The Economic Impact of the Extreme Climatic Events in Argentina

The case of the soybean on the core area

Climate risk or infrastructure deficit?

Research program on the Valuation of the Socioeconomic Vulnerability to the Climate Risk

School of Economics

Universidad de Buenos Aires

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The economic impact of the extreme climate events in Argentina: the case of the soybean in the core area Climate risk or infrastructure deficit? / Esteban Otto Thomasz, Gonzalo Rondinone, Ana Vilker, Mariano Eriz. – 1st ed. – City of Buenos Aires: Universidad de Buenos Aires. School of Economics, 2018.

El impacto económico de los eventos climáticos extremos en Argentina: el caso de la soja en la zona núcleo ¿riesgo climático o déficit de infraestructura? / Esteban Otto Thomasz… [et al.]. - 1a ed. - Ciudad Autónoma de Buenos Aires, 2017. 60 p.: 22 x 15 cm.

ISBN 978-950-29-1661-3 FCE-UBA

1.Cambio Climático. I. Thomasz, Esteban Otto II.
CDD 551.6

ISBN 978-950-29-1661-3

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Research program on the valuation of the socioeconomic vulnerability to the climate risk

The objective of the research program on the valuation of the socioeconomic vulnerability to the climate risk is to study models, approaches, methodologies, and metrics to value the economic costs and estimate the social vulnerability of the climatic risk events, such as droughts, heat waves, and other climate variability events which affect the assets, economic activities, and the welfare of specific communities.

Currently, it is part of the *Instituto de Investigaciones en Administración, Contabilidad y Métodos Cuantitativos para la Gestión* (IADCOM) (Institute of Research in Administration, Accounting and Quantitative Methods for Management) of the University of Buenos Aires located in the School of Economics.

The creation of the specific program in the school of economics is due to 11 years of experience on investigating this subject, stemming from the PICT project, in the year 2006, titled "Economic, financial, and actuarial impact of the climate change in Argentina" located at the School of Economics of the University of Buenos Aires. Recently, researchers of this study have made an extensive research (2015-2018) at the Massachusetts Institute of Technology, where the project "Study of Socio-Economic Impact of Climate Change Risk in Developing Countries" took place with main emphasis in the measurement of the socioeconomic vulnerability to the climate risk in emerging markets.

As a result of these exchanges, from these networking, and from the knowledge generated, this specific program is created, which has as mission to provide consensual and rigorous metrics of the socioeconomic impact of the climate risk in Argentina.

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ACKNOWLEDGEMENTS

This brief document represents a summary of the years dedicated to the research and development of public policies. Many have been the actors who have helped, directly or indirectly, to the formalization of this line of research.

In the first place, acknowledge the authorities of the School of Economics, for its continuous institutional support on the generation of new projects. Mainly, to Mr Dean Cesar Albornoz and the Emeritus Professor María Teresa Casparri. Also, the Associate Professor Juan Ramón Garnica Hervas for its continuous guidance to innovate in the investigation.

In the second place, to the Director of the Special Program for Urban and Regional Studies at the MIT, Bish Sanyal, for providing us all the elements to base our project at the MIT. To the fruitful discussions with Dr. Linda Shi, PhD of the MIT and current associate professor at Cornel University.

To Dr. Kenneth Strepeck, *Research Scientist* of the MIT and current Director of the Adaptation Program to the Climate Change from the *Joint Program on the Science and Policy of Global Change*, for its passion and commitment in the training of young professionals as well as proclaim the importance of studying the water resources.

To Dan Osgood, *Lead Scientist, Financial Instruments Sector Team* from the *International Research Institute for Climate and Society* at *Columbia University*, for his selfless openness to debate on the economic impacts of the climate risk on the agricultural sector. To Paula Gonzales, *Research Scientist* del *National Center for Atmospheric Science (NCAS)* at *University of Reading*, for its guidance on the current state of the climate sciences and provide us with the material applied to the south cone.

To Andres Ravelo and Roberto Zantovar, Director and Researcher, respectively, of the *Centro de Relevamiento y Evaluación de Recursos Agrícolas y Naturales* (UNC-CONICET) (Center for Study and Assessment of Agricultural and Natural Resources) for the exchanges we continued doing related to the agroeconomic impacts of the water excesses and deficits in Argentina.

To Gabriella Carolini, *Assistant Professor* of *International Development Group* at the MIT, for her valuable discussions on methodologies to measure the social vulnerability.

To the actuary, Alejandra Muzzio, Researcher of the Research Program on the Valuation of the Socio-economic Vulnerability to the Climate Risk, for her help in the elaboration of the simulation models.

"Whiskey is for drinking; water is for fighting over."

Mark Twain

PROLOGUE

This publication reflects the continuum of the research project that began under my guidance in the year 2006, named "Economic, Financial, and Actuarial Impact of the Climate Change in Argentina". From that moment on, different lines of research were initiated, and essential human resources were established.

Mainly, this work summarizes the main issues that can be allocated to the climate risk problem, from an economic science point of view. In general terms, to address the economic and social impact measurement problem. In specific details, to include in the studies, the following issues: impact and losses valuation methodologies, the impact on the pricing system, estimating the integrated production, estimating of the interest rates, etc. Elements which, at last, shall help for a better design and implementation of fiscal and financial instruments to substantiate, on a technical basis, the investment in adaptation measures to climate risk.

