THE REGIONAL ECONOMIC IMPACTS OF CLIMATE CHANGE ON FAMILY FARMING AND LARGE-SCALE AGRICULTURE IN BRAZIL: A COMPUTABLE GENERAL EQUILIBRIUM APPROACH

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Summary

This paper analyzes the regional economic impacts of climate change on the agricultural productivity of crops linked to family farming and large-scale agriculture in Brazil. Variations in agricultural productivity estimated according to scenarios RCP 4.5 and RCP 8.5 (IPCC, 2014), between 2021 and 2050, were used as inputs in the Computable General Equilibrium Model (CGE) AGRO-BR. The model presents regional configuration composed of the 27 Federation Units and 42 agricultural sectors, disaggregated into family farming and large-scale agriculture sectors. The results, in terms of economic impacts, indicate that the North and Northeast regions would be negatively affected, Midwest and Southeast would suffer moderate impacts, while the South region would benefit mostly. São Paulo, Paraná, and Rio Grande do Sul would show economic growth, softening the negative impacts on national GDP, which would show a decline of 0,01% in both scenarios. The phenomenon could contribute to the increase of regional disparities and the deterioration of food security conditions in Brazil.

Keywords: Climate Change, Family Farming, Agricultural Productivity and Computable General Equilibrium Models.

JEL Code: R15, R22, Q12

1. Introduction

Global Climate Change (CC) greatly affects life on Earth. Its impacts on ecological, economic and social systems, amplifies externalities and uncertainties along an extensive time horizon. The phenomenon is spatially heterogeneous and historically unprecedented in humanity, which elevates the complexity of its understanding. The immediate effects of climate change are verified by changes in average temperature and precipitation levels, key variables for determining agricultural productivity. Thus, changes in world agricultural production are expected (Mendelsohn and Schlesinger, 1999; Cline, 2007; Rosenzweig *et al.*, 2014). In Brazil, the scenarios projected by the Brazilian Panel on Climate Change, indicate changes in precipitation levels between +5% to -50%, temperature rise between 1ºC to 5.5ºC and increased occurrence of extreme events (PBMC, 2014). In this scenario, a new geography of agricultural production may be configured, with possible implications on food supply and consequently on food security (FAO, 2005; Assad; Pinto, 2008; Calzadilla *et al.*, 2013).

Brazil, a country of great territorial extension and whose agricultural sector plays an important economic role, may be severely affected by the phenomenon, with possible impacts on the supply, price, and stability of international food trade. The country stands out as one of the largest producers and exporters of soybeans, sugar, corn, orange juice, coffee, cotton, as well as poultry, pork, and beef (FAOSTAT, 2020). Internally, the sum of goods and services related to agribusiness corresponded to 21.4% of GDP in 2019, with 68% of this participation related to agriculture and 32% to livestock (CNS, 2020).

The literature related to the impacts of climate change on Brazilian agriculture indicates considerable losses, especially for commodities. Assad; Pinto (2008), assess that losses in 2020 would reach R$7.4 billion, with a significant reduction in the production of corn, rice, soybeans, and beans. Feres *et al*., (2009); Massetti *et al*., (2013); Assunção; Chein (2016) and De Paula (2018) indicates that, on average, there would be a decrease in agricultural productivity in low latitudes, with negative impacts in the North, Northeast and Midwest regions, precisely the least developed regions of the country. Moraes (2010) and Margulis; Dubeux (2011) project GDP accumulated decline between 0.2% and 2.3% in 2070. Regarding the effects on international trade, Nazareth *et al*., (2020) indicates an economic downturn in regions that demands Brazilian agricultural products, such as the rest of Mercosur, the rest of the Americas, and China.

Despite the relatively extensive literature, it focuses on commodity studies and makes no distinction between types of producers. It should be emphasized that the Brazilian agricultural production structure is heterogeneous. Producers are distinguished in the use of inputs, productive factors, types of crops and in the linkage to the domestic and foreign markets. Family farming is largely linked to food security and food production for the domestic market, while large-scale agriculture stands out in commodity production and the foreign market. The analysis of the impacts of CM on agriculture and its potential economic effects should address the productive and regional specificities of farmers.

In this sense, the objective of this work is to analyze the regional economic impacts of climate change on agricultural production of family farmers and large-scale agriculture in Brazil, as well as to analyze its indirect economic effects, according to scenarios RCP 4.5 and RCP 8.5 (IPCC, 2014), between the years 2021 and 2050. The study seeks to answer: i) What are the economic, direct, and indirect impacts triggered by the effects of climate change on agriculture? ii) What are the effects on the production of family farmers and large-scale agriculture? iii) What are the regional effects of the phenomenon? Thus, the work seeks to indicate the direction and magnitude of the economic impacts arising from climate change on Brazilian agriculture, through explicit modeling of the family farming and large-scale agricultural sectors, considering its productive and regional specificities.

The study differs and, therefore, seeks to contribute to the literature on the impacts of climate change on agriculture by incorporating a disaggregated analysis, considering the impacts on the production of family farming and the production of large-scale agriculture. Adopts a General Computable Equilibrium model (CGE) called AGRO-BR (Tanure, 2020), the first CGE model in Brazil to address in a disaggregated way the producing sectors related to family farming and large-scale agriculture. It is an inter-regional CGE model with recursive dynamics mechanisms for 27 Federation Units (UF) and capable of analyzing regional and sectoral economic impacts resulting from the effects of climate change in Brazil over time. Its theoretical structure originates from the TERM model (Horridge; Madden; Wittwer, 2005).

The methodology used in this study has been more indicated for the analysis and economic projections of the impacts of climate change, because the dynamics of regional economic variables observed, in addition to being affected by climate change is also affected by conjuncture and structural factors, such as demographic, macroeconomic, and public policy aspects. Nevertheless, the effects of climate change on agricultural productivity and consequent economic effects are heterogeneous among the types of producers and regions. This chain of interrelations is captured by the CGE model. Thus, the results of the research could complement the information available on the theme, helping policymakers and producers, especially family farmers, to carry out a better planning to face the phenomenon, since the existing literature prioritizes studies involving commodities and the economic effects related to agribusiness.

The study is divided into 5 sections, including this introduction. Section 2 presents a brief literature review on the economic impacts of CC on Brazilian agriculture. Section 3 presents the methodology and data used. In section 4, the results of the simulations and discussions are presented, and finally, in section 5, the final considerations.

2. Literature Review

One of the first studies in Brazil to project the impacts of climate change on the economy through CGE modelling was developed by Domingues *et al.,* (2008; 2016). The study analyzed the impact of climate change on the economy of the Northeast region, based on estimates of areas suitable for agricultural cultivation, using the TERM-Cedeplar model. The estimates of land aptitude for rice, beans, corn, cotton, cassava, soybean, sugarcane, and sunflower crops, were used in the model, with the A2 and B2 climatic scenarios. Reductions in the land production factor, by Federation Units (FUs), were used as a shock in the agricultural sector of the model and represent a proxy for the effects of climate change on the region's economy between 2005 and 2050. The results indicate high economic losses, especially for the poorest states, with potential effects on migratory flows. The study projected a 13.1% decline in regional GDP and a decrease in employment levels by 5.95% in 2050.

The study by Moraes (2010) evaluated the economic effects of climate change scenarios A2 and B2 on Brazilian agriculture through the TERM-BR model. The policy scenarios implemented in the model were based on estimates of the aptitude of areas for the cultivation of beans, corn, soybeans, cotton, rice, sugar cane, cassava and coffee provided by Embrapa, considering two-time horizons: 2020 using scenario B2 and disregarding social and economic changes, and 2070 using scenario A2, with social and economic adaptations. The results of the simulation with scenario A2 indicate greater negative impacts in the states of the Northeast region, in addition to Mato Grosso and Mato Grosso do Sul, as a result of the reduction of the area suitable for soybean cultivation. The Southeast region would benefit from the increase of areas suitable for sugarcane cultivation. In scenario B2, the results indicate negative impacts for the Northeast and Midwest regions, and reduction of the positive impact in the Southeast region with the intensification of climate warming. The projections of impact on national GDP indicate a reduction in both scenarios, being 0.28% in 2020 in scenario A2, and 1.12% in 2070 in scenario B2.

Ferreira Filho and Horridge (2010) analyzed the impacts of climate change on agriculture and internal migration in Brazil using the TERM-MIG model. The simulations used changes in production and land availability for a group of crops, calculated according to scenarios A2 and B2 of the IPCC, for the years 2020 and 2070, respectively. The results showed that the economic downturn of the Northeast and Midwest regions could reverse the migratory flow, increasing the emigration of less qualified workers to the South and Southeast regions, resuming the migratory pattern observed before the 1980s in Brazil. The results indicate that the national GDP could retract by 0.8% in 2070, considering scenario B2.

In the study by Margulis; Dubeux (2011), the impacts of climate change verified through changes in river basin flows, sea level rise and changes in agricultural productivity have been quantified and analyzed. The study used the EFES (Economic Forecasting Equilibrium System) CGE model integrated with other impact projection models, adopting IPCC scenarios A2 and B2 as a reference. The results of the EFES were incorporated into the B-MARIA CGE model to carry out regional and sectoral macroeconomic projections. The results indicated reductions of 0.5% (Scenario A2) and 2.3% (Scenario B2) of national GDP in 2050, and large losses of areas of low risk of agricultural production for soybean crops (30% to 34%), corn (15%) and coffee (17%).

Farias (2012) developed an CGE model with detailed specification of land use in Brazil and evaluated the economic impacts of climate change in the country. The implemented shocks were calculated through the estimated sensitivity of land use changing, considering the climatic scenarios A2 and B2 of the IPCC, and the periods of 2010/2039, 2040/2069 and 2070/2100. In scenario A2, the results indicated an accumulated reduction in national real GDP by 0.02% in 2039, 0.05% in 2069 and 0.11% in 2099. For scenario B2, projections indicate a 0.02% decline in 2039, 0.04% in 2069 and 0.07% in 2099. In sectoral terms, the greatest losses would occur in agricultural activities, especially the retraction of the wheat and cereal producing sectors, Coffee in Grain and Soybean grain. The Sugarcane and Herbaceous Cotton sectors would benefit from the projections.

Miyajima (2018) evaluated the impacts of climate change on agricultural production in the regions of the Brazilian Legal Amazon, using the EGC model, REGIA. The shocks used as a proxy for the effects of CM were established through estimates of agricultural productivity calculated for 11 crops, with scenarios RCP 4.5 and RCP 8.5 as reference. The results indicated heterogeneous economic losses in both scenarios, with greater loss in the RCP 8.5 scenario. The regions with the highest agricultural participation in GDP were the most negatively impacted. For the GDP of the Legal Amazon region, projections indicate accumulated decline of 1.68% in the RCP 4.5 and 1.92% in the RCP 8.5 scenario in 2080.

Souza (2018) measured the economic impacts of climate change on Brazilian regions through changes in agricultural productivity of soybean, sugarcane, corn, beans, coffee, and orange crops and established a regional vulnerability indicator to climate change impacts. The climatic scenarios analyzed are RCP 2.6 and RCP 8.5, between 2020 and 2100. The results point to a variation in agricultural losses from 9.7% to 55.6% by 2100, with negative impacts on GDP in the order of 0.05% in the optimistic scenario and 0.26% in the pessimistic scenario. São Paulo, Paraná, and Minas Gerais would be the most affected states in terms of losses.

Nazareth *et al.*, (2020) analyze the economic effects of the reduction of agricultural productivity resulting from climate change on Brazilian regions and consequent impacts on international trade using the PAEGDyn model, derived from GTAP. They find that the economic effects are negative, especially in less developed regions, such as North, Northeast and Midwest of Brazil, whose GDP could be up to 4% lower in contrast to a scenario without climate change. The negative impacts also affect the rest of Mercosur, the rest of the Americas, the rest of the world and China, regions characterized by low income and dependence on agricultural products. The other regions would be negatively impacted via indirect economic effects. A positive impact on GDP would be observed only in southern Brazil, characterized by increases in agricultural productivity.

It is verified that use the CGE methodology to analyze climate change in Brazil began after the disclosure of the Fourth Assessment Report (IPCC, 2007), with more detailed climate projections, and which allowed the estimation of variables used as input in the CGE models. Those who analyzed direct impacts on agriculture basically used three approaches as a parameter for calculating the shocks used in the simulations: i) changes in areas suitable for agricultural cultivation; ii) land use changes; and iii) changes in agricultural productivity. Of these, the use of agricultural productivity is recent in the literature, being verified in Souza (2018), Miyajima (2018) and Nazareth et al. (2020). This approach is also used in the present study, however, we advanced in the regional and sectoral disaggregation, analyzing 21 agricultural crops for each type of producer, family farmers and large-scale agriculture, in the 27 Brazilian Federation Units.

3. Methodology and Data

AGRO-BR (Tanure, 2020) is an interregional CGE model with recursive dynamics mechanisms for 27 Federation Units (UF) in Brazil and large sectoral disaggregation for agricultural products, capable of analyzing regional and sectoral economic impacts resulting from the effects of climate change in Brazil over time. Its theoretical structure originates from the TERM model (Horridge; Madden; Wittwer, 2005). It is a bottom-up type model, whose national results come from aggregations of regional results. Moreover, it is the first model of CGE in Brazil, to adopt in a disaggregated way, sectors[1] related to family farming and large-scale agriculture. The i) agricultural; ii) livestock and other animal production, iii) forestry and iv) vegetal extraction sectors, are disaggregated into family farming and large-scale agriculture sectors, totaling 48 sectors. The AGRO-BR database is composed of the latest Input-Output table available by IBGE (2018), for the year 2015 and the latest Agricultural Census (IBGE, 2017).

3.1 Agricultural sector disaggregation

The process of disaggregation of agricultural sectors uses a set of data to differentiate family farming production from large-scale agriculture production, which is heterogeneous in terms of the use of inputs, productive factors, types of crops and linkage to the internal and external market. For example, following the IBGE Agricultural Census (2017), 23.2% of agricultural producers are large-scale, employ 33% of agricultural workers, occupy 77% of the area of the establishments and are the largest responsible for the production of Soybeans, Corn, Sugarcane and Cotton. Family farmers, represents 76.8% of the producers, employ 67% of the agricultural workers, occupy only 23% of the area and are the main producers of Cassava, Pineapple, Tobacco, Onion, Cashew nuts and Grapes, Coffee and Banana.

The definition of family farming, used to guide the configuration of the model sectors, is established by Law 11,326 of 2006, created to guide public policies aimed at the category in Brazil. Family farmers are considered to be individuals who simultaneously meet the following requirements: i) does not have an area greater than 4 fiscal modules[2]; (ii) predominantly use family labor; iii) obtain a minimum percentage of family income originated from economic activities of your establishment; iv) direct your establishment with your family (BRASIL, 2006).

