,958.7	8,209.6	14,251.4	13,980.5	8,988.4
2012-2013	Deferred	4,335	10,794	10,345	1,963	27,437
	Amount (BRL)**	77,810	116,802	229,563	29,799	453,974
	Average (BRL)***	17,949.3	10,821.0	22,190.7	15,180.3	16,546.1

		Excessive Rainfall	Drought	Frost	Hail	Total
2013-2014	Deferred	30,529	18,572	1,254	1,667	52,022
	Amount (BRL)**	590,384	233,593	24,966	30,435	879,378
	Average (BRL)***	19,338.5	12,577.7	19,909.1	18,257.3	16,904.0
2014-2015	Deferred	10,229	7,447	15,078	2,324	35,078
	Amount (BRL)**	192,588	119,314	338,816	49,445	700,163
	Average (BRL)***	18,827.6	16,021.8	22,470.9	21,275.8	19,960.2
2015-2016	Deferred	6,857	10,819	6,676	2,195	26,547
	Amount (BRL)**	172,357	297,656	200,347	47,124	717,484
	Average (BRL)***	25,135.9	27,512.3	30,010.0	21,468.8	27,026.9
2016-2017	Deferred	14,817	11,904	2,734	1,285	30,740
	Amount (BRL)**	334,007	292,380	72,634	33,379	732,400
	Average (BRL)***	22,542.1	24,561.5	26,566.9	25,975.9	23,825.6
2017-2018	Deferred	1,058	4,794	237	484	6,573
	Amount (BRL)**	26,370	101,926	10,921	12,155	151,372
	Average (BRL)***	24,924.4	21,261.2	46,080.2	25,113.6	23,029.4

* Values referring to Proagro Plus and Traditional Proagro; **Million reais; ***Reais per insurance.

Source: CENTRAL BANK OF BRAZIL, 2019.

The impacts of extreme events on Brazilian agricultural production can also be seen when information from the Crop Assurance Program (Figure 3) is assessed, whose actions portray the effects of systematic crop loss due to the occurrence of extreme climate events for family farmers who live in the country's semiarid region. It is observed that the number of insurers increased significantly, from 200 thousand farmers in 2002 to around 1.2 million farmers in 2014. Therefore, the financial resources applied by this program also increased, according to the intensity of the extreme events upon the production and volume of losses presented.

In the 2011-2012 crop year, there was an increase in the number of payments due to droughts in the period, amounting to 769 thousand insurances, which corresponded to 1.4 billion reais (Figure 3). The 2014-2015 crop year again showed an increase in insurances paid, due to the continuity of drought in the region, amounting to a total of 829.4 thousand reais. In the 2015– 2016 crop year, the Crop Assurance Program provided assistance to approximately 700 thousand farmers in 1,220 municipalities struck by drought (SAF/MDA 2017), with 12 thousand people affected in the region where SUDENE operates, with expenses of approximately 600 million reais (ALVALÁ et al ., 2017). During this period, the annual accumulated rainfall in the semiarid region correspondent to a situation of severe drought presented figures lower than 600 mm (ALVALÁ et al., 2017).

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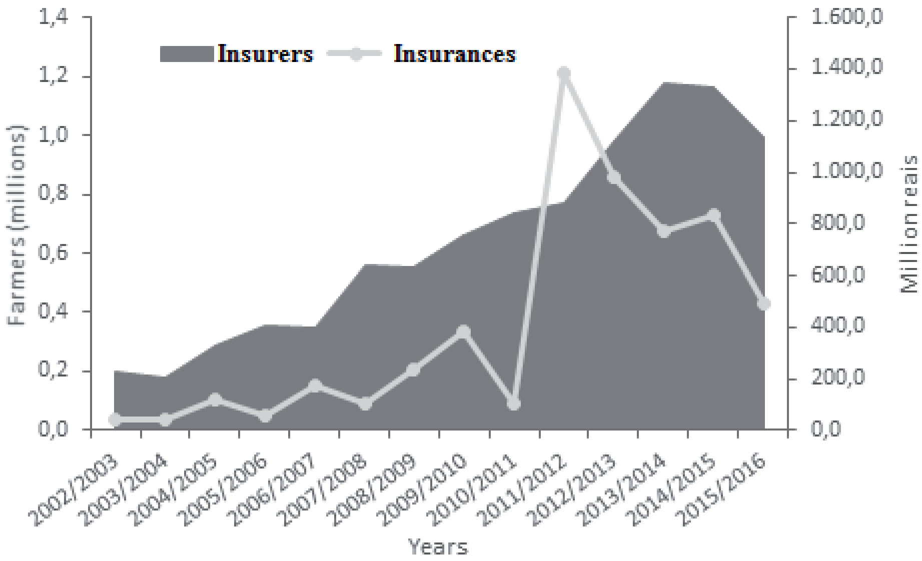

Figure 3 | Annual total of (a) new insurers and payments made by the Crop Assurance Program in the period from 2002 to 2016.

Source: http://www.mda.gov.br/sitemda/secretaria/saf-garantia/sobre-o-programa. Accessed: December 2016.

These results show that the impacts of climate phenomena cause serious damage to the country's agricultural production and, consequently, affect those who directly and indirectly depend on this sector, such as farmers and the population. Other factors, such as production cost and food prices (MARENGO et al., 2020), are also affected by the occurrence of extreme climate events, in addition to the influence of economic indicators, such as inflation.

4 CONCLUSION

The results showed that the Brazilian agricultural production suffers major losses due to the occurrence of extreme climate events, with the Caatinga being the biome that presents the highest rates of loss. The drought that has hit the semiarid region in recent years was responsible for the decrease in several crops, mainly maize, beans and cassava. In general, droughts and dry spells events affect agricultural production in all regions of the country. Frost and hail events occurred mostly in the country's Southeastern and Southern regions, affecting the production of crops such as rice, soybeans and wheat. The exception was excessive rainfalls, which were responsible for the increase in coffee production in Bahia in 2014 and wheat in Paraná in 2013.

As a consequence, especially of the drought/dry spell events, there was a substantial increase in the actions carried out by the PROAGRO and Crop Assurance programs, mainly in Brazil's semiarid region. It will necessarily imply an increase in public spending on financing and agricultural insurance.

Given the current climate change scenarios, the trend is for an increase in the frequency and intensity of extreme climate events in all regions of the country. Therefore, further impacts on agriculture may be expected (production, productivity and agricultural credits), with adverse effects on food security.

It is worth noting that such impacts will affect both large and small farmers, thus generating imbalances in the production and export of commodities (soybean, coffee, orange, beef, etc.), as well as in the production and/or prices of the Brazilian staples food basket, which are mostly produced by small farmers. In other words, given the magnitude of the Brazilian agricultural sector, climate change may affect regional food security, at the national level, and even at the global level. Therefore, it is necessary to adopt sustainable management practices and environmental policies aimed to mitigate and adapt to climate change, but which seek to contemplate the entire production chain, especially small farmers.

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