Concurrently, it summarizes, shortly and naturally, the main elements of the economic valuation, and at the same time, it shows the result of several forecasts for the Argentine agriculture. It is a form of transferring knowledge generated not only to the academic sector but also to the public sector, companies and to the society in general. The results showed herein put a scale of magnitude to the measurement of the impact of the extreme climate events in Argentina. Once quantified the relevance, the actors may proceed to search for solutions to mitigate risks and increase the mutual benefits.

Since the object of study is affected by agriculture, meteorology, social sciences, urban planning, and other disciplines, it is, especially important, the contribution this work makes. Stemming from the economic science and through the monetization of the climate impacts, it can be made a comprehensive analysis of the problem. The policies of adaptation or mitigation which are recommended shall be executed in a multidisciplinary way, but it is the work of the economy to make a pragmatic quantification of the problem. The results showed herein fill a space hardly researched by the economic science.

Professor Eméritus María Teresa Casparri

Director IADCOM

Universidad de Buenos Aires

EXECUTIVE SUMMARY

Macroeconomic impacts, valuation of the agricultural sector, and infrastructure financing: *How to design a financing system for adaptation under uncertain events?*

- **Macroeconomic relevance:** the agricultural sector represents 10.4% of the Gross Domestic Product (GDP), grain harvest amounts approximately to USD 27.000 million annually, and the agroindustry exports make the 60% of the total exports.

- **Climate risk:** the focus of this study is on the climate variability events, especially droughts and floods. These have significant effects in the short term and in medium-term. The adaptation measures should be prioritized to reduce the impact of these events.

- **Economic valuation:** the economic valuation comprises the monetization of the impacts, where not only are intervening the physical quantities (direct impact) but also the pricing forecasts, indirect impact over the chain and valuation of interest rates. In the meantime, the socio-economic assessment implies adding effects which are not readily monetizable like the social vulnerability of the affected populations.

- **Losses due to floods:** during the campaign 2016/17, the forecasted losses of direct income due to floods of the soybean crops rises to USD 354.4 million, allocated in the following way: Buenos Aires USD 149 million, Cordoba USD 60.7 million, La Pampa USD 96.7 million, and Santa Fe USD 47.1 million.

- **Losses due to droughts:** during the campaigns 2008/09 and 2011/12, the forecasted losses of direct income due to droughts of the soybean crop rises, respectively, to USD 4115.88 million and USD 2606.37 million

- **Forecasts:** the current value for the direct loss of the soybean production forecasted due to droughts rises to an amount between USD 22985 and USD 3339 million, depending on the valuation rate applied. The higher the macroeconomic risk, the higher the rate will be, and the less the financial viability to invest in adaptation infrastructure.

- **Survey to the producers:** the 64% considers the climate events as the major risk of their crops. From this, the 58% are highly concerned about the floods and 39% about the droughts. The higher demand of public works is placed on roads and hydraulic works. The 80% would be willing to be part of public private partnership (PPP)

- **Droughts vs. Floods:** it is seen that the droughts generate higher losses than the floods when assessing the direct losses of the soybean crop. Additionally, its geographic extent is wider, and the scale of the loss turns it almost into an event with macroeconomic impacts. However, the indirect impact and the social vulnerability may be higher due to the floods.

- **Financing:** due to the high interest rates, the financing of the infrastructure for the adaptation to the climate risk is unsustainable in financial terms. The high cost of funding is one of the major problems of the investment in the adaptation to climate phenomena in developing countries: it generates that future losses to have such limited importance in current terms, attracting few or zero resources to the sector.

- **Conclusion**: the level of international prices, the expansion of the agricultural frontier, the valuation of the crops and also, the value of the land, produce that even facing the same climate events which occurred in the past, the economic impact will be, substantially, higher. Due to more significant resources and shared risks, there is space to research on instruments of public-private participation to finance adaptation infrastructure projects. The correct forecast and monetization of the future losses and also, its financial discount are crucial elements for the right distribution of the risk between the parties.

INTRODUCTION

The objective of this study is to provide a first estimation of the income losses of the soybean production in Argentina due to the climate variability. To value the phenomenon in monetary terms, may provide vital information to plan and emphasize, correctly, adaptation strategies for a problem which is becoming more intense and have more relevance in countries which depend on agricultural exports, as the case in Argentina.

This report is focused on being a tool for the diffusion of results and advances in the research to be used by a wide range of people. It seeks to contribute to the enhancement of the debate about the economic cost of the climate variability events, and, the financial-economic viability to invest in adaptation infrastructure; additionally, the distribution of costs and benefits between the involved parties.

This report constitutes an executive summary of extensive research which attempts to answer the following question: how much does a country lose due to variability or climate risk events? This simple question proves out to be incredibly complicated as to answer it accurately, the sector, the scale, the terms, and lastly, the valuation methodology have to be defined. It is worth noting that the approach taken is based on the financial-economic analysis, so this question will be answered from a point that allows us to monetize the impacts to provide a basis to, technically, justify the viability to finance adaptation investments.

In the first section of this document, there is a summary of the problem. In the second section, the leading figures of the impact on the agricultural sector in Argentina are shown. In the third section, the basic concept guidelines are introduced to understand the definition of climate events and its economic valuation. In the fourth section, the results -preliminary and definite- of the losses of income due to both floods and droughts are outlined. In the fifth section, the results of an exploratory survey made to agricultural producers related to their perception about the climate risk and the state of the infrastructure are shown. Finally, in the conclusions, some challenges are summarized for the economic and territorial planning in the light of the analyzed issue.