Data from the Brazilian Agricultural Census (IBGE, 2006; 2017) were used to establish the sector shares related to land use, labor, machinery, and equipment (proxy for capital), internal consumption, exportation, and production value. Data from Agrianual (2018) and AnualPec (2018) were used to measure the participation of family farmers and large-scale producers in terms of the use of intermediate inputs: i) Fertilizers, ii) Pesticides; iii) Diesel; iv) Inorganic chemicals; (v) Electricity, Gas, and others; vi) Cargo Transport; and vii) Financial and Insurance Institutions, for representing together about 70% of the total inputs consumed by the agricultural sectors.

3.2 Structure of Production Technology

In the AGRO-BR model, the productive sectors operate in perfect competition, obtaining zero profit, and each sector produces only one product on a constant scale of

[1] Table A1 in the Appendix section presents the sectors of the AGRO-BR model.
[2] The size of the fiscal module varies from 5 to 110 hectares among Brazilian municipalities.

production. Producers choose a combination of intermediate, domestic, or imported, and primary factors, capital, land, and labor, in order to minimize production costs, subject to production functions (Leontief and CES), as illustrated in Figure 1. The functional structures of optimization correspond to the figures in the form of trapezoid, the other structures refer to the products, factors, and inputs.

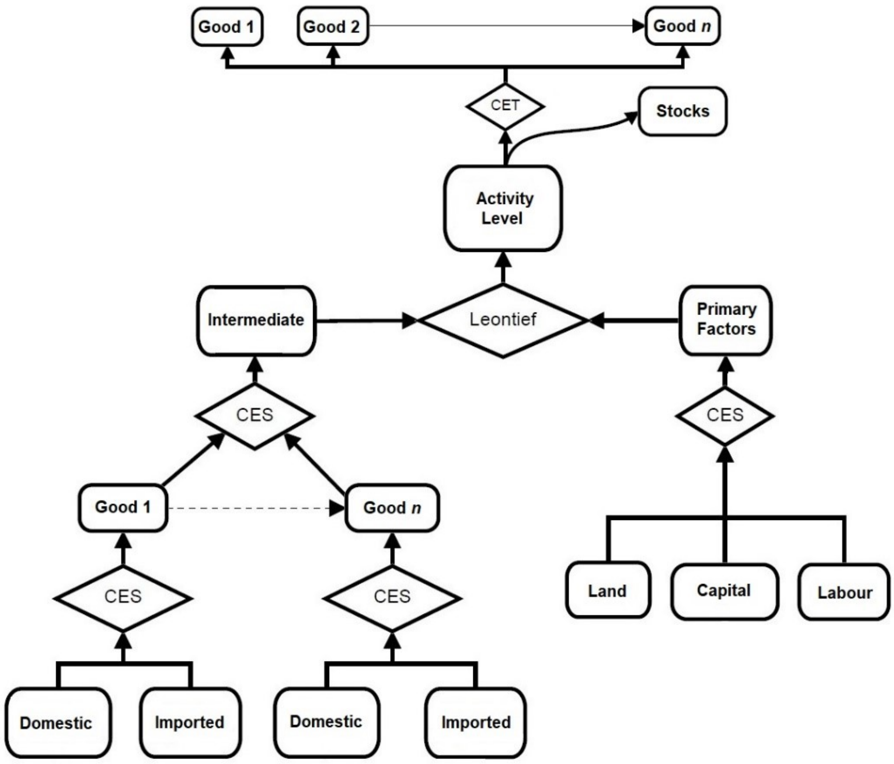

Figure 1: Production structure of the AGRO-BR model
Source: Adapted from Horridge (2011)

In the production process, the primary factors and intermediate inputs are demanded in fixed proportions, following a Leontief production function. That is, it is necessary to use the intermediate inputs and primary factors together, and it is not possible to replace them, as verified in the second level of Figure 1. At the level below, capital, land and labor factors are demanded through a CES-type production function. It is emphasized that the land factor is demanded only by the sectors producing agricultural products, cattle, other animals, forestry, vegetal extraction, and aquaculture. The demand for intermediate inputs is structured by a CES-type function, which allows replacement between different products. The source is also structured by a CES-type function, allowing the product to be replaced between the source regions.

3.3 Shocks and Scenarios

The policy scenarios, RCP 4.5, and RCP 8.5, used in the simulations of the AGRO-BR model, start from the projections of loss (or gain) of agricultural productivity estimated in Tanure (2020). The productivity changes, used as proxy to climate change in the model, were estimated with temperature and precipitation projections elaborated by INPE (Chou *et al*., 2014) according to RCP 4.5 and RCP 8.5 scenarios (IPCC, 2014) and presented in Figure 2. The scenarios represent a plausible (RCP 4.5) and a pessimist (RCP 8.5) path in terms of GHG emissions.

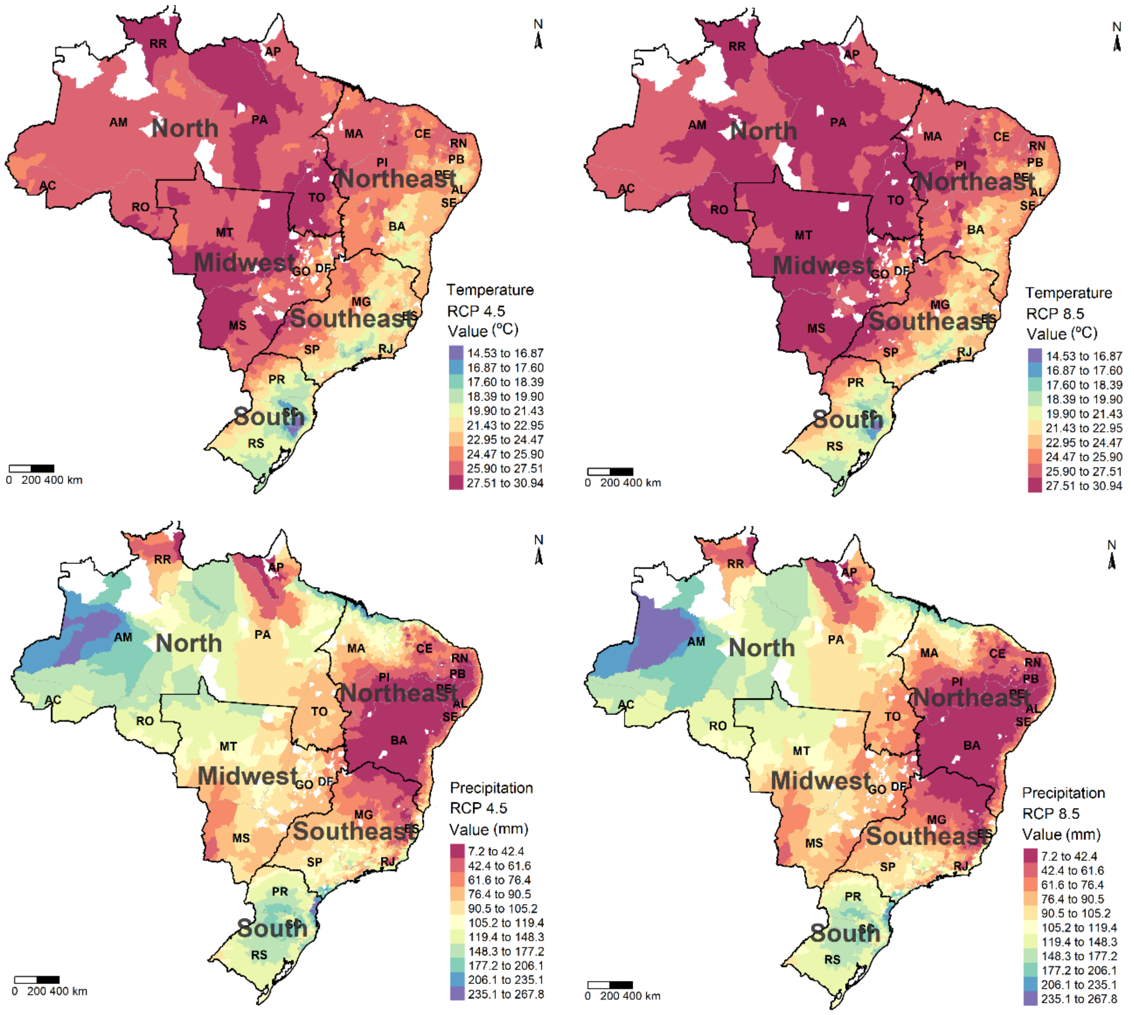

Figure 2: Average Temperature and Precipitation Projected by RCP 4.5 and RCP 8.5 (ºC) (mm) (2050)

Source: Own development based on Chou *et al*., (2014)

The North, Northeast, and Midwest regions, typical of high temperature, has the highest projected temperature elevations, while the Northeast, region characterized by low rainfall levels, has the highest projected rainfall reduction, compared to historic levels. Then, on average, an increase in agricultural productivity is projected on high latitudes, comprising the states in southern regions, while a decrease is projected in northern and northeast regions according to Tanure (2020).

The RCP 4.5 and RCP 8.5 policy scenarios are distinguished by the land productivity shocks applied to agricultural sectors. In RCP 8.5 policy scenario, the average land productivity variation is greater (in module) than the values verified in the RCP 4.5 policy scenario. In the baseline scenario, the growth rates of macroeconomic variables are exogenous and follow the recent performance verified by the Brazilian economy. In policy simulations, land productivity is exogenous to allow the implementation of the estimated shocks. The behavior (deviation from the baseline scenario) of the main macroeconomic aggregates, such as national GDP, household consumption and investment, are endogenous.

The period used in the simulations respects the climatological periodization of 30 years, established to cover all-natural climatic variability that can influence the mean of the variables analyzed. In this sense, the variations in agricultural productivity estimated in Tanure (2020), by cultivation and by type of producer, represent projections of variation for 30 years, carried out between the years 2021 to 2050. For the construction of the shocks in the model, these productivity variations were transformed into five-year rates. Section B in the Appendix presents the data used as shock in the simulations.

The agricultural sectors are directly affected by climate shocks. The land productivity shock alters the cost of the land factor, causing the sectors to refocus their primary production factors in order to minimize costs. Sectors with land productivity gain (positive shocks), will replace labor and capital by land, reducing costs. Sectors with productivity decrease (negative shocks) will replace land with labor and capital, resulting in rising costs. The magnitude of substitution is determined by the substitution elasticities[3] of primary factors and by the intensity of use of each factor. The size of this substitution effect between primary factors is guided by the productive structure extracted from the model database, being distinct between family farming and large-scale agriculture sectors and regions.

4. Results and Discussion

The results of the simulations performed with RCP 4.5 and RCP 8.5 policy scenarios are interpreted as deviations from the baseline scenario, in which the shocks of land productivity caused by climate change are not considered. The projections in 2050 represent the accumulated results related to the productivity shocks between the years 2021 and 2050.

4.1 Sectorial results

Table 1 presents the results of simulations for national sectoral production in RCP 4.5 and RCP 8.5 scenarios. Climate change directly affects agricultural sectors, via productivity shock, and indirectly other sectors of the economy. The greater the proximity to the agricultural sectors, the greater the indirect effects of the phenomenon. Moreover, the effects of CM on sectoral production, on average, intensify over time and in the RCP 8.5 scenario. Tables C1 and C2, in the Appendix section, shows the level of economic activity of the agricultural sectors, by UF.

Table 1: National Sectoral Production (Accumulated % variation in relation to baseline scenario)

Sector	RCP 4.5			RCP 8.5		
	2025	2040	2050	2025	2040	2050
Family Farming Rice	-0,02	-0,07	-0,10	0,00	0,03	0,07
Large-scale Rice	-0,10	-0,43	-0,67	-0,16	-0,69	-1,10
Family Farming Wheat and Cereals	0,20	0,83	1,28	0,05	0,24	0,39
Large-scale Wheat and Cereals	0,96	3,83	5,67	0,97	3,92	5,87
Family Farming Corn	0,03	0,12	0,18	0,02	0,10	0,15
Large-scale Corn	-0,97	-4,38	-7,13	-1,21	-5,47	-8,91
Family Farming Cotton Fiber	0,01	0,06	0,11	0,01	0,07	0,14
Large-scale Cotton Fiber	-0,71	-3,29	-5,46	-1,12	-5,25	-8,74
Family Farming Sugarcane	0,00	0,02	0,05	0,00	0,03	0,08
Large-scale Sugarcane	0,67	2,71	4,04	1,02	4,00	5,85
Family Farming Soybeans	-0,01	-0,02	-0,03	-0,01	-0,01	-0,01
Large-scale Soybeans	0,07	0,32	0,51	0,10	0,45	0,72

[3] Domingues *et al*. (2009) provides the substitution elasticities of primary factors. Table A2, in the Appendix section, presents the other elasticities used in the study.

Family Farming Cassava	-0,34	-1,83	-3,26	-0,45	-2,43	-4,30
Large-scale Cassava	0,04	0,12	0,14	0,00	-0,04	-0,09
Family Farming Tobacco Leaf	0,20	0,67	0,97	0,19	0,66	0,96
Large-scale Tobacco Leaf	0,03	0,12	0,20	0,03	0,13	0,21
Family Farming Tomato	0,00	0,00	0,00	0,00	0,00	0,00
Large-scale Tomato	-0,01	-0,05	-0,07	-0,01	-0,06	-0,08
Family Farming Potato	0,00	0,01	0,02	0,00	0,02	0,03
Large-scale Potato	-0,01	-0,03	-0,05	-0,01	-0,06	-0,09
Family Farming Onion	0,00	-0,02	-0,03	-0,01	-0,03	-0,06
Large-scale Onion	-0,01	-0,03	-0,05	0,00	-0,02	-0,03
Family Farming Peanuts	0,01	0,02	0,04	0,01	0,02	0,04
Large-scale Peanut	0,08	0,25	0,31	0,08	0,26	0,32
Family Farming Pineapple	0,00	0,00	0,00	0,00	-0,02	-0,03
Large-scale Pineapple	0,00	-0,02	-0,03	-0,01	-0,03	-0,04
Family Farming Banana	-0,25	-1,39	-2,62	-0,43	-2,40	-4,49
Large-scale Banana	-0,16	-0,68	-1,05	-0,39	-1,59	-2,39
Family Farming Beans	-0,20	-1,09	-1,94	-0,35	-1,92	-3,46
Large-scale Beans	-0,32	-1,29	-1,94	-0,49	-2,00	-3,02
Family Farming Cashew Chestnut	0,02	0,04	0,04	-0,20	-1,05	-1,88
Large-scale Cashew Chestnut	0,22	0,89	1,36	-0,08	-0,36	-0,61
Family Farming Grape	-0,07	-0,34	-0,60	-0,07	-0,35	-0,63
Large-scale Grape	0,03	0,12	0,18	0,07	0,26	0,37
Family Farming Out. temp crop.	0,12	0,48	0,70	0,30	1,17	1,71
Large-scale Out. temp crop.	0,01	-0,11	-0,32	0,11	0,30	0,30
Family Farming Orange	-0,08	-0,38	-0,67	-0,11	-0,52	-0,90
Large-scale Orange	-0,74	-3,32	-5,26	-0,86	-3,88	-6,18
Family Farming Coffee Grains	-0,44	-2,09	-3,55	-0,54	-2,54	-4,25
Large-scale Coffee Grains	-0,23	-1,06	-1,75	-0,25	-1,18	-1,97
Family Farming Out. perm crop.	0,07	-0,17	-0,79	0,15	0,04	-0,59
Large-scale Out. perm crop.	0,04	0,01	-0,14	0,38	1,34	1,79
Family Farming Cattle Other Animals	-0,01	-0,03	-0,05	-0,01	-0,05	-0,07
Large-scale Cattle and Other Animals	-0,01	-0,04	-0,07	-0,01	-0,06	-0,09
Family Farming Forestry	0,00	-0,01	-0,01	0,00	-0,01	-0,01
Large-scale Forestry	0,00	0,00	0,00	0,00	0,00	0,00
Family Farming Vegetal Extraction	0,00	-0,01	-0,01	0,00	0,00	-0,01
Large-scale Vegetal Extraction	0,00	0,00	0,01	0,00	0,01	0,02
Fishing and Aquaculture	0,00	0,00	0,00	0,00	0,00	0,00
Extractive Industry	0,00	0,01	0,02	0,00	0,01	0,02
Industries	0,01	0,06	0,09	0,02	0,07	0,12
Electronic	0,00	0,01	0,01	0,00	0,01	0,01
Food and Drink	0,01	0,03	0,03	0,01	0,05	0,07
Diesel Fuel	0,00	0,00	0,00	0,00	0,01	0,01
Inorganic Chemicals	0,00	0,01	0,01	0,00	0,01	0,02
Fertilizer	0,00	-0,04	-0,11	0,01	-0,03	-0,11
Pesticides	0,01	-0,01	-0,04	0,02	0,01	-0,04
Electricity and Gas	0,00	0,00	0,00	0,00	0,00	-0,01
Financial and Insurance Institutions	0,00	0,00	0,00	0,00	-0,01	-0,01
Trade	0,00	-0,02	-0,03	0,00	-0,02	-0,04

Cargo Transport	0,00	0,00	0,00	0,00	0,01	0,01
Services	0,00	0,00	0,00	0,00	0,00	0,00
Public Sector	0,00	0,00	0,00	0,00	0,00	0,00
Construction	0,00	0,00	0,00	0,00	0,00	0,00

Source: Own elaboration based on model results

In the RCP 4.5 scenario, economically relevant sectors for family farming would perform negatively. The Cassava, Coffee, and Banana sectors would accumulate losses of 3.26%, 3.55%, and 2.62%, respectively, in 2050. Soybean production would also be negatively affected, in lower magnitude. On the other hand, Tobacco, Other sectors of temporary tillage, and Corn sectors would show a production increase of 0.9%, 0.7%, 0.18% in 2050. As part of the production originated from family farming is consumed on the property, the negative impacts on the production of cassava, beans, orange, banana, coffee, grape and others of permanent farming, could deteriorate the food security of producers, and consequently increase their condition of vulnerability. This pattern deteriorates in the RCP 8.5 scenario.

Among the large-scale agricultural sectors with the highest share of domestic production, Corn, Cotton and Orange would tend to be negatively affected with a reduction in production by 8.91%, 8.74%, and 6.18%, respectively, in 2050. These sectors, together with Coffee, also with negative performance, have relevant participation in the foreign market, which could contribute to the retraction of supply and increase in international prices, as also verified by Calzadilla *et al.*, (2013) and Nazareth *et al.*, (2020). Among the beneficiaries, we highlight the producers of Wheat and Sugarcane, with projections of a production increase of 5.8% in the year 2050. It is also noteworthy the positive impacts, even if minor, on the Soybean sector, relevant in economic terms. The national performance of soybeans would be guaranteed by the increase in productivity in large producing regions, such as SP, MT, MS, PR, SC, and RS, however, the projections for the MATOPIBA region, the current frontier of crop expansion, are negative, as verified in Zilli *et al.*, (2020). These effects would be intensified in the RCP 8.5 scenario.

Climate change would indirectly affect other economic sectors, with the most pronounced impacts on sectors close to the agricultural sectors. The Cattle and Other Animals, Forestry and Vegetal extraction sectors, by competing for production factors, would be negatively impacted. The replacement of land by capital and labor in the agricultural sectors would reduce the availability of these factors for the others. The Cattle and Other Animals sector, the main responsible for the meat production of beef, pork, and poultry, would be negatively impacted, with possible effects for international trade, since Brazil has the largest cattle herd in the world, being the largest exporter of beef and poultry, and the third-largest exporter of pork (FAO, 2020). Nevertheless, the economic downturn of the agricultural sectors would negatively affect the Pesticides and Fertilizers sectors since these are the main suppliers for the agricultural sectors.

4.2 Regional Results

The impacts of CM on productivity and its consequent economic effects are heterogeneous between sectors and regions. The aggregate performance of the family farming and large-scale agricultural sectors by UF, presented in Table 2, is the net result of the effects on the activity of all agricultural sectors and allows us to evaluate the direction of impacts in regional terms and by type of producer. The family farming sectors of Cassava, Tobacco Leaf, Coffee and Soybean, and the large-scale agriculture sectors of Sugarcane, Soybeans and Coffee, have great economic relevance and therefore play a decisive role in regional results. The results for the RCP 8.5 scenario would indicate higher losses compared to the RCP 4.5 scenario.

Table 2: Aggregate production variation of the family farming and large-scale agriculture sector in 2050 (Accumulated % variation in relation to the baseline scenario)

Scenario	RCP 4.5		RCP 8.5	
Federal Unit / Agricultural Sector	Family Farming	Large-Scale Agriculture	Family Farming	Large-Scale Agriculture
Rondônia (RO)	-2,13	-1,13	-0,87	-1,21
Acre (AC)	-2,31	-1,6	-2,41	-1,97
Amazonas (AM)	-1,14	-0,36	-0,62	-0,18
Roraima (RR)	-2,31	-3,1	-0,51	-3,27
Pará (PA)	-4,88	-1	-1,36	-0,53
Amapá (AP)	-8,64	5,44	-7,91	5,57
Tocantins (TO)	0,15	-0,77	-0,03	-0,96
Maranhão (MA)	2,14	-1,7	0,25	-2,24
Piauí (PI)	3,55	-2,92	2,59	-3,66
Ceará (CE)	0,47	1,36	-1,79	-1,62
Rio Grande do Norte (RN)	-2,45	2,94	-3,33	-2,09
Paraíba (PB)	-1,27	-2,37	-3,43	-3,19
Pernambuco (PE)	-2,04	-0,68	-4,13	-0,97
Alagoas (AL)	-2,45	-3,59	-4,29	-4,73
Sergipe (SE)	-3,72	-3,68	-5,67	-5,44
Bahia (BA)	-1,26	-4,19	-3,45	-4,57
Minas Gerais (MG)	-2,24	-1,5	-2,55	-1,4
Espírito Santo (ES)	-4,01	-2,77	-5,47	-3,87
Rio de Janeiro (RJ)	-1,68	-3,22	-3,27	-4,76
São Paulo (SP)	0,91	2,42	0,62	3,59
Paraná (PR)	0,68	1,3	0,54	1,17
Santa Catarina (SC)	1,32	0,17	1,19	-0,01
Rio Grande do Sul (RS)	1,47	0,98	1,4	1,05
Mato Grosso do Sul (MS)	-2,2	-0,74	-2,27	-0,25
Mato Grosso (MT)	-0,96	-1,09	-0,68	-1,95
Goiás (GO)	2,76	-0,71	0,9	0,09
Distrito Federal (DF)	0,56	0,04	0,91	0,05

Source: Own elaboration based on the results of the AGRO-BR model

The aggregate sector results, by type of producer, reflect the magnitude of the productivity shock and the economic importance of each sector. Thus, crops with great economic participation can contribute positively to the aggregate performance of the sector. In the family farming sector, the states of Maranhão, Piauí, Ceará, São Paulo, Goiás, as well as the states of the Southern region and the Federal District would show growth. All the others would show a fall in the level of economic activity in relation to the baseline scenario. In the large-scale agriculture sector, the states of Amapá, Ceará, Rio Grande do Norte, and São Paulo and all in the Southern region would show growth in the level of sectoral activity.

The positive performance in both scenarios of the Southern region is due to the positive shock of agricultural productivity, caused by the increase of the average levels of temperature and precipitation. The region is characterized by milder temperatures. This explains the increase in the level of activity in the pessimistic scenario, with higher temperatures in the region. The positive performance of the state of São Paulo is due to the increase in productivity of sectors whose participation in the state GDP is relevant, such as Soybeans, Coffee, Sugarcane and Cotton for the large-scale agriculture sectors, and Beans, Coffee and Grapes for the family farming sectors.

From the perspective of aggregate regions in the RCP 4.5 scenario, the activity of family farming would be negatively affected in the North, Northeast, and Southeast regions of the country. These regions concentrate the largest share of family producers in Brazil. Only the Midwest and South regions would show an increase in the level of activity. Large-scale agriculture production would be negatively affected in the North, Northeast, and Midwest. The Southeast and South regions would benefit in terms of economic activity. These results could contribute to the increase of regional inequalities in Brazil since the negative impacts affect regions that concentrate family farmers with a less developed profile and a focus on subsistence production, while positive impacts would affect the South region, which in turn concentrates mechanized family farmers well established in the market. The simulations of the RCP 8.5 scenario indicate possible intensification of the effects over time, for all regions, except the North region, which would have the negative effects mitigated. Figure 3 shows the effects of climate change in RCP 4.5 and RCP 8.5 scenarios.

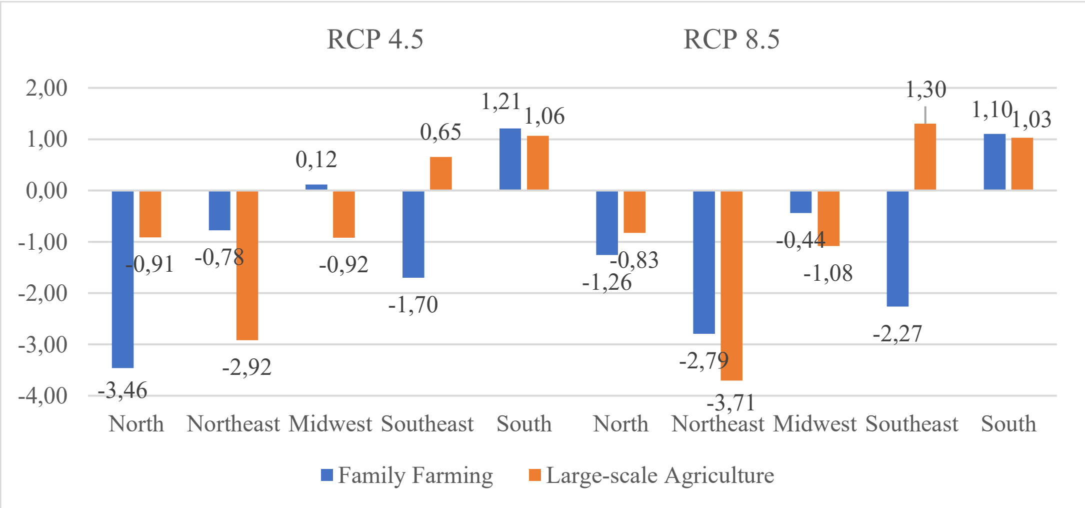

Figure 3: Regional Economic Activity Level in RCP 4.5 and RCP 8.5 scenarios in 2050 (Accumulated % variation in relation to baseline scenario)

Source: Own elaboration based on the results of the AGRO-BR model

The relevance of the participation of the state of São Paulo to the level of activity in the Southeast region would explain the positive performance of the large-scale agriculture sector in the region, given that in the states of Minas Gerais, Espírito Santo, and Rio de Janeiro (the other states that compound the southeast region) the economic performance would be negative in both scenarios. São Paulo stands out in the large-scale production of Cotton, Sugarcane, Wheat, and Others of the Permanent Crop. Some economically expressive sectors would show a decline in the level of activity, such as the large-scale production of Corn and Orange, however, the net effect in terms of activity is positive.

4.3 Macroeconomic results

The impacts of climate change projected by the AGRO-BR model would imply a negative impact on GDP in both scenarios. The retraction would be gradual over time, reaching -0.01% in 2050. Considering the nominal GDP of 2019 in the amount of R$7 trillion, the climate change represented in the model by the RCP 4.5 scenario could generate, roughly, accumulated losses of R$105 billion over 30 years, in current values, with annual losses of R$3.5 billion, reaching R$243 billion (R$8.1 billion annually) in the RCP 8.5 scenario. Table 3 presents the projected macroeconomic results.

Table 3: Macroeconomic Results in 2050 (accumulated % variation in relation to the baseline scenario)

Variables / Scenarios	RCP 4.5	RCP 8.5
Household Consumption	-0,010	-0,010
Investment	-0,001	-0,002
Exports	-0,129	-0,154
Imports	-0,092	-0,121
GDP	-0,010	-0,010
Family Farming Production	-0,490	-0,830
Large-Scale Agriculture Production	-0,590	-0,920

Source: Own elaboration based on model results

Compared to other studies, such as Margulis; Dubeux (2011), the estimated magnitude in terms of impacts on GDP is lower due to being due only to the net result of land productivity changes, while other studies that project larger impacts consider other aspects related to climate change. In the present study, although projections indicate that most crops would be negatively impacted, crops relevant in terms of representativeness in GDP were positively impacted, especially in commodities producing regions such as SP, PR, and RS states, minimizing the aggregate negative effects. Nevertheless, the final impact is negative, for both types of producers in the RCP 4.5 scenario, with a 0,49% accumulated decrease in family farmer's production and a 0,59% decrease in large-scale agricultural production in 2050. The results deteriorate in the RCP 8.5 scenario.

The results presented are similar to studies with similar approaches. Farias (2012) projects the impacts of CC on the economy through the integration of Monash and B-MARIA models and estimates of land-use change according to scenarios A2 and B2, for a group of eleven crops. With projected a accumulated reduction in national GDP between 0.02% in 2039 and 0.11% in 2099 considering scenario A2, and between 0.02% in 2039 and 0.07% in 2099 in scenario B2. The results are also close to those observed by Silva (2018), who estimates the agricultural productivity of five crops and projected a negative impact of 0,05% on GDP considering the RCP 2.6 scenario and a decrease of 0.26% in the RCP 8.5 scenario, accumulated in 2099. Our study advances by providing up-to-date estimates with the most recent scenarios for a higher number of crops and for distinct groups of family farmers and large-scale producers.