1. Importance of the problem

The risks related to the climate change are increasing quickly in vulnerable communities at an urban and rural level, and especially in informal settlements. The possible direct impacts of the climate change and variability include extreme precipitations, rain and river floods, landslides, drought, more arid, and water shortage with broad indirect impacts in people, economies, and ecosystems (Revi *et al*, 2014).

The Intergovernmental Panel on Climate Change –IPCC- *[Grupo Intergubernamental de Expertos sobre el Cambio Climático*] expects that in developing countries, the climate change will have critical short-term impacts due to extreme precipitations and droughts. These events will lead to changes in the food production and non-food crops areas, and it will have huge impacts regarding food safety and agricultural incomes, mainly, affecting the welfare of the rural populations (IPCC, 2015).

However, the adaptation and mitigation policies are still limited in middle-income countries. Limited resources and technology restricts the capacity of adaptation, especially, in developing countries. (Kates *et al*, 2012; Moser and Ekstrom, 2010).

In the case of Argentina, there has been a marked increase of precipitations in most of the subtropical region, especially since 1960, which has benefited the agricultural performance and the expansion of the farmland in the semi-arid areas (Barros, 2015). This effect, within other economic factors, such as the Asian miracle and the growth of technology (Massot, 2016), made the agricultural exports reach 55% of the total exports for the 2003-2016 period. The soybean, soybean oil, and the soybean flour contribute to 23% of the total value exported in the same period.

Even though estimations have been carried out of the change of production of different crops based on the increase of C02 emission scenarios, showing positive reactions on the soybean performance (Murgida, 2014), there is a lack of studies which considers the current climate variabilities such as droughts and floods at a national level.

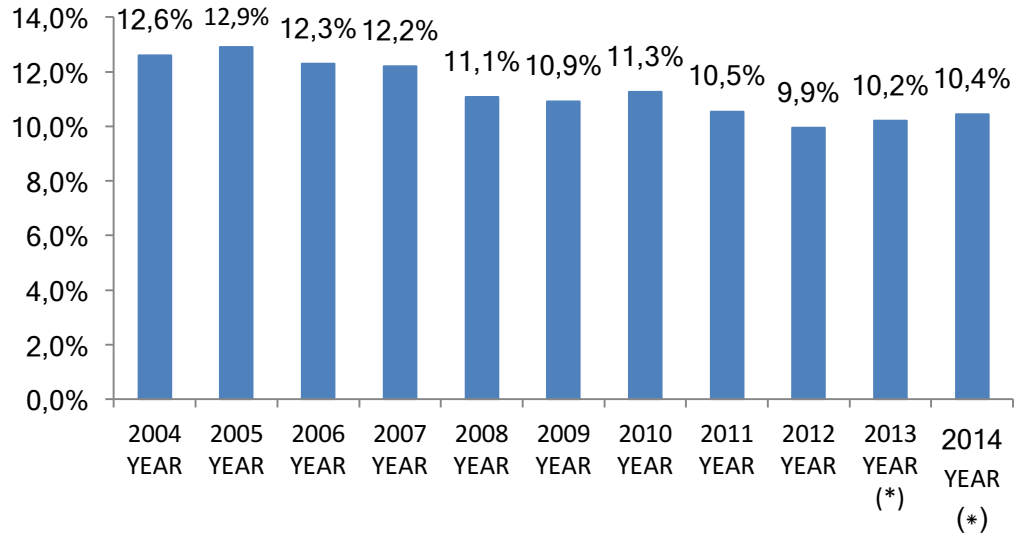
In consequence, the objective of this project is to provide a first **estimation of the economic losses of the agricultural production in Argentina due to climate variabilities**. These assessments are the first step in planning infrastructure adaptation strategies, which should be adopted, or not, by developing countries depending on agricultural exports as in the case of Argentina.

2. Importance of the Agricultural sector in Argentina

The agricultural sector represents the 10.4% of the GDP, grain harvest rises to USD 27,000 million annually, and the agribusiness exports are the 60% of the total exports.

The agricultural sector (excluding hunt and forestry) and the processing and food industry represent the 10.4% of the GDP (figure 1). This percentage may be substantially higher if it is added the services related to the supply chain, as logistic, commercial services, financial services, consumption of inputs such as agrochemicals and machine production.

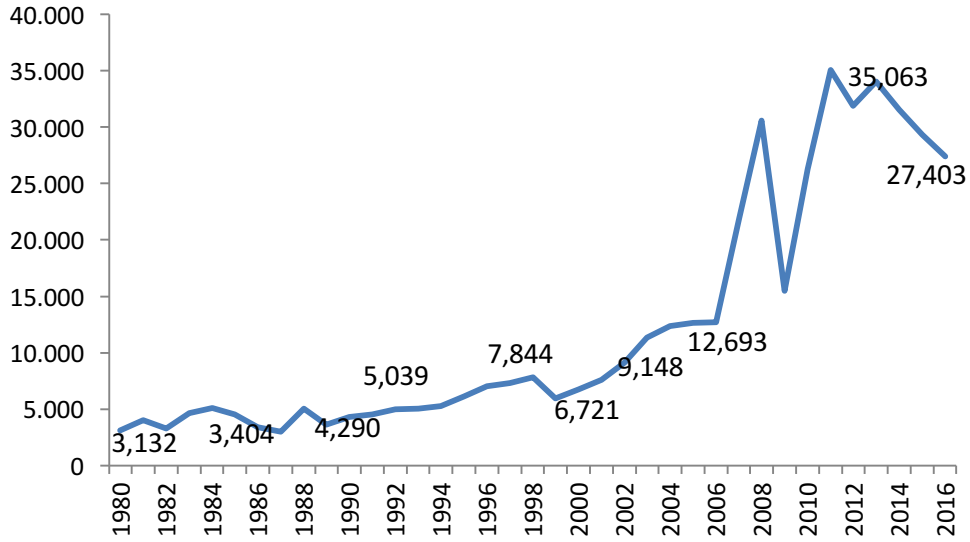
Figure No 1: Evolution of the agricultural sector participation in the GDP (2004-2014)