On household consumption performance, projected results indicate possible retraction in the same magnitude of GDP. The impact on household consumption would be more intense in the RCP 8.5 scenario. This performance is determined by the closing of the model, with the aggregate consumption following the variation of income and, therefore, GDP. Regarding investment, it is verified that at the aggregate level there is no retraction related to the decline of economic activity in the national economy. In sectoral terms, agriculture would increase the level of investment, especially in sectors with a retraction of land productivity, through the incorporation of capital and labor.

Sectors directly affected by productivity shocks, especially large-scale agriculture sectors, are, on average, exporters. The net effect of shocks on the level of activity is negative, and positive on their costs. In this sense, exports would be negatively affected and would show a sharp decline over time. The decrease in the level of economic activity would determine the reduction in imports. The use of imported productive inputs would be reduced due to decreased production. Moreover, the reduction of income of factors would negatively affect the consumption of families and the volume of imported goods. Therefore, negative impacts on Brazilian trade with the foreign market, as pointed by Calzadilla *et al*., (2013) and Nazareth *et al*., (2020), are expected.

Table 4 presents the GDP results at the Federation Units level for RCP 4.5 and RCP 8.5. The performance of each FU, in terms of GDP, reflects the economic importance of agricultural sectors affected by land productivity shocks. Projections indicate heterogeneity of results. On average, there would be a reduction in GDP in most FUs and of greater magnitude in the pessimistic scenario RCP 8.5. The States of the North, Northeast and Midwest regions would be the most affected, meeting the results of Ferreira Filho; Horridge (2010), Moraes (2010) and Farias (2012). It should be emphasized that such regions are the least developed in Brazil. The only FUs that would present positive growth in both scenarios would be RR, TO, AL, RJ, SP, PR and RS.

Table 4: GDP per Federation Unit (Var. % Accumulated in 2050)

Regions	Federation Units / Scenarios	RCP 4.5	RCP 8.5
North	Rondônia	-0,04	-0,03
	Acre	-0,06	-0,07
	Amazonas	-0,01	-0,02
	Roraima	0,16	0,28
	Pará	-0,2	-0,07
	Amapá	-0,09	-0,08
	Tocantins	0,14	0,21
Northeast	Maranhão	-0,05	-0,08
	Piauí	-0,15	-0,21
	Ceará	0,03	-0,02
	Rio Grande do Norte	0,0	-0,08
	Paraíba	-0,04	-0,07
	Pernambuco	-0,01	-0,01
	Alagoas	0,05	0,08
	Sergipe	-0,1	-0,14
	Bahia	-0,13	-0,16
Southeast	Minas Gerais	-0,1	-0,11
	Espírito Santo	-0,13	-0,18
	Rio de Janeiro	0,0	0,0
	São Paulo	0,03	0,04
South	Paraná	0,07	0,05
	Santa Catarina	0,0	-0,02
	Rio Grande do Sul	0,12	0,14
Midwest	Mato Grosso do Sul	-0,05	0,03
	Mato Grosso	-0,19	-0,36

	Goiás	-0,06	0,01
	Distrito Federal	-0,01	-0,01

Source: Own elaboration based on model results

Therefore, the simulated macroeconomic results show that the average impacts of land productivity shocks, used in the model as a proxy for the effects of climate change on agricultural productivity, would be negative on the Brazilian economy. However, the effects are heterogeneous. The Southern region would be the least negatively affected in economic terms, with the state of RS as a positive highlight. It is emphasized that part of the UF benefited from economic growth, such as SP, PR and RS, are the most developed in the country. Thus, the advent of CC could widen regional disparities in Brazil.

5. Final Considerations

There is a consensus that the impacts of climate change on agriculture in Brazil will be mostly negative, but there are few analyses that assess how the effects would be distributed in sectoral terms and by type of producer. This study is the first to provide projections of how the effects would be distributed over the 27 FUs, considering 21 crops produced by family farmers and large-scale agriculture sectors. We found that family farming production in less developed regions would be negatively affected, while developed regions would benefit from CC. Therefore, the phenomenon could deteriorate the situation of vulnerability and inequality conditions in the country.

The sectoral results projected for family farming indicate that the production of Cassava, Banana, Soybean, and Coffee would be affected by reduction over time, with negative implications on food security, while Tobacco, Corn, and Others from the Temporary Crop would be affected with increased production. On the part of the large-scale agriculture production, Corn, Cotton, and Orange would decrease, while Sugarcane, Soybeans, and Wheat would benefit from increased production. The pattern of results is similar between scenarios, however, the magnitude of the effects in RCP 8.5 would, on average, be more intense. Table 5 presents the synthesis of the results.

Table 5: Summary of the results

Producers	Family Farming		Large-scale Agriculture	
Impacts	Positive	Negative	Positive	Negative
Sector Highlights	Tobacco Leaf, Peanut, Grape, Other. Temporary	Cassava, Coffee, Corn, Banana and Beans	Sugarcane, Grape and Tobacco Leaf	Corn, Cotton, Beans, Coffee
Federation Unit	MA, PI, CE, SP, SC, PR, RS, GO, DF	All the rest of FUs	AP, CE, RN, SP, PR, SC, and RS	All the rest FUs
Regions	South	North, Northeast, Midwest and Southeast	South and Southeast	North, Northeast and Midwest

Source: Own elaboration based on the results of the AGRO-BR model

In the indirectly affected sectors, the effects on the level of activity of Cattle and Other Animal, Forestry and Vegetal extraction sectors would be negative since they compete for inputs and production factors with the agricultural sectors. As Brazil stands out as one of the world's leading meat exporters, the phenomenon of climate change could bring instability to international meat trade. In addition, the sectors that concentrate their activity on supplying inputs to the agricultural sectors, such as Fertilizers and Pesticides, would also be affected with production retraction in 2050, in both scenarios.

Finally, macroeconomic results would be negative. The magnitude of the variation is small, due to the heterogeneity of the effects, which despite being on the average negative, would be positive for important Federation Units in terms of participation in national GDP, such as SP, PR, and RS. Since the regions benefited are the most developed, such results could contribute to the widening of regional disparities in Brazil. The effect of climate change would generate a negative accumulated impact on GDP of around 0.01% in 2050, in both scenarios. In relation to the GDP of the Federation Units, the greatest variations would be verified in states whose share of agriculture in GDP is more relevant. Mato Grosso, Mato Grosso do Sul, Pará, Bahia, Minas Gerais, Piauí, and Maranhão, are negative highlights, while Tocantins and Rio Grande do Sul, Paraná and São Paulo are positive highlights in both scenarios.

References

AGRIANUAL. (2018). Anuário da agricultura brasileira. 23ª. ed. São Paulo: *FNP Consultoria e Comércio*.

ANUALPEC. (2018). Anuário da pecuária brasileira. São Paulo: *FNP Consultoria & Comércio*, 2018. 280 p.

Assad, Eduardo D; Pinto, Hilton S.; (2008). Aquecimento global e a nova geografia da produção agrícola no Brasil. *São Paulo: Embrapa/Unicamp*.

Assad, E. D. Oliveira, A. F; Nakai, A. M; Pavão, E; Pellegrino, G; Monteiro, J. E; (2016) Capítulo 4: Impactos e Vulnerabilidades da Agricultura Brasileira às Mudanças Climáticas. In: *Modelagem climática e vulnerabilidades Setoriais à mudança do clima no Brasil / Ministério da Ciência, Tecnologia e Inovação. Brasília: Ministério da Ciência, Tecnologia e Inovação*, 2016. 590p. il. ISBN: 978-85-88063-30-3

Assunção, J; Chein, F. (2016). Climate change and agricultural productivity in Brazil: future perspectives. *Environment and Development Economics*, 21(5), 581-602.

BRASIL. (2006). Lei nº 11.326, de 24 de julho de 2006. Estabelece as diretrizes para a formulação da Política Nacional da Agricultura Familiar e Empreendimentos Familiares Rurais. *Diário Oficial [da] República Federativa do Brasil*.

Calzadilla, A., Rehdanz, K., Betts, R., Falloon, P., Wiltshire, A., & Tol, R. S. (2013). Climate change impacts on global agriculture. *Climatic change*, *120*(1-2), 357-374.

Chou, S. C., Lyra, A., Mourão, C., Dereczynski, C., Pilotto, I., Gomes, J., ... & Campos, D. (2014). Assessment of climate change over South America under RCP 4.5 and 8.5 downscaling scenarios. *American Journal of Climate Change*, *3*(05), 512.

Cline, W. R. (2007). Global warming and agriculture: Impact estimates by country. *Peterson Institute*.

CNA, 2020. Confederação da Agricultura e Pecuária do Brasil, CNA. Panorama do Agro. Junho de 2020. Disponível em: https://www.cnabrasil.org.br/cna/panorama-do-agro#_ftn1

DePaula, Guilherme. (2018) The Distributional Impact of Climate Change in Brazilian Agriculture: A Ricardian Quantile Analysis with Census Data. *Center for Agricultural and Rural Development*. Iowa State University. Working Paper 18-WP 583.

Domingues, E. P; Magalhães, A. S; Ruiz, R. M. (2008). Cenários de mudanças climáticas e agricultura no Brasil: impactos econômicos na região Nordeste. Belo Horizonte: Cedeplar.

Domingues, E. P., Magalhães, A. S., & Faria, W. R. (2009). Infraestrutura, crescimento e desigualdade regional: uma projeção dos impactos dos investimentos do Programa de Aceleração do Crescimento (PAC) em Minas Gerais.

Domingues, E. P., Magalhães, A. S., & Ruiz, R. M. (2016). Cenários de mudanças climáticas e agricultura no Brasil: impactos econômicos na região Nordeste. Revista Econômica do Nordeste, 42(2), 229–246.

EMBRAPA. (2020). Empresa Brasileira de Pesquisa Agropecuária. Ministério da Agricultura, Pecuária e Abastecimento. Embrapa Themes. About Matopiba. Disponível em: https://www.embrapa.br/en/tema-matopiba/sobre-o-tema Acesso em set/2020

FAO. (2005). Special event on impact of climate change, pests and diseases on food security and poverty reduction. *Background Document. 31st Session of the Committee on World Food Security* Available in: ftp://ftp.fao.org/docrep/fao/meeting/009/j5411e.pdf]

FAO. (2020). Meat Market Review*, Overview of global meat market developments in 2019*, April 2020. Rome.

FAOSTAT. (2020). Food and Agriculture Organization of the United Nations. *Crops and livestock products*. Available in: <http://www.fao.org/faostat/en/#data/TP/visualize>. Acesso em: set. 2020.

Faria, W. R. (2012). Modelagem e avaliação de fenômenos relacionados ao uso da terra no Brasil (Doctoral dissertation, Universidade de São Paulo).

Faria, W. R., & Haddad, E. A. (2014). Estimação das elasticidades de substituição do comércio regional do Brasil. *Nova Economia*, *24*(1), 141-168.

Féres, J., Reis, E., & Speranza, J. (2009). Mudanças climáticas globais e seus impactos sobre os padrões de uso do solo no Brasil. In *XLVII Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural*. Brasília: SOBER. (in Portuguese)

Ferreira Filho, J. B. S; Horridge, M. (2010). Climate change impacts on agriculture and internal migrations in Brazil. *Centre of Policy Studies* (CoPS), Victoria University.

Hoffmann, R. (2010). Estimativas das elasticidades-renda de várias categorias de despesa e de consumo, especialmente alimentos, no Brasil, com base na POF de 2008-2009. *Economia Aplicada*, v. 57, n. 2, p. 49-57.

Horridge, M., Madden, J., & Wittwer, G. (2005). The impact of the 2002–2003 drought on Australia. *Journal of Policy Modeling*, *27*(3), 285-308.

Horridge, M. (2011). The TERM model and its data base. *Centre of Policy Studies - General Paper n. G-219*. [S.l.], p. 21.

IBGE. (2006). Instituto Brasileiro de Geografia e Estatística (IBGE). *Censo Agropecuário 2006*. Rio de Janeiro.

IBGE. (2017). Instituto Brasileiro de Geografia e Estatística (IBGE). *Censo Agropecuário 2017*. Rio de Janeiro.

IBGE. (2018). Instituto Brasileiro de Geografia e Estatística. Sistema de Contas Nacionais - SCN. Tabela de Recursos e Usos. Disponível em: <https://www.ibge.gov.br/estatisticas/economicas/servicos/9052-sistema-de-contas-nacionais-brasil.html?=&t=downloads>.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the *Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Margulis, S., & Dubeux, C. (2011). Economia da mudança do clima no Brasil. IPEA. *Boletim Regional, Urbano e Ambiental*. Brasília.

Massetti, E., Nascimento Guiducci, R. D. C., Fortes de Oliveira, A., & Mendelsohn, R. O. (2013). The Impact of Climate Change on the Brazilian Agriculture: A Ricardian Study at Microregion Level. The Impact of Climate Change on the Brazilian Agriculture: A Ricardian Study at Microregion Level (December 2013). *CMCC Research Paper*, (200).

Mendelsohn, R., & Schlesinger, M. E. (1999). Climate-response functions. *Ambio*, 28(4), 362-366.

Miyajima, D. N. (2018). Cenário de mudanças climáticas, efeitos sobre a produtividade agrícola e seus impactos econômicos nas regiões da Amazônia Legal Brasileira. *Dissertação de Mestrado. Cedeplar*, UFMG.

Moraes, Gustavo Inácio de. (2010). Efeitos econômicos de cenários de mudança climática na agricultura brasileira: um exercício a partir de um modelo de equilíbrio geral computável. *Tese de Doutorado. Universidade de São Paulo*.

Nazareth, M. S., Gurgel, A. C., & da Cunha, D. A. (2020). Economic effects of projected decrease in Brazilian agricultural productivity under climate change. *GeoJournal*, 1-14.

PBMC, 2014: Impactos, vulnerabilidades e adaptação às mudanças climáticas. *Contribuição do Grupo de Trabalho 2 do Painel Brasileiro de Mudanças Climáticas ao Primeiro Relatório da Avaliação Nacional sobre Mudanças Climáticas* [Assad, E.D., Magalhães, A. R. (eds.)]. COPPE. Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brasil, 414 pp.

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., ... & Neumann, K. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences*, *111*(9), 3268-3273.

Souza, B. S., (2018). Mudanças climáticas no Brasil: efeitos sistêmicos sobre a economia brasileira provenientes de alterações na produtividade agrícola. *Tese de Doutorado. Universidade de São Paulo*.

Tanure, T. M. do P. (2020). Mudanças climáticas e agricultura no Brasil: impactos econômicos regionais e por cultivo familiar e patronal. *Tese (doutorado) - Universidade Federal de Minas Gerais*, Centro de Desenvolvimento e Planejamento Regional.

Zilli, M., Scarabello, M., Soterroni, A. C., Valin, H., Mosnier, A., Leclere, D., ... & Ramos, F. M. (2020). The impact of climate change on Brazil's agriculture. *Science of The Total Environment*, 139384.