Source: Compiled on INDEC data

Regarding the gross income generated, the value of the soybean, corn, and wheat harvest on 2016 valued at international prices rose to USD 27,403 million (figure 2). This value, as a scale reference, represents, as of the date of this report, 54% of the Central Bank's international reserves, reaching more than 100% in 2014. The total generated between 2004 and 2016 rose to USD 320,000 million.

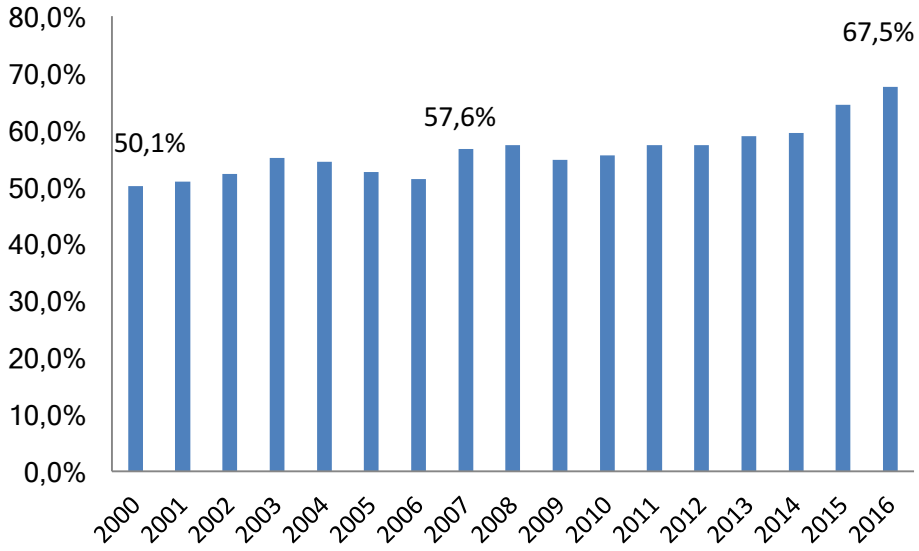
Figure No 2: Evolution of the gross income of the soy, corn, and wheat (1980-2016) – (millions of USD)



Source: compiled on INDEC data

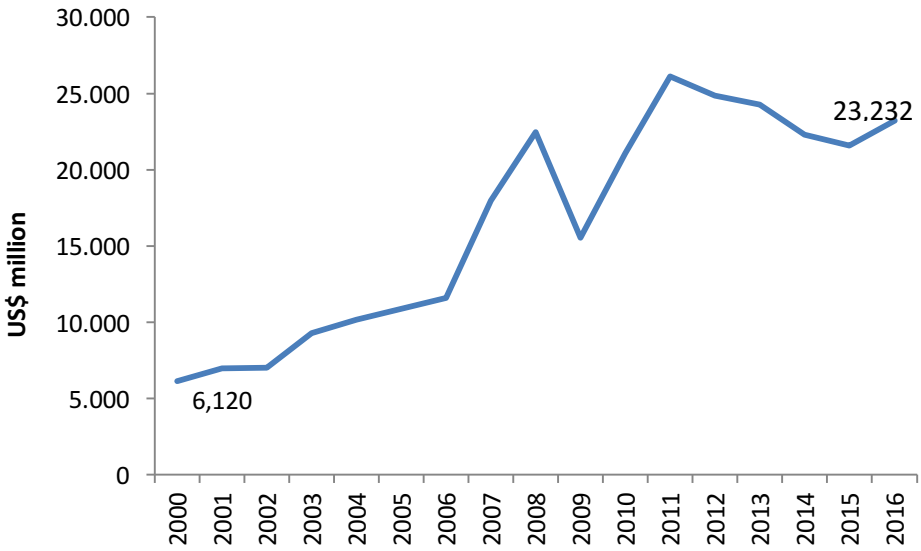
Regarding the impacts on the external sector, the primary sector and the manufacture of agricultural origin (MAO) represented the 57% of the exported goods value between 2004 and 2016 (figure 3). Mainly, the 40% of the total exports were generated by the grain sector.