APPENDIX A - Sectors and elasticities of the AGRO-BR Model

Table A1: AGRO-BR model sectors

1	Family Farming Rice	23	Family Farming Peanuts	45	Family Farming Forestry
2	Large-scale Rice	24	Large-scale Peanut	46	Large-scale Forestry
3	Family Farming Wheat and Cereals	25	Family Farming Pineapple	47	Family Farming Vegetal Extraction
4	Large-scale Wheat and Cereals	26	Large-scale Pineapple	48	Large-scale Vegetal Extraction
5	Family Farming Corn	27	Family Farming Banana	49	Fishing and Aquaculture
6	Large-scale Corn	28	Large-scale Banana	50	Extractive Industry
7	Family Farming Cotton Fiber	29	Family Farming Beans	51	Industries
8	Large-scale Cotton Fiber	30	Large-scale Beans	52	Electronic
9	Family Farming Sugarcane	31	Family Farming Cashew Chestnut	53	Food and Drink
10	Large-scale Sugarcane	32	Large-scale Cashew Chestnut	54	Diesel Fuel
11	Family Farming Soybeans	33	Family Farming Grape	55	Inorganic Chemicals
12	Large-scale Soybeans	34	Large-scale Grape	56	Fertilizer
13	Family Farming Cassava	35	Family Farming Out. temp crop.	57	Pesticides
14	Large-scale Cassava	36	Large-scale Out. temp crop.	58	Electricity and Gas
15	Family Farming Tobacco Leaf	37	Family Farming Orange	59	Financial and Insurance Institutions
16	Large-scale Tobacco Leaf	38	Large-scale Orange	60	Trade
17	Family Farming Tomato	39	Family Farming Coffee Grains	61	Cargo Transport
18	Large-scale Tomato	40	Large-scale Coffee Grains	62	Services
19	Family Farming Potato	41	Family Farming Out. perm crop.	63	Public Sector
20	Large-scale Potato	42	Large-scale Out. perm crop.	64	Construction
21	Family Farming Onion	43	Family Farming Cattle Other Animals		
22	Large-scale Onion	44	Large-scale Cattle and Other Animals		

Fonte: Own elaboration

Table A2: Elasticity parameters in the AGRO-BR model

Parameter	Dimension	Description	Value
EPS	COM	Elasticity of family's expenditure	0 to 1.65
EXP_ELAST	IND	Elasticity of demand for exports	1
FRISCH	DST	Frisch parameter	-2,48
DPRC	IND	Depreciation Rate	0,5
QRATIO	IND AND DST	Investment/capital ratio (maximum trend)	4
RNORMAL	IND AND DST	Gross normal rate of return	12%
GROTREND	IND AND DST	Investment/capital ratio (trend)	0.06 to 0.15
ALPHA	IND AND DST	Investment elasticity	5
SIGMA1LAB	IND	Work replacement elasticity	0,02
SIGMA1PRIM	IND	Elasticity of substitution of primary factors	0.63 to 1.0
ARMSIGMA	IND	Substitution elasticity of intermediate goods	0.04 to 2.42
SIGMADOMDOM	IND	Region Substitution elasticities	0.8 to 2.37
SIGMAMAR	IND	Substitution elasticity between margin regions	0,2
SIGMA1OUT	IND	CET transformation elasticity	0,5

Source: Own elaboration based on Domingues *et al*. (2009); Hofmann (2010); Faria; Haddad (2014).

APÊNDICE B - Productivity Shocks

Table B1: Five-year Land Productivity Shocks in Family Farming Sectors (%) (RCP 4.5 Scenario) (2021-2050)

FU / Sector	Banana	Coffee	Cashew Nuts	Orange	Grape	Others. Perm.	Pineapple	Cotton Fiber	Peanut	Rice and Cereals	Potato	Sugarcane	Onion	Beans	Tobacco Leaf	Cassava	Corn	Soybeans	Tomato	Wheat	Others. Temp.
AC	-6,07	-2,78	0,00	-3,48	0,00	-4,66	-0,35	-0,97	1,67	0,66	11,45	2,78	0,00	-2,02	-3,95	-3,40	-2,11	0,00	0,00	0,00	-3,82
AP	1,08	0,00	0,00	4,50	0,00	-7,77	2,19	0,00	0,00	8,55	0,00	1,34	0,00	-7,67	0,00	-9,61	-9,41	0,00	0,00	0,00	-8,00
AM	-3,52	1,68	0,00	6,61	0,00	-4,66	2,15	0,00	3,49	1,29	11,96	-2,87	0,00	-1,72	-7,71	-3,92	-3,36	0,00	0,00	0,00	3,59
PA	-2,18	-5,50	-6,61	4,50	0,00	-7,33	1,56	-9,66	2,91	2,27	3,31	1,08	-2,24	0,72	5,97	-7,54	-3,53	-3,54	4,83	0,00	-2,27
RO	-7,42	-1,38	0,00	4,60	0,00	-5,84	0,23	0,00	5,35	1,09	11,50	2,16	9,58	-0,51	0,00	-6,09	-2,23	-6,05	-6,20	0,00	-1,58
RR	1,76	-8,03	0,00	4,50	0,00	-9,12	-8,77	0,00	-9,89	5,99	0,00	3,43	0,00	1,46	0,00	-7,47	-0,01	0,00	4,02	0,00	6,14
TO	-2,85	0,00	-6,02	-9,70	0,00	11,15	-1,13	0,00	9,78	0,27	7,55	-6,69	0,00	4,52	0,00	-7,33	-1,36	-3,59	0,00	0,00	5,74
AL	3,04	-6,24	-1,85	-3,27	0,00	-7,67	0,76	-9,37	-2,81	0,21	-5,97	4,97	0,00	-4,17	-6,85	-4,36	-5,44	0,00	2,02	0,00	-3,35
BA	0,34	-6,51	-5,38	-10,14	-9,28	-3,44	3,34	-10,03	5,77	2,63	-5,66	-2,61	-5,94	-4,81	-4,28	-4,28	-5,87	-4,09	5,94	0,00	1,47
CE	-0,45	-5,19	0,18	-7,96	0,00	-4,25	1,00	2,01	2,74	0,39	-1,31	0,23	3,51	-0,22	-3,72	4,11	-1,34	0,00	0,59	0,00	-2,37
MA	0,09	-6,47	9,07	1,75	0,00	1,45	-0,28	0,00	3,39	1,11	0,00	-1,00	0,00	-0,65	0,00	0,05	-1,99	-4,87	0,00	0,00	5,24
PB	-2,23	-5,18	-4,01	-9,94	-9,03	-4,76	0,57	-5,03	1,25	-0,71	-0,32	2,86	6,35	-3,11	-7,36	-3,05	-4,44	0,00	0,99	0,00	-0,23
PE	-0,46	-5,04	-5,42	-9,84	-7,02	-2,23	3,41	-10,07	6,43	0,76	-3,56	5,12	-1,17	-4,11	-6,32	-4,61	-5,20	-1,22	4,02	0,00	-1,81
PI	4,25	0,00	4,42	6,51	0,00	8,53	3,05	-7,57	8,52	0,44	0,00	-3,11	0,00	1,66	-4,25	-1,22	-1,48	-5,24	-0,75	0,00	8,48
RN	0,29	-3,50	-2,29	-9,38	0,00	-7,71	0,28	6,91	1,99	-1,50	0,00	3,67	6,35	-2,08	-6,65	-2,57	-3,43	1,82	-0,67	-11,91	-3,98
SE	3,53	0,00	5,28	-8,23	0,00	-7,26	-0,72	0,00	-3,61	0,06	-6,92	3,96	-0,18	-4,67	-7,30	-4,88	-6,38	0,00	8,84	0,00	-4,85
ES	-5,32	-4,26	0,00	-6,48	-7,81	-2,19	-4,73	0,00	6,58	2,36	-5,97	1,18	-7,68	-5,13	0,00	3,23	-6,44	0,00	3,63	0,00	-4,18
MG	-3,91	-2,78	0,00	-2,46	-6,75	0,63	0,85	-7,10	12,10	2,92	0,56	-1,15	-6,60	-4,42	-2,57	-4,28	-4,42	-5,79	-0,83	0,00	1,49
RJ	-6,25	-4,05	0,00	2,55	0,00	0,29	-4,77	0,00	0,00	2,83	-4,60	1,74	-6,14	-5,57	0,00	3,03	-4,38	0,00	-1,89	0,00	-5,55
SP	-7,92	8,99	0,00	-7,55	12,25	4,73	-8,03	0,46	9,13	1,20	7,22	-6,48	-5,66	0,60	8,77	-3,76	2,89	-1,72	-6,64	6,15	5,74
GO	0,95	-3,21	0,00	-0,46	0,00	3,80	10,03	0,00	11,90	1,24	7,55	-3,37	10,39	1,69	-1,73	-6,62	-2,94	-5,82	-9,03	0,00	11,73
MT	-8,34	1,34	-7,32	-1,83	0,00	0,00	-3,80	-3,09	7,01	0,10	7,55	-6,12	0,00	2,92	0,00	-7,62	0,56	-6,51	-4,06	0,00	5,74
MS	-10,23	6,39	0,00	-11,30	0,00	4,73	-7,59	-5,72	6,77	1,02	7,55	-9,66	-5,29	2,02	0,00	-8,48	4,27	0,32	-7,63	6,15	5,74
PR	-9,24	6,39	-0,38	-7,46	2,53	4,73	2,09	6,29	6,77	0,64	5,32	-7,24	-0,18	-1,55	12,24	-3,99	2,96	0,21	-5,17	6,15	5,74
RS	-7,83	11,63	0,00	-2,72	-7,60	7,82	2,40	0,00	10,85	-0,71	7,91	-5,49	-1,38	0,92	5,50	2,45	2,71	0,89	-5,70	6,15	5,74
SC	-9,80	6,39	0,00	-5,37	-1,80	5,87	2,40	0,00	11,83	-1,50	5,89	-4,27	0,26	-2,23	10,60	6,47	1,01	0,72	-5,94	6,15	5,74

Source: Own elaboration based on Tanure (2020).

Table B2: Five-year Land Productivity Shocks in Family Farming Sectors (%) (RCP 8.5 Scenario) (2021-2050)

FU / Sector	Banana	Coffee	Cashew Nuts	Orange	Grape	Others. Perm.	Pineapple	Cotton Fiber	Peanut	Rice and Cereals	Potato	Sugarcane	Onion	Beans	Tobacco Leaf	Cassava	Corn	Soybeans	Tomato	Wheat	Others. Temp.
AC	-7,10	-2,45	0,00	-6,85	0,00	-3,99	-1,45	1,54	3,53	-0,12	9,15	3,00	0,00	-1,27	-0,82	-4,36	-1,38	0,00	0,00	0,00	0,15
AP	0,54	0,00	0,00	5,60	0,00	-6,20	0,33	0,00	0,00	8,24	0,00	-0,50	0,00	-7,11	0,00	-9,85	-9,20	0,00	0,00	0,00	-5,58
AM	-4,19	3,21	0,00	4,03	0,00	-3,18	2,91	0,00	4,99	0,61	9,15	-2,65	0,00	0,31	-5,31	-4,43	-2,59	0,00	0,00	0,00	6,46
PA	-3,02	-3,72	-8,44	3,51	0,00	-3,94	-1,58	-9,55	6,16	2,57	8,97	-2,00	-3,34	2,35	-3,30	-8,49	-3,39	-4,00	3,78	0,00	6,81
RO	-8,31	-0,35	0,00	-2,40	0,00	-4,54	-1,69	0,00	7,83	0,28	9,15	1,10	11,05	1,16	0,00	-7,26	-1,22	-7,16	-5,65	0,00	7,38
RR	9,27	-7,75	0,00	3,51	0,00	-9,84	-9,56	0,00	-10,06	4,29	0,00	6,31	0,00	3,22	0,00	-7,70	2,55	0,00	7,48	0,00	6,24
TO	-6,06	0,00	-7,13	-10,58	0,00	7,44	-5,72	0,00	7,68	0,90	9,15	-7,68	0,00	6,83	0,00	-8,72	-0,72	-5,31	0,00	0,00	6,24
AL	-4,62	-6,77	-4,74	-8,87	0,00	-8,27	-1,62	-11,00	0,35	1,37	-8,32	8,23	0,00	-6,79	-2,48	-4,12	-6,52	0,00	11,10	0,00	-7,89
BA	-6,78	-6,54	-7,45	-11,11	7,06	-5,44	1,31	-11,47	9,77	3,40	-7,91	-0,49	-9,87	-7,14	2,92	-4,66	-6,94	-6,28	7,48	0,00	-4,80
CE	-1,11	-6,25	-5,38	-9,57	0,00	-1,51	2,59	-7,07	7,05	1,70	-3,48	0,29	-7,81	-3,01	6,23	3,01	-3,36	0,00	8,68	0,00	-4,02
MA	-0,98	-6,71	-6,28	-4,18	0,00	9,48	-0,19	0,00	7,96	2,27	0,00	-3,86	0,00	-0,53	0,00	-3,02	-3,02	-6,71	0,00	0,00	6,24
PB	-5,46	-6,88	-4,87	-10,82	7,06	-4,44	-0,48	-9,85	5,14	0,79	-5,40	4,87	-3,77	-5,88	-3,09	-2,43	-5,92	0,00	9,88	0,00	-4,86
PE	-5,76	-5,70	-6,79	-11,14	7,06	-3,78	1,53	-11,45	11,46	1,59	-6,63	6,94	-8,49	-6,68	-2,88	-4,67	-6,64	-4,80	7,48	0,00	-6,17
PI	-0,69	0,00	2,55	0,57	0,00	7,44	-0,49	-10,56	7,68	1,71	0,00	-4,99	0,00	-0,64	2,91	-3,40	-2,84	-7,02	7,98	0,00	12,06
RN	-2,85	-5,25	-3,60	-10,95	0,00	-7,05	-0,49	-5,53	6,67	-0,03	0,00	5,19	-0,78	-4,82	-1,69	-2,17	-4,88	-1,99	8,53	1,81	-6,48
SE	-4,83	0,00	-0,21	-10,03	0,00	-8,17	-1,95	0,00	-1,03	1,12	-9,04	7,58	-8,28	-7,04	-2,65	-4,55	-7,12	0,00	7,48	0,00	-8,60
ES	-9,32	-5,00	0,00	-9,01	9,24	-4,92	-5,50	0,00	11,89	3,90	-6,88	4,23	-9,76	-6,92	0,00	0,73	-7,35	0,00	8,18	0,00	-7,63
MG	-6,81	-2,91	0,00	-4,11	-4,22	1,46	-2,56	-10,57	7,68	4,10	-0,64	-0,41	-9,00	-6,33	1,06	-5,07	-5,18	-7,01	6,51	0,00	2,59
RJ	-9,07	-4,94	0,00	-5,21	0,00	-2,02	-5,34	0,00	0,00	4,31	-5,57	4,37	-9,17	-7,23	0,00	0,14	-6,03	0,00	0,87	0,00	-8,32
SP	-9,84	3,38	0,00	-9,62	7,06	7,44	-9,71	-3,20	7,68	2,03	11,67	-8,07	-7,03	0,75	5,86	-5,81	3,36	-2,42	-7,38	1,81	6,24
GO	-3,98	-2,47	0,00	-6,04	0,00	7,93	7,76	0,00	7,68	1,61	9,15	-4,54	1,87	0,01	5,18	-7,83	-2,73	-6,81	-8,69	0,00	6,24
MT	-9,46	3,56	-8,69	-3,71	0,00	8,77	-6,22	-1,72	9,40	-0,19	9,15	-7,41	0,00	5,65	0,00	-8,73	2,54	-7,45	-3,38	0,00	6,24
MS	-11,15	3,38	0,00	-11,84	0,00	7,44	-9,47	-6,79	7,68	0,23	9,15	-10,49	-5,80	2,51	0,00	-9,57	7,61	1,68	-8,22	1,81	6,24
PR	-10,50	3,38	-2,78	-9,20	4,62	7,44	-0,78	2,14	7,68	1,19	6,36	-8,47	-2,02	-1,90	11,74	-6,10	3,38	0,48	-6,08	1,81	6,24
RS	-10,21	3,38	0,00	-4,34	-7,91	9,55	11,43	0,00	12,03	-0,01	10,73	-6,64	-3,46	1,11	6,01	-0,05	2,65	1,52	-6,85	1,81	6,24
SC	-11,16	3,38	0,00	-6,52	-2,86	6,39	11,40	0,00	7,68	-0,56	7,57	-5,06	-1,07	-2,79	8,81	3,78	0,12	0,46	-7,10	1,81	6,24

Source: Own elaboration based on Tanure (2020).

Table B3: Five-year Land Productivity Shocks in Large-scale Agricultural Sectors (%) (RCP 4.5 Scenario) (2021-2050)

FU / Sector	Banana	Coffee	Cashew Nuts	Orange	Grape	Others. Perm.	Pineapple	Cotton Fiber	Peanut	Rice and Cereals	Potato	Sugarcane	Onion	Beans	Tobacco Leaf	Cassava	Corn	Soybeans	Tomato	Wheat	Others. Temp.
AC	-8,22	-1,40	0,00	-9,33	0,00	2,99	0,23	0,00	0,58	0,50	0,00	0,37	0,00	-3,55	-0,12	-6,47	-1,52	0,00	0,00	0,00	1,17
AP	0,00	0,00	0,00	-9,07	0,00	-3,66	5,06	0,00	0,00	-1,58	0,00	0,00	0,00	0,00	0,00	-9,83	-8,64	0,00	0,00	0,00	4,76
AM	-5,38	1,90	0,00	6,94	0,00	-1,62	11,35	0,00	0,00	-0,96	0,00	-1,87	0,00	-3,03	0,00	-4,92	-2,28	0,00	0,00	0,00	-3,60
PA	-3,44	-6,34	6,87	6,49	0,00	-4,30	3,10	0,00	-2,00	-1,72	-6,30	2,09	0,00	-0,18	-5,92	-8,03	-4,99	-1,51	-9,95	0,00	2,95
RO	-10,25	-0,02	0,00	-9,20	0,00	0,38	1,18	0,00	-8,06	-0,56	0,00	1,33	0,00	-3,56	0,00	-8,22	-4,22	-0,11	3,25	0,00	1,59
RR	5,43	0,00	0,00	6,94	0,00	-5,62	-8,38	0,00	0,00	-1,89	0,00	2,15	0,00	-3,16	0,00	-7,09	-6,73	-5,15	0,00	0,00	4,76
TO	-5,40	0,00	-12,00	-5,16	0,00	4,41	-7,98	0,00	2,91	-2,02	0,00	7,89	0,00	-1,49	0,00	-1,55	-6,89	-0,96	0,00	0,00	8,60
AL	5,43	0,00	-2,61	-6,45	0,00	-7,25	8,81	-8,52	-4,95	-1,59	2,85	-1,71	0,00	-4,61	-3,46	-5,16	-2,91	0,00	0,00	0,00	4,76
BA	3,70	-4,95	-1,79	-6,28	0,00	0,80	5,06	-11,03	3,76	2,74	-11,17	0,84	9,20	-5,61	4,25	-4,10	-7,05	-2,33	-3,16	0,00	-4,78
CE	1,53	-4,72	6,87	6,94	0,00	-5,12	2,75	6,69	-5,87	-0,39	0,00	-1,11	4,06	0,08	11,61	0,26	1,07	-1,45	5,71	0,00	-3,04
MA	-1,90	0,00	8,02	-3,21	0,00	6,52	0,09	0,00	1,88	-0,53	0,00	5,46	0,00	-1,06	0,00	2,16	-4,37	-1,44	0,00	0,00	5,34
PB	-0,36	-0,95	-0,68	-6,01	10,16	-0,53	8,23	-5,71	2,47	-1,27	-3,39	-1,18	1,31	-3,75	-5,21	-4,32	-1,91	0,00	7,44	2,27	-2,13
PE	2,18	-2,40	-5,19	-8,06	-2,13	1,92	5,06	-10,79	3,58	1,19	1,83	0,37	6,45	-5,18	0,00	-4,90	-3,39	0,00	11,25	0,00	-3,08
PI	8,10	-1,55	-5,89	11,07	0,00	7,59	0,00	-8,38	-1,74	0,09	0,00	-0,70	0,00	-0,77	0,00	3,25	-4,47	-1,95	-4,17	0,00	-1,95
RN	4,21	0,00	5,66	0,00	0,00	-5,34	5,06	0,16	0,00	-1,65	0,00	-1,41	-4,98	-2,28	-5,13	-4,65	1,61	0,00	9,03	1,96	5,23
SE	11,14	0,00	0,00	-5,17	0,00	-6,33	5,06	0,00	-6,00	-0,98	-2,75	-1,99	0,00	-5,53	-5,29	-5,05	-3,61	0,00	0,00	0,00	-1,46
ES	-5,54	-3,24	0,00	6,10	2,34	-0,77	-8,73	0,00	5,54	1,96	-8,80	-0,31	5,45	-6,87	0,00	0,71	-5,48	0,00	-2,04	0,00	-3,55
MG	-3,27	-1,88	0,00	-6,74	6,32	7,27	-8,53	-4,20	3,70	-0,25	3,94	3,95	-7,48	-4,58	-3,76	-4,29	-6,10	-0,64	-6,30	10,73	-2,97
RJ	-6,81	-4,82	0,00	2,06	0,00	2,18	-8,07	0,00	0,00	2,19	-3,54	-2,04	0,00	-4,27	0,00	-1,08	-3,29	0,00	-7,32	0,00	-4,30
SP	-8,03	2,37	0,00	-6,16	6,32	4,41	-11,99	11,67	8,39	1,81	-3,16	6,17	-1,15	0,00	8,24	3,58	-5,13	1,68	-5,77	0,79	9,84
GO	-2,56	-3,75	0,00	-7,82	0,00	8,16	9,99	-5,58	-1,25	-0,26	-1,44	5,53	-11,58	-4,68	0,00	-3,92	-6,59	-0,64	-7,23	9,80	0,29
MT	-10,70	0,67	0,00	8,92	0,00	4,41	-8,45	-4,58	-5,86	-1,56	2,89	9,22	0,00	-4,63	0,00	-7,76	-4,40	0,19	7,07	0,00	4,76
MS	-10,90	10,78	0,00	-1,92	0,00	4,41	-11,92	-8,09	7,50	-3,94	0,00	4,25	0,00	1,83	0,00	5,09	-8,47	0,72	0,00	6,15	4,76
PR	-10,45	9,32	-5,10	-1,37	6,32	4,41	-10,82	-2,16	4,40	-2,72	-1,95	7,87	5,45	1,06	8,24	6,67	-5,65	2,20	7,44	9,71	5,74
RS	-6,65	0,00	0,00	-2,37	5,74	-1,57	0,50	0,00	4,40	-0,73	-3,05	3,36	5,45	2,81	8,24	9,99	-2,51	1,94	7,44	5,21	-2,59
SC	-10,30	0,00	0,00	5,92	-5,21	-2,90	-5,90	0,00	4,40	3,65	-3,08	-0,33	5,45	1,37	8,24	0,01	-2,02	2,48	7,44	-0,39	-6,38

Source: Own elaboration based on Tanure (2020).

Table B4: Five-year Land Productivity Shocks in Large-scale Agricultural Sectors (%) (RCP 8.5 Scenario) (2021-2050)

FU / Sector	Banana	Coffee	Cashew Nuts	Orange	Grape	Others. Perm.	Pineapple	Cotton Fiber	Peanut	Rice and Cereals	Potato	Sugarcane	Onion	Beans	Tobacco Leaf	Cassava	Corn	Soybeans	Tomato	Wheat	Others. Temp.
AC	-9,24	-0,23	0,00	-10,89	0,00	7,93	-3,37	0,00	2,12	-0,10	0,00	2,15	0,00	-3,67	6,48	-7,09	-2,55	0,00	0,00	0,00	4,71
AP	0,00	0,00	0,00	-10,10	0,00	0,23	6,27	0,00	0,00	-1,90	0,00	0,00	0,00	0,00	0,00	-9,75	-9,16	0,00	0,00	0,00	4,89
AM	-6,00	3,86	0,00	6,77	0,00	0,74	4,60	0,00	0,00	-1,61	0,00	-0,34	0,00	-2,92	0,00	-5,41	-3,33	0,00	0,00	0,00	-0,90
PA	-4,87	-5,45	-2,52	0,96	0,00	1,55	-5,55	0,00	-3,64	-1,46	-9,29	5,20	0,00	-2,54	-9,24	-8,13	-6,95	-1,22	-10,13	0,00	3,01
RO	-10,78	1,59	0,00	-10,87	0,00	6,23	-4,00	0,00	-7,94	-1,36	0,00	3,86	0,00	-3,71	0,00	-8,70	-5,25	-0,05	4,47	0,00	6,81
RR	2,61	0,00	0,00	5,88	0,00	-3,79	-9,49	0,00	0,00	-3,16	0,00	3,42	0,00	-2,27	0,00	-7,89	-6,68	-5,11	0,00	0,00	4,89
TO	-8,77	0,00	-12,14	-7,65	0,00	3,60	-11,03	0,00	0,60	-1,84	0,00	11,51	0,00	-2,78	0,00	-3,75	-8,45	-0,78	0,00	0,00	4,89
AL	4,05	0,00	8,36	-7,33	0,00	-5,25	5,01	-7,55	-4,78	1,18	7,46	-1,98	0,00	-6,93	0,36	-7,50	-3,81	0,00	0,00	0,00	4,32
BA	-6,78	-5,53	8,36	-7,92	0,00	3,57	9,42	-11,21	3,58	4,48	-11,00	0,17	7,38	-7,61	11,43	-7,42	-7,86	-2,49	-2,78	0,00	-5,92
CE	-0,08	-5,90	-3,04	6,75	0,00	-1,39	-0,44	11,08	-3,47	2,26	0,00	-0,30	8,77	-3,40	6,48	-1,71	-3,21	-1,61	-1,51	0,00	-5,16
MA	-4,83	0,00	-6,55	-5,03	0,00	3,60	-6,89	0,00	2,54	0,96	0,00	8,32	0,00	-2,91	0,00	-0,03	-6,88	-1,53	0,00	0,00	7,91
PB	-5,19	-3,57	9,27	-7,94	-10,14	3,32	2,59	-8,78	3,58	1,44	-2,32	-1,27	10,53	-6,37	5,40	-6,19	-4,72	0,00	7,74	10,35	-4,64
PE	-4,91	-2,98	7,00	-8,42	-11,47	5,98	10,89	-10,75	6,07	3,48	1,37	-0,08	7,38	-7,31	0,00	-7,09	-5,24	0,00	9,96	0,00	-5,13
PI	1,05	-2,86	-3,87	10,31	0,00	3,60	0,00	-10,42	-1,65	1,61	0,00	1,99	0,00	-3,77	0,00	0,84	-6,98	-2,21	-8,35	0,00	-1,23
RN	-0,65	0,00	8,76	0,00	0,00	-2,77	7,97	-4,12	0,00	0,84	0,00	-1,41	-1,31	-5,11	5,36	-6,19	-2,27	0,00	1,33	10,43	-1,82
SE	-2,70	0,00	0,00	-7,33	0,00	-5,12	6,27	0,00	-6,04	2,14	4,80	-2,76	0,00	-7,38	-2,47	-7,63	-4,14	0,00	0,00	0,00	-4,35
ES	-10,02	-4,50	0,00	9,19	-9,98	0,94	-9,06	0,00	5,37	3,82	-8,37	-1,48	7,38	-8,26	0,00	-6,07	-6,52	0,00	-2,66	0,00	-5,99
MG	-7,51	-2,11	0,00	-8,33	11,54	3,60	-10,62	-7,57	4,61	0,89	3,42	6,41	-6,29	-6,38	2,82	-6,87	-7,43	-0,58	-7,39	7,20	-1,41
RJ	-10,02	-5,42	0,00	0,59	0,00	4,01	-8,07	0,00	0,00	4,25	-3,96	-2,97	0,00	-6,68	0,00	-6,44	-4,96	0,00	-7,94	0,00	-6,53
SP	-10,65	4,05	0,00	-7,06	8,98	3,60	-12,16	11,08	8,90	3,09	-5,68	9,58	1,91	-1,60	6,48	2,45	-6,75	1,81	-6,72	4,64	4,89
GO	-6,86	-3,63	0,00	-9,81	0,00	3,60	1,71	-9,44	-0,35	-0,16	-2,55	8,90	-11,45	-5,86	0,00	-6,01	-7,82	-0,47	-7,88	7,20	5,71
MT	-11,37	2,86	0,00	2,60	0,00	3,60	-10,39	-9,39	-6,14	-2,07	4,38	6,39	0,00	-4,71	0,00	-8,42	-5,78	0,46	10,75	0,00	4,89
MS	-11,54	4,92	0,00	-3,36	0,00	3,60	-12,15	-10,65	7,26	-5,44	0,00	6,39	0,00	3,39	0,00	4,36	-9,10	1,33	0,00	7,20	4,89
PR	-11,26	10,90	-6,08	-0,95	8,98	3,60	-11,16	-7,11	4,60	-3,91	-2,38	11,40	7,38	-0,32	6,48	5,97	-7,11	2,41	10,54	7,20	4,89
RS	-10,21	0,00	0,00	2,11	11,94	-0,62	-4,82	0,00	4,60	-1,25	-4,09	4,60	7,38	2,20	6,48	8,66	-4,09	2,02	7,74	7,67	1,00
SC	-11,61	0,00	0,00	10,56	2,09	-2,75	-8,02	0,00	4,60	4,57	-3,14	-0,62	7,38	-0,17	11,17	-4,30	-3,59	2,65	7,74	1,60	-6,43

Source: Own elaboration based on Tanure (2020).