Figure No 3: Evolution of the impact of the primary products and MAO in its total exported value (2000-2016)



Source: compiled on INDEC data

Figure No 4: Evolution of the grain exports

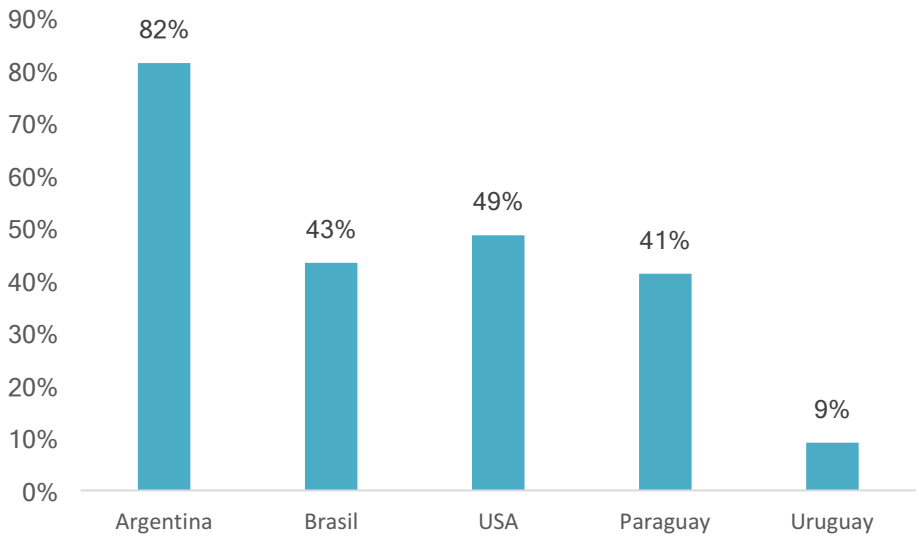


Source: Compiled on INDEC data

Regarding the direct fiscal impact, the export tax to the corn, wheat and soy export rose to USD 6,572 million in 2015 and the soybean complex to USD 4,717 million in 2016 and, approximately, to USD 2,500 million as of the date of this report in 2017. Between 2003 and 2016, the total generated by the export tax rose to approximately USD 70,000 million. Once again, as a reference, the total made by export tax between 2003-2016 represents 1.3 times the Central Bank's international reserves as of this date.

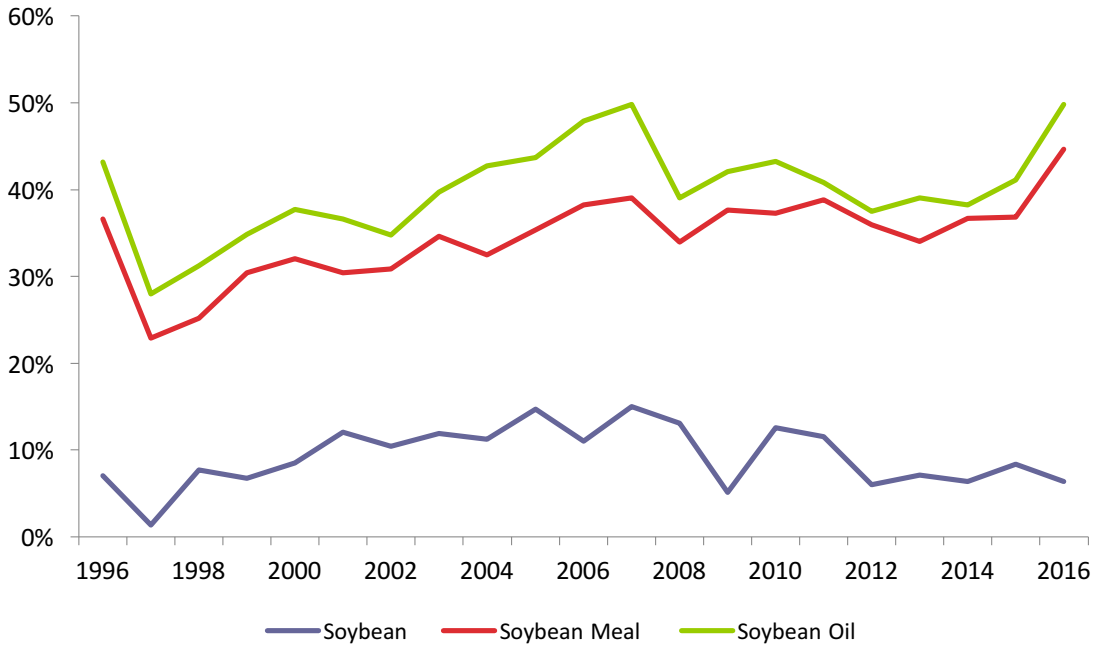
Finally, it is worth noting the high level of industrialization of the soybean production in Argentina regarding the rest of the producing countries. In Argentina, during the year 2016, the 82% of the soybean production was crushed into soybean oil and soybean meal (figure 5) while the competitor countries are below 50%. As it is shown in the following figures, Argentina is the world's primary exporter of soybean meal and oil, having a low share in beans. This fact is important when assessing the productive chains and the determination of the international prices.

Figure No 5: Soybean Crushing/Production 2016



Source: Compiled on USDA data

Figure No 6: Argentine *Share* of the world exports of the soybean complex



Source: Compiled on COMTRADE data

In short, the agricultural sector in Argentina covers:

- Impact at a GDP level
- Impact at a regional level
- Impact at an external sector
- Impact on public budget

For this reason, it is essential to study the economic cost of the extreme climate events, such as droughts and floods, not only at local level but also at regional level, to open the debate on whether the costs justify, or not, the financing of adaptation infrastructure. To serve that objective, in the following section, the concepts of climate variability and economic valuation are defined, mainly in relation with models that allow impact monetization.

3. Climate events

The focus of this study is on climate variability or climate risk: droughts and floods. These have an effect on the present. It is necessary to have adaptation measures to reduce the costs of those events.

In the meantime, the climate change is referred as to the changes in the trend values of the variables in long-term, associated to the greenhouse gas emissions. The actions to reduce those emissions are named mitigation strategies.