APPENDIX C - Level of economic activity of the agricultural sectors per Federation Unit

Table C1: Activity Level of agricultural sectors by Federation Unit in 2050 (accumulated % change over baseline scenario) (RCP 4.5)

Sector / FU	RO	AC	AM	RR	PA	AP	TO	MA	PI	CE	RN	PB	PE	AL	SE	BA	MG	ES	RJ	SP	PR	SC	RS	MS	MT	GO	DF
Family Farming Rice	0,31	0,19	0,39	1,55	0,55	2,04	0,16	0,32	0,14	0,12	-0,39	-0,15	0,23	0,29	0,04	0,74	0,81	0,68	0,81	0,33	0,22	-0,35	-0,13	0,34	0,11	0,39	0,05
Large-scale Rice	-0,52	0,62	-0,93	-1,91	-1,79	-1,63	-2,08	-0,47	0,19	-0,32	-1,70	-1,28	1,35	-1,63	-0,98	2,95	-0,19	2,15	2,39	1,95	-2,87	3,81	-0,75	-4,21	-1,58	-0,19	0,10
Family Farming Wheat and Cereals	-0,72	-0,73	-0,72	-0,72	-0,72	-0,74	-0,72	-0,72	-0,70	-0,72	-5,86	-0,67	-0,71	-0,69	-0,72	-0,65	-0,72	-0,70	-0,72	1,31	1,30	1,33	1,29	1,37	-0,68	-0,72	-0,73
Large-scale Wheat and Cereals	-1,49	-1,48	-1,48	-1,48	-1,47	-1,46	-1,48	-1,44	-1,43	-1,44	0,82	1,20	-1,42	-1,43	-1,46	-1,44	9,82	-1,50	-1,51	-0,61	8,70	-1,77	4,20	5,20	-1,49	9,02	-1,51
Family Farming Corn	-0,77	-0,71	-1,15	-0,02	-1,31	-3,53	-0,42	-0,60	-0,47	-0,37	-1,09	-1,33	-1,63	-1,59	-2,07	-1,99	-1,71	-2,40	-1,65	0,88	0,86	0,25	0,78	1,28	0,18	-1,07	-0,02
Large-scale Corn	-5,33	-2,02	-3,34	-8,81	-6,11	-11,28	-8,60	-6,08	-5,68	1,30	2,01	-2,10	-4,14	-3,48	-4,39	-8,51	-7,56	-7,41	-4,79	-7,01	-7,52	-3,06	-3,09	-10,94	-5,88	-8,43	-0,18
Family Farming Cotton Fiber	0,12	0,12	0,14	0,14	0,07	0,12	0,15	0,14	0,10	0,14	0,13	0,10	0,06	0,09	0,13	0,11	0,05	0,16	0,11	0,04	0,06	0,07	0,07	0,10	0,15	0,13	0,13
Large-scale Cotton Fiber	0,06	0,06	0,08	0,09	0,10	0,12	0,16	0,25	-7,32	5,74	0,65	-4,65	-9,64	-7,49	0,21	-10,05	-3,79	-0,01	-0,21	9,90	-2,04	-0,13	0,07	-7,43	-4,15	-5,14	0,00
Family Farming Sugarcane	0,38	0,47	0,27	0,77	0,06	0,29	0,14	0,20	0,11	0,27	0,38	0,24	0,36	0,88	0,42	0,17	0,13	0,36	0,29	-0,17	-0,22	0,01	-0,07	-0,21	0,10	0,09	0,31
Large-scale Sugarcane	-0,75	-2,01	-4,87	0,27	0,43	-2,43	7,68	4,63	-3,09	-3,71	-3,96	-3,30	-1,51	-4,18	-4,81	-1,15	2,62	-2,73	-5,16	5,02	7,09	-3,04	1,75	3,03	9,01	4,51	-2,44
Family Farming Soybeans	-0,96	0,06	0,07	0,10	-0,55	0,02	-0,43	-0,75	-0,81	0,06	0,33	0,08	-0,14	0,08	0,06	-0,56	-0,93	0,09	0,06	-0,28	0,04	0,14	0,17	0,11	-0,99	-0,88	0,07
Large-scale Soybeans	-0,10	0,03	0,04	-5,78	-1,70	0,03	-1,03	-1,63	-2,19	-1,64	0,06	0,07	0,05	0,06	0,04	-2,58	-0,71	0,03	0,02	1,90	2,51	2,83	2,23	0,85	0,26	-0,69	0,04
Family Farming Cassava	-6,17	-2,36	-3,10	-8,21	-8,37	-11,38	-7,65	2,40	0,48	6,66	-1,18	-1,84	-4,10	-3,78	-4,40	-3,71	-3,56	6,49	6,62	-2,81	-3,15	10,20	4,67	-9,12	-8,30	-6,90	2,53
Large-scale Cassava	-2,10	-1,71	-1,29	-1,84	-2,11	-2,63	-0,36	0,44	0,61	0,04	-1,07	-1,03	-1,13	-1,31	-1,24	-1,07	-1,11	0,11	-0,31	0,73	1,28	-0,09	2,07	1,02	-2,08	-1,00	-0,03
Family Farming Tobacco Leaf	0,53	0,37	0,16	0,55	0,58	0,49	0,37	0,36	0,16	0,15	0,08	0,08	0,02	-0,03	-0,15	0,62	0,45	0,42	0,56	0,91	1,32	1,06	0,84	0,50	0,57	0,45	0,52
Large-scale Tobacco Leaf	0,20	0,20	0,21	0,20	0,16	0,19	0,17	0,18	0,18	0,21	0,15	0,15	0,17	0,14	0,11	0,13	0,15	0,16	0,17	0,19	0,21	0,21	0,20	0,18	0,19	0,18	0,17
Family Farming Tomato	-0,04	-0,01	0,01	0,01	-0,05	0,00	-0,03	-0,01	0,00	0,00	-0,02	0,00	0,01	-0,01	0,04	0,06	0,00	0,03	-0,03	-0,12	-0,08	-0,09	-0,09	-0,07	-0,04	-0,06	-0,01
Large-scale Tomato	0,11	0,04	0,04	0,04	-0,22	0,04	0,05	0,04	-0,06	0,16	0,22	0,20	0,27	0,04	0,04	-0,02	-0,10	0,00	-0,13	-0,11	0,18	0,18	0,18	0,04	0,20	-0,13	0,05
Family Farming Potato	0,15	0,19	0,22	-0,01	-0,06	-0,01	0,11	0,01	0,01	-0,03	-0,01	-0,04	-0,07	-0,13	-0,14	-0,09	-0,01	-0,12	-0,12	0,05	0,02	0,05	0,09	0,09	0,09	0,13	-0,01
Large-scale Potato	0,02	0,02	0,03	0,03	-0,54	0,01	0,03	0,02	0,03	0,03	0,03	-0,26	0,18	0,27	-0,18	-0,95	0,28	-0,75	-0,25	-0,24	-0,12	-0,22	-0,21	0,02	0,26	-0,10	0,03
Family Farming Onion	0,38	0,06	0,06	0,05	-0,03	0,06	0,06	0,08	0,02	0,19	0,29	0,29	0,02	0,07	0,07	-0,13	-0,23	-0,24	-0,22	-0,26	-0,02	0,02	-0,02	-0,18	0,06	0,40	0,05
Large-scale Onion	0,03	0,03	0,03	0,03	0,02	0,02	0,03	0,02	-0,02	0,14	-0,14	0,05	0,20	0,02	0,03	0,28	-0,21	0,19	0,03	-0,03	0,17	0,17	0,17	0,03	0,04	-0,36	0,03
Family Farming Peanuts	0,04	-0,02	0,02	-0,26	0,00	-0,06	0,12	0,03	0,09	0,01	-0,02	-0,02	0,07	-0,09	-0,11	0,10	0,12	0,09	-0,06	0,03	0,00	0,10	0,08	0,07	0,07	0,13	-0,05
Large-scale Peanut	-1,23	-0,24	-0,30	-0,29	-0,54	-0,32	-0,04	-0,13	-0,50	-0,95	-0,29	-0,03	0,07	-0,80	-0,91	0,01	0,01	0,22	-0,32	0,33	0,18	0,14	0,12	0,31	-0,99	-0,44	-0,31
Family Farming Pineapple	0,06	0,04	0,17	-0,45	0,11	0,17	0,08	0,04	0,20	0,08	0,02	0,02	0,15	0,06	-0,03	0,17	0,08	-0,16	-0,21	-0,48	0,10	0,14	0,16	-0,36	-0,19	0,43	0,06
Large-scale Pineapple	0,04	0,03	0,18	-0,11	0,07	0,10	-0,06	0,03	0,01	0,07	0,08	0,13	0,09	0,14	0,09	0,07	-0,12	-0,14	-0,11	-0,21	-0,18	-0,08	0,03	-0,19	-0,13	0,15	0,03
Family Farming Banana	-6,26	-4,36	-1,37	4,36	-0,91	3,30	-0,79	1,65	5,09	1,15	1,80	-0,75	1,08	4,91	4,52	1,50	-1,59	-3,29	-4,90	-6,50	-8,37	-8,05	-6,40	-10,61	-7,08	2,68	2,66
Large-scale Banana	-4,96	-3,59	-2,15	2,96	-1,39	0,48	-1,99	-0,39	3,85	1,04	2,04	0,21	1,34	2,83	4,77	2,06	-0,93	-1,99	-2,76	-3,25	-4,75	-4,55	-2,72	-5,21	-4,96	-0,77	0,64
Family Farming Beans	0,51	-2,16	-2,07	4,09	2,35	-12,99	9,48	0,38	4,78	1,34	-2,11	-4,06	-5,86	-5,92	-6,63	-6,75	-6,17	-7,68	-8,89	2,72	-1,35	-2,66	2,63	4,98	6,24	4,72	1,54

Large-scale Beans	-3,34	-3,30	-2,69	-2,77	0,60	0,84	-0,88	-0,51	-0,19	0,73	-1,78	-3,55	-5,25	-4,54	-5,63	-5,13	-4,20	-7,21	-4,05	0,84	1,72	2,11	3,94	2,82	-4,47	-3,77	0,92
Family Farming Cashew Chestnut	-0,05	-0,04	-0,03	-0,04	-6,03	-0,11	-5,46	6,14	2,66	0,11	-1,84	-3,26	-4,59	-1,41	4,28	-3,95	-0,03	0,08	0,09	0,06	-0,31	0,04	0,03	0,02	-6,77	0,03	0,05
Large-scale Cashew Chestnut	0,01	0,01	0,01	0,02	2,59	-0,01	-5,43	2,93	-2,47	2,51	2,09	-0,34	-2,23	-1,11	-0,01	-0,73	0,06	0,00	0,02	-0,16	-2,18	0,03	0,02	0,02	0,04	0,02	0,01
Family Farming Grape	0,90	0,90	0,90	0,88	0,89	0,88	0,91	0,94	0,92	0,92	0,90	-0,99	-0,66	0,89	0,89	-1,04	-0,52	-0,72	0,87	2,73	1,24	0,48	-0,69	0,90	0,93	0,89	0,90
Large-scale Grape	0,00	0,00	0,00	0,00	0,01	0,00	0,01	0,03	0,03	-0,04	-0,01	0,37	-0,08	-0,03	-0,01	0,01	0,26	0,11	-0,02	0,23	0,22	-0,29	0,22	0,00	0,01	-0,01	0,00
Family Farming Out. temp crop.	-1,40	-5,09	0,26	8,25	-2,85	-10,18	10,11	9,42	15,68	-5,29	-8,77	-1,28	-1,99	-7,53	-10,69	0,61	0,19	-8,42	-12,40	4,49	8,35	8,86	8,50	9,69	1,84	18,93	-2,02
Large-scale Out. temp crop.	2,18	0,75	-0,28	7,76	1,82	8,12	20,18	11,50	-4,54	-5,90	12,20	-4,34	-2,39	11,21	-1,26	-4,62	-5,10	-3,68	-6,46	6,65	12,67	-13,84	-5,53	10,92	10,10	0,56	-0,13
Family Farming Orange	1,58	-0,03	2,02	1,74	1,46	1,70	-1,76	1,29	2,39	-1,25	-1,65	-1,90	-1,81	0,25	-1,13	-1,46	0,42	-0,56	1,41	-0,99	-1,03	-0,61	0,17	-2,28	0,56	0,86	1,01
Large-scale Orange	-10,44	-10,62	12,89	12,93	12,48	-10,42	-4,33	-1,51	18,48	13,12	3,27	-5,87	-8,94	-6,43	-4,53	-6,07	-6,34	12,08	6,52	-5,60	1,19	11,61	-0,13	0,53	15,71	-8,40	3,40
Family Farming Coffee Grains	-2,22	-3,20	0,43	-8,68	-6,11	-0,90	-1,05	-6,76	-0,86	-5,63	-3,89	-5,31	-5,41	-6,61	-0,99	-6,46	-3,80	-5,14	-5,16	5,80	4,01	3,92	7,53	4,05	0,19	-4,15	-1,10
Large-scale Coffee Grains	-0,22	-1,40	1,08	-0,34	-5,49	-0,29	-0,33	-0,26	-1,47	-4,05	-0,25	-0,94	-2,14	-0,28	-0,32	-4,22	-1,88	-2,94	-4,33	1,36	5,99	-0,40	-0,40	6,91	0,14	-3,24	-0,34
Family Farming Out. perm crop.	-10,00	-8,36	-8,19	-17,01	-11,87	-14,29	19,76	3,71	14,63	-7,16	-13,20	-7,99	-3,29	-13,77	-12,47	-5,40	1,01	-3,52	0,29	7,48	6,82	7,20	9,62	8,90	-0,16	7,31	0,11
Large-scale Out. perm crop.	0,39	4,56	-2,58	-9,23	-6,70	-6,08	6,76	10,08	11,62	-8,09	-8,51	-1,03	2,80	-11,64	-10,19	0,99	10,77	-1,38	3,12	6,56	6,67	-4,61	-2,45	6,70	6,73	12,42	-0,25
Family Farming	-2,13	-2,31	-1,14	-2,31	-4,88	-8,64	0,15	2,14	3,55	0,47	-2,45	-1,27	-2,04	-2,45	-3,72	-1,26	-2,24	-4,01	-1,68	0,91	0,68	1,31	1,47	-2,20	-0,96	2,76	0,56
Large-scale Agriculture	-1,13	-1,60	-0,36	-3,10	-1,00	5,44	-0,77	-1,70	-2,92	1,36	2,94	-2,37	-0,68	-3,59	-3,68	-4,18	-1,50	-2,77	-3,22	2,42	1,30	0,17	0,98	-0,74	-1,09	-0,71	0,04