In the first instance, it is necessary to show a differentiation between the several events of climatic nature to introduce a right diagnosis of the problem. In this sense, there exists a significant difference between the following:

1. Climate change
2. Climate variability
3. Catastrophe
4. Environmental issues

The climate change is associated to the effects of the increase of the greenhouse gas emissions, which within a long-term period, they will generate trending changes on the temperature, precipitations levels, and sea-level rise at a global scale.

The climate variability is a current phenomenon and it linked to the short/medium-term changes in the climatological variations values, but without this being a trend change per se. For example, the annual level of precipitations of a region may stay constant, but its distribution within the year may change (for example, they can concentrate in shorter periods). In this case, there is a variability change but not a trending change.

Catastrophes are defined as extreme climate variability events, and usually, they cause damage to the natural, human and economic systems. A general example of catastrophic events is the floods due to heavy precipitations, overflowing rivers, hurricanes, high tides, etc. Mostly, these events take place in a very short period, with high intensity, and a small capacity to predict them.

Lastly, the environmental issues have not been, strictly, linked to climate impact, but to contamination and the relationship between the population, economic activity, and environment.

Even though the four dimensions are tightly interconnected, it is necessary to differentiate them to choose an economic valuation model to plan focused adaptation policies.

At the urban level, the historical emphasis has been made on the study of environmental issues, such as contamination, waste management, access to green areas, etc. However, during the last years, due to the international agenda on climate change, mitigation policies

have been enforced, regarding the creation of an inventory of gas emissions, or to apply reduction policies of those emissions. Less emphasis has been made on extreme climate variability events (heat waves, flash flooding) or catastrophes (floods, hurricane-force winds). Nonetheless, the events recorded during the last decade worldwide has prompted the focus on adaptation policies, especially regarding the flood control and the high tide in coastal regions.

In the agricultural sector, the primary emphasis has been made on the study of climate change impact, with limited research of the areas focused on the climate variability impact (for example, the losses estimations due to the changes in the frequency and intensity of the precipitation levels).

In the case of Argentina, there are some studies on the climate change impact in the agricultural sector. Notwithstanding, those estimations have limited use when justifying, in monetary terms, the funding adaptation projects.

In this sense, it is necessary to establish incidents, terms and value assessment to define the nature of the event and consequently, the kind of policy to be applied. Overall, a first classification of the type of policies are mitigation, adaptation and loss and damage:

- Mitigation: constitutes a set of policies focused on resolving the cause, which in the case study is the reduction of greenhouse gas emissions. It implies the transformation of a production apparatus which reduces the gas emissions.
- Adaptation: a set of measures to face the problem and reduce the social impact and the productive chain, due to the existence of the event and in case of not being able to mitigate it.
- Loss and damage: arises from cases in which the adaptation measures are not feasible, and it shall proceed to relocate those damaged, as fairly as possible.

The study shown in this report is related to the economic cost of the climate variability or risk events, to provide a monetized estimation to scale the issue at a regional and national level. In this way, it can be decided whether it is a local or macroeconomic, private or public problem and to provide, from a financial standpoint, guidelines to justify the feasibility of the investments in adaptation. However, it is necessary to define what is meant by economic valuation, a subject outlined in the following paragraph.

4. What is meant by economic valuation?

"Quantities + Prices + Productive Chains + Rate interests"

The economic valuation comprises the monetization of the impacts, where not only are intervening the physical quantities (direct impact) but also the pricing forecasts, productive chains (indirect impact), and valuation interest rates. Meanwhile, the socio-economic valuation implies adding effects which are not easily monetizable like the social vulnerability of the affected populations.

One of the main features of the economic valuation is the monetization of the impacts. In other words, besides estimating the effects on the quantities (basically, the damages or production loss measured in physical volumes), the impact on the pricing system should be assessed to make value estimations, that is to say: money.

The forecasting of prices is one of the most complex tasks because to isolate the price sensitivity of a product or an activity sector to climate events results in a difficult task. In this sense, most of the studies are limited to estimating the effects of the produced quantities.

At the same time, another essential element is the valuation of the indirect effects, in other words, the impact on the productive chain: transport, commerce or all other activities that form the supply chain. Estimating the indirect effects also proves out to be a highly complex task, which implies researching the system of national accounts and the input-output matrix.

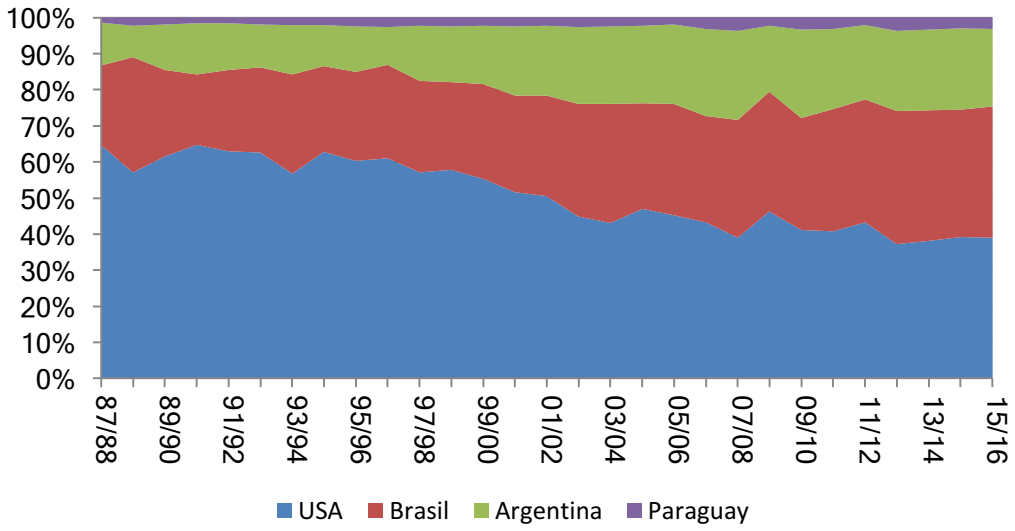
Regarding the direct and indirect impacts, it can also be estimated the fiscal effects, providing information on the impact in the private income and the public budget. This will allow us to answer the question whether if the economic impact is only private or it comprises the public sector.

However, for these purposes, it can be made a first important differentiation:

- Markets in which the internal production is the one, which determines the prices. This is the case, for example, of the soybean production in the United States of America. The stocks, which may vary depending on the climate variability, are the ones that fix the international price. Consequently, a loss of production may be compensated by a rise of the price, being able, in extreme cases, of not altering the producer's income. In this case, there would not exist a direct economic effect. However, the loss of the quantities produced causes indirect effects through the productive chain: less logistic services, less transformation in derivatives products, fewer storage services, less commercial services, etc.

- Markets where the price is fixed exogenously, that is to say: where the local producers do not have an impact on its determination. In this case, besides the indirect effects caused by the low produced quantities, there is a loss of direct income for the primary producers (the low production is not compensated by the rise of prices). This is the case of the soybean production in Argentina under normal conditions of the market, in other words, assuming there is no record of huge shocks on the main producers (mainly, United States of America and in second place, Brazil).
- Also, a complicated task is to estimate when the severe climate impact on the quality of the product that is reflected in the price but not in a low of the quantities produced,

Figure N 7: Percentage distribution of the worldwide production of soybean.



Source: Compiled on USDA data.

Moreover, as the climate effects are over time, and generally, the climate variability events are reflected during long periods of time, to standardize the monetary losses, it is necessary to fix a valuation interest rate. Estimating the interest rate (usually known as discount rate) comprises a specific study area within finance, and it is difficult to assess it for particular activities in emerging countries, given the limitations of the internal market and the impact of the macroeconomic risk.

Lastly, another highly significant dimension relates to the impacts on the social vulnerability. There can exist events that, at first, do not cause impacts on the produced value of economic activity, or as well as in damages on the fixed assets, but which can cause damages to the social vulnerability of the affected groups. These impacts, although difficult to monetize, is an essential part of the economic assessment of climate risk. The impacts can be observable as evacuation costs or higher costs due to a catastrophe, as well as, complex ones such as effects on mental and physical health.

4.1 Limitations of the assessment models

The study of the economic impacts of the climate events has been driven, mainly, by the international agenda related to the climate change. As it is a phenomenon that will be reflected on the long term, the forecast of the impacts is made on such a long time frame that it requires the presumption of countless variables and on the other hand, the level of certainty of the estimations may result low.

In the case of the agricultural sector, the climate impacts have been deeply analyzed from an agronomy standpoint, since the climate is the primary input for this activity. However, the estimations are, in general, strictly focused on a limited geographic area, and in general, they lack appropriate price forecast to estimate the economic impact.

Within the main limitations of the economic assessment of climate change impacts, it can be mentioned:

- Forecast periods extremely long for the planning of public policies in developing countries, which register deep instabilities in the short-term.
- A high uncertainty related to the analyzed variables.
- A large number of assumptions.
- Technical problems of assessment for fixing future prices and estimating the discount rate on extremely long-term periods.
- Lack of database of primary information.

Meanwhile, within the limitations of the agroeconomic approach to reply the question of this work, it can be summarized into the following:

- A difficult extrapolation to more extensive geographical areas, due to the necessity of a great quantity of information, which is limited or inexistent in developing countries or the peripheral regions of the main agricultural areas in each country.
- A necessity to have climate forecasts which are reflected within an information system compatible with economic information.

It is worth noting that most of the studies applied to Argentina are mainly focused on the effects of quantities produced or on the benefits of the farmers but studying the case on a limited geographic area.

At the same time, the estimation cases on the value added (GDP) correspond to future forecasts of climate change and not to climate variability scenarios, and the recorded losses of past events are not valued.

Given those limitations, it is necessary to count with an assessment model of economic losses at a regional and national level, assessing the cost of the past events forecasted in the medium-term period, which allows a better substantiation to enforce adaptation policies.

On the other hand, due to the recurrence of water excesses in Argentina during the last years, it was encouraged to estimate economic losses. However, it can be observed the lack of implementation of a standardized and duly tested model that, during the passing of time,

it can turn into a reference to appraise the level of economic losses. In this sense, the estimations introduced in the following section constitute the first step into the goal, being a key the intervention of the academic sector and the research on the making of relevant but rigorous models.

"All models are wrong; some are useful."

George Box

5. Economic assessment of extreme climate events in Argentina

Our proposal of "intermediate approach" is focused on making a consensual model that has a broad geographic scope and that it can be turned quickly into income losses estimations within a medium-term time frame. This information is critical to justify the financial-economic viability of the adaptation investments.

The primary objective of this section is to provide estimations of income losses due to variability events in the Argentine agricultural sector based on a rigorous methodology but, at the same time, standardized and replicable to an extended geographical area.