Source: Own elaboration based on the results of the AGRO-BR model

Table C2: Activity Level of agricultural sectors by Federation Units in 2050 (% change over baseline scenario) (RCP 8.5)

Sector / FU	RO	AC	AM	RR	PA	AP	TO	MA	PI	CE	RN	PB	PE	AL	SE	BA	MG	ES	RJ	SP	PR	SC	RS	MS	MT	GO	DF
Family Farming Rice	0,05	-0,05	0,15	1,14	0,62	1,93	0,29	0,56	0,40	0,38	-0,06	0,20	0,39	0,63	0,26	0,88	1,05	1,02	1,13	0,47	0,31	-0,14	0,02	0,10	0,00	0,43	0,01
Large-scale Rice	-1,34	0,02	-1,60	-3,24	-1,46	-1,95	-1,85	1,14	1,80	2,49	1,01	1,66	3,74	1,37	2,37	4,75	1,06	4,09	4,52	3,28	-4,17	4,74	-1,31	-5,86	-2,10	-0,04	0,14
Family Farming Wheat and Cereals	-0,21	-0,21	-0,22	-0,20	-0,17	-0,22	-0,20	-0,21	-0,19	-0,21	0,47	-0,16	-0,19	-0,17	-0,18	-0,13	-0,22	-0,17	-0,20	0,36	0,39	0,40	0,40	0,45	-0,13	-0,22	-0,21
Large-scale Wheat and Cereals	-1,55	-1,55	-1,55	-1,55	-1,52	-1,52	-1,54	-1,51	-1,50	-1,52	9,73	9,72	-1,49	-1,50	-1,52	-1,50	6,26	-1,53	-1,54	3,57	6,20	0,38	6,63	6,22	-1,52	6,31	-1,56
Family Farming Corn	-0,43	-0,47	-0,88	0,79	-1,18	-3,41	-0,17	-0,93	-0,88	-0,98	-1,62	-1,81	-2,11	-1,89	-2,32	-2,38	-2,00	-2,76	-2,29	1,03	1,00	-0,03	0,77	2,18	0,85	-0,97	0,00
Large-scale Corn	-6,66	-3,30	-4,76	-8,84	-8,57	-12,03	-10,63	-9,49	-8,91	-3,94	-2,71	-5,61	-6,49	-4,59	-5,06	-9,55	-9,28	-8,87	-7,05	-9,22	-9,51	-5,14	-5,02	-11,84	-7,71	-10,07	-0,23
Family Farming Cotton Fiber	0,16	0,16	0,14	0,18	0,13	0,16	0,18	0,16	0,11	0,10	0,09	0,10	0,09	0,11	0,17	0,14	0,05	0,20	0,13	0,02	0,05	0,09	0,09	0,12	0,21	0,14	0,15
Large-scale Cotton Fiber	0,06	0,05	0,07	0,10	0,11	0,15	0,18	0,29	-9,27	8,98	-3,14	-7,54	-9,55	-6,53	0,21	-10,22	-7,00	-0,07	-0,38	10,05	-6,69	-0,23	0,11	-9,96	-8,77	-8,91	-0,04
Family Farming Sugarcane	0,41	0,58	0,39	1,10	0,11	0,29	0,23	0,10	0,06	0,31	0,47	0,34	0,46	1,25	0,63	0,35	0,18	0,58	0,45	-0,24	-0,26	0,03	-0,07	-0,17	0,15	0,07	0,37
Large-scale Sugarcane	1,28	-0,88	-3,97	0,67	3,13	-3,52	10,64	6,82	-0,77	-3,69	-4,92	-4,26	-3,03	-5,40	-6,77	-3,07	4,33	-5,27	-7,42	7,55	9,70	-4,57	2,06	4,44	4,37	7,17	-3,54
Family Farming Soybeans	-1,16	0,06	0,06	0,12	-0,58	0,03	-0,71	-1,08	-1,14	0,03	-0,28	0,07	-0,75	0,07	0,05	-0,94	-1,17	0,09	0,05	-0,42	0,07	0,08	0,26	0,32	-1,18	-1,06	0,07
Large-scale Soybeans	-0,04	0,03	0,03	-5,72	-1,35	0,03	-0,83	-1,73	-2,51	-1,85	0,03	0,05	0,03	0,04	0,03	-2,77	-0,66	0,03	0,01	2,03	2,74	3,02	2,32	1,54	0,58	-0,51	0,02
Family Farming Cassava	-7,22	-3,00	-3,12	-7,89	-9,11	-11,13	-9,03	-1,16	-1,85	6,01	-0,02	-0,49	-3,67	-2,85	-3,43	-3,66	-4,02	3,92	3,49	-5,04	-5,48	7,73	2,22	-10,11	-9,35	-8,04	3,33
Large-scale Cassava	-2,16	-1,78	-1,32	-1,95	-2,01	-2,51	-0,77	0,03	0,15	-0,33	-1,37	-1,41	-1,60	-1,84	-1,82	-1,84	-1,68	-1,49	-1,58	0,59	1,23	-1,07	1,91	0,96	-2,20	-1,44	0,08

Family Farming Tobacco Leaf	0,53	0,51	0,28	0,55	0,24	0,52	0,37	0,38	0,42	0,47	0,28	0,27	0,15	0,13	0,00	1,05	0,59	0,40	0,56	0,79	1,29	0,99	0,85	0,48	0,58	0,70	0,52
Large-scale Tobacco Leaf	0,21	0,23	0,21	0,21	0,16	0,21	0,19	0,21	0,20	0,23	0,24	0,24	0,21	0,20	0,15	0,18	0,20	0,18	0,18	0,19	0,21	0,24	0,20	0,19	0,21	0,19	0,19
Family Farming Tomato	-0,04	-0,01	0,00	0,02	0,06	-0,01	-0,02	-0,02	0,04	0,03	0,01	0,04	0,03	0,03	0,04	0,08	0,02	0,05	-0,03	-0,16	-0,10	-0,11	-0,11	-0,07	-0,06	-0,08	-0,02
Large-scale Tomato	0,15	0,05	0,04	0,05	-0,21	0,05	0,05	0,05	-0,16	0,00	0,07	0,21	0,25	0,05	0,05	-0,01	-0,13	-0,01	-0,14	-0,14	0,24	0,19	0,19	0,05	0,28	-0,14	0,05
Family Farming Potato	0,12	0,17	0,17	0,02	0,24	0,01	0,17	0,02	0,02	-0,06	0,02	-0,15	-0,12	-0,16	-0,16	-0,13	-0,03	-0,12	-0,14	0,09	0,03	0,07	0,13	0,15	0,10	0,15	-0,01
Large-scale Potato	0,07	0,07	0,07	0,08	-0,78	0,08	0,08	0,08	0,08	0,07	0,08	-0,12	0,19	0,65	0,47	-0,89	0,28	-0,66	-0,24	-0,42	-0,12	-0,19	-0,26	0,06	0,43	-0,14	0,08
Family Farming Onion	0,48	0,12	0,11	0,11	0,01	0,13	0,12	0,15	0,08	-0,21	0,12	-0,02	-0,20	0,14	-0,22	-0,23	-0,30	-0,28	-0,32	-0,30	-0,05	0,01	-0,05	-0,15	0,12	0,16	0,10
Large-scale Onion	0,02	0,01	0,01	0,02	0,02	0,02	0,02	0,02	-0,04	0,25	-0,04	0,29	0,21	0,01	0,02	0,23	-0,19	0,24	0,01	0,04	0,20	0,21	0,21	0,01	0,04	-0,37	0,02
Family Farming Peanuts	0,09	0,02	0,04	-0,26	0,09	-0,06	0,09	0,11	0,07	0,08	0,06	0,06	0,15	-0,02	-0,05	0,17	0,05	0,17	-0,07	-0,02	0,00	0,03	0,09	0,09	0,10	0,06	-0,06
Large-scale Peanut	-1,22	-0,09	-0,31	-0,29	-0,70	-0,30	-0,25	-0,06	-0,50	-0,69	-0,31	0,07	0,29	-0,80	-0,93	-0,03	0,06	0,18	-0,34	0,34	0,18	0,13	0,12	0,30	-1,10	-0,36	-0,32
Family Farming Pineapple	0,02	0,04	0,25	-0,43	0,04	0,14	-0,05	0,09	0,09	0,21	0,04	0,02	0,12	0,00	-0,05	0,13	-0,05	-0,13	-0,20	-0,56	-0,01	0,57	0,62	-0,40	-0,31	0,40	0,12
Large-scale Pineapple	-0,02	-0,01	0,12	-0,11	-0,03	0,14	-0,07	-0,07	0,02	0,04	0,13	0,08	0,18	0,11	0,12	0,14	-0,14	-0,13	-0,09	-0,20	-0,17	-0,10	-0,04	-0,16	-0,16	0,07	0,05
Family Farming Banana	-5,98	-4,00	-0,40	13,48	-0,59	4,64	-2,86	2,26	2,36	2,48	0,55	-2,58	-2,76	-1,26	-1,83	-3,72	-3,42	-6,59	-7,25	-7,69	-8,96	-8,70	-8,37	-10,77	-7,41	-1,32	4,66
Large-scale Banana	-4,61	-3,49	-1,89	2,59	-1,42	1,28	-2,96	-1,07	1,72	1,07	0,81	-1,40	-1,14	3,12	-0,11	-1,91	-2,14	-3,54	-3,79	-3,94	-4,56	-4,77	-4,01	-4,87	-4,62	-2,30	1,48
Family Farming Beans	4,89	0,39	2,71	8,66	6,37	-10,90	15,12	1,95	1,97	-2,59	-5,94	-8,12	-9,53	-9,67	-9,77	-9,75	-8,59	-10,00	-11,06	4,40	-1,04	-2,68	3,82	7,26	12,09	3,11	2,98
Large-scale Beans	-3,08	-3,00	-2,09	-1,35	-1,64	1,38	-1,91	-2,23	-3,19	-2,76	-4,71	-6,30	-7,41	-6,92	-7,44	-6,98	-5,85	-8,47	-6,44	-0,43	0,60	0,81	3,72	5,02	-4,17	-4,63	1,35
Family Farming Cashew Chestnut	1,98	1,99	1,66	2,00	-5,86	2,04	-4,85	-3,59	3,12	-2,56	-1,07	-2,24	-4,15	-2,23	1,90	-4,37	1,50	2,03	1,93	1,96	-0,99	1,79	1,84	1,97	-6,55	1,95	1,99
Large-scale Cashew Chestnut	0,03	0,03	0,02	0,03	-0,99	0,04	-5,47	-2,68	-1,52	-1,19	3,26	3,41	2,66	3,15	0,03	3,05	0,01	0,03	0,02	0,04	-2,66	0,01	0,01	0,03	0,05	0,02	0,03
Family Farming Grape	0,95	0,95	0,93	0,93	0,97	0,93	0,95	0,98	0,96	0,94	0,92	2,10	2,15	0,92	0,93	2,12	0,06	2,49	0,91	2,02	1,63	0,31	-0,72	0,95	1,01	0,94	0,95
Large-scale Grape	-0,02	-0,02	-0,03	-0,02	0,00	-0,02	-0,02	0,02	0,02	-0,12	-0,04	-0,60	-0,64	-0,08	-0,05	-0,01	0,41	-0,56	-0,06	0,28	0,27	0,02	0,41	-0,04	-0,01	-0,04	-0,04
Family Farming Out. temp crop.	2,36	-1,09	1,17	7,77	5,50	-8,85	10,49	9,99	21,39	-8,49	-13,76	-10,69	-5,48	-16,92	-18,50	-4,22	0,56	-15,01	-18,08	4,27	8,81	9,31	8,99	10,45	2,33	9,94	-1,91
Large-scale Out. temp crop.	9,33	3,09	-0,21	7,85	1,77	8,23	11,18	17,12	-2,96	-9,85	-4,21	-9,26	-4,18	10,16	-3,88	-5,82	-2,68	-6,49	-9,92	3,05	10,55	-14,04	1,96	11,05	10,12	12,47	-0,39
Family Farming Orange	0,35	-0,59	1,85	1,89	1,52	2,23	-1,70	0,10	1,43	-1,44	-1,83	-1,88	-1,93	-0,96	-1,34	-1,46	0,37	-0,89	-0,09	-1,27	-1,25	-0,65	0,08	-2,12	0,46	-0,32	1,39
Large-scale Orange	-12,59	-12,60	13,35	12,21	5,36	-11,59	-7,68	-3,79	18,29	13,57	3,84	-8,41	-9,06	-7,32	-7,36	-8,12	-8,27	16,91	5,06	-6,49	2,30	18,33	6,97	-1,10	7,83	-11,03	4,00
Family Farming Coffee Grains	-1,51	-3,07	1,44	-8,57	-4,55	-1,07	-1,26	-7,15	-1,04	-6,85	-5,71	-7,09	-6,20	-7,29	-1,19	-6,63	-4,17	-6,09	-6,28	1,35	1,58	1,32	1,34	1,52	1,80	-3,68	-1,32
Large-scale Coffee Grains	0,92	-0,54	2,43	-0,37	-4,75	-0,32	-0,37	-0,29	-2,54	-5,08	-0,29	-3,03	-2,64	-0,31	-0,35	-4,73	-2,11	-4,01	-4,88	2,50	6,87	-0,45	-0,44	3,16	1,73	-3,18	-0,37
Family Farming Out. perm crop.	-7,99	-7,46	-5,85	-18,68	-6,27	-11,68	13,24	16,53	12,40	-2,52	-12,12	-7,47	-6,21	-15,01	-14,15	-8,97	2,15	-8,35	-4,46	11,02	10,07	7,35	11,03	12,82	15,09	14,01	-0,33
Large-scale Out. perm crop.	8,49	11,21	0,46	-6,90	1,53	-0,64	4,60	4,62	4,59	-2,95	-5,19	4,07	8,00	-9,13	-8,90	4,35	4,41	0,44	5,12	4,50	4,65	-4,96	-1,59	4,57	4,65	4,60	-1,00
Family Farming	-0,87	-2,41	-0,62	-0,51	-1,36	-7,91	-0,03	0,25	2,59	-1,79	-3,33	-3,43	-4,13	-4,29	-5,67	-3,45	-2,55	-5,47	-3,27	0,62	0,54	1,19	1,40	-2,27	-0,68	0,90	0,91
Large-scale Agriculture	-1,21	-1,97	-0,18	-3,27	-0,53	5,57	-0,96	-2,24	-3,66	-1,62	-2,09	-3,19	-0,97	-4,73	-5,44	-4,57	-1,40	-3,87	-4,76	3,59	1,17	-0,01	1,05	-0,25	-1,95	0,09	0,05

Source: Own elaboration based on the results of the AGRO-BR model