The study is focused on the soybean case, for its relevance in economic terms, for the provinces of Buenos Aires, Córdoba, Santa Fe, and Entre Ríos.

Regarding the climate event analyzed, a first approach of the economic losses due to the floods recorded in 2017 ("campaign 2016/17") is made, to later research deeply the past events of droughts, mainly in the years 2009 and 2012, due to its severity.

The study focuses on the assessment of past events, mainly due to two motives. In the first place, there cannot be found estimations entirely consensual at department level of the income losses generated in the recent past. In the second place, given that the events have already taken place, it is not necessary to appeal to forecast of the climate variabilities nor prices. In this way, it can be provided with a specific reference of the order of the scale of the economic losses (monetized) necessary to reply to the question whether if it is a local or macroeconomic, public or private problem. Consequently, whether it is justified the investment on adaptation measures, and eventually, which one should be the set of actors involved.

Our proposal of "intermediate approach" is focused on making a consensual model that has a broad geographic scope and that it can be turned quickly into income losses estimations within a medium-term time frame. This information is critical to justify the viability of the adaptation investments.

5.1 Water excesses

During the campaign 2016/17, the forecasted losses of direct income due to the floods of the soybean crop rises to USD 354.4 million, allocated in the following way: Buenos Aires USD 149 million, Cordoba USD 60.7 million, La Pampa USD 96.7 million, and Santa Fe USD 47.1 million.

The economic cost of the water excess results complicated to estimate. Mainly, because the flooded area and the level of the flood depend on geographic, topographic aspects, and the kind of soil which generates the event to have an impact at a local level, but not necessarily at a state level. Only extreme water excesses create changes on the relevant variables at a state level because the water excess may cause the destruction of the crops within an area inside of a farm, but on the other hand, produce extraordinary crop yields in nearby areas that due to geographical aspects, they are not flooded.

From the analysis of the historical information at a state level, it cannot be observed extreme precipitation on the crop yields which are a product of water excesses in contrast to events of the moderate and severe droughts, as it will be seen further on.

Although there are affected people at local level, the added economic assessment is complicated due to, on one hand, the existence of compensations and on the other side, the hidden costs. The compensations are given due to the destruction of the crops or the failure to harvest it in the wholly flooded areas, with the generation of exceptional crop yields in other areas. Regarding the hidden costs, the more prolonged transport times due to the impossibility of using the traditional roads given that they are flooded, the machinery or infrastructure damage, and the impact on social vulnerability, are external aspects to the agroeconomic information and they are difficult to forecast to an added level. It is worth noting that even moderate events which increase the humidity of the crops may carry additional costs, for example, drying, which could have been avoided if the climate event had not taken place.

In short, the critical points of the water excesses may be summarized in the following concepts:

- Losses at a local level
- There can be compensations at a state level, and an added loss may not be generated.
- Hidden costs

Following the clarifications, it is shown below a preliminary forecast of the direct losses due to water excesses for the campaign 2016/17.

Estimation of losses due to water excesses in 2017

The information at the head of the central delegations of the states of Buenos Aires, Cordoba, Entre Rios, Santa Fe, and La Pampa is reviewed, according to the one forecasted by the Ministry of Agroindustry for the campaign 2016/17. The group of delegations are reflected in table 1 (the case of Entre Rios is not listed as there is no record of significant losses).

Table 1: Delegations

Buenos Aires	Córdoba	La Pampa	Santa Fe
Bahía Blanca, Bolívar, Bragado, Gral. Madariaga, Junín, La Plata, Lincoln, Pehuajó, Pergamino, Pigué, Salliqueló, Tandil, Tres Arroyos, 25 de Mayo.	Laboulaye, Marcos Juárez, Río Cuarto, San Francisco, Villa María	General Pico Santa Rosa	Avellaneda, Cañada de Gómez, Casilda, Rafaela, Venado Tuerto

For the group of the departments listed herein, the following methodology was applied:

- The lost area was calculated, in other words, the difference between the sown area and the harvested area.
- The historical average loss of each department was calculated.
- The loss of the analyzed campaign was net from the historical average.
- In the cases where the current loss exceeds the historical loss, the water excess level was analyzed through the Palmer Drought Index (using the information given by the Centro de Relevamiento y Evaluación de Recursos Agrícolas y Naturales (CREAN) [Center for Study and Assessment of Agricultural and Natural Resources].
- In cases where water excesses are observable, the loss was assessed. For this, it was applied to the net area lost, the trending performance of the department[1].
- The loss in quantities is monetized by the international price of the soybean from the current year.

[1] According to the model and study devised by Thomasz *et al* (2017).

The added values by state, considering only the departments with loss due to water excesses, are summarized in the following table:

Table 2: Direct losses for each soybean cop
Campaign 2016/17, in US dollars

Buenos Aires	149,805,937
Córdoba	60,745,762
La Pampa	96,709,046
Santa Fe	47,144,064
Total	**354,404,810**

Source: Compiled

As it can be seen, the state of Buenos Aires registers direct economic losses equal to USD 149 million, Córdoba USD 60.7 million, La Pampa USD 9.7 million y Santa Fe USD 47.1 million. In total, the income loss for the reviewed area amount to USD 354.4 million.

In the meantime, regarding the relative production value of each state, the losses are of the 2% in Santa Fe, 4% in Cordoba, 4.4% in Buenos Aires, and 32.6% in La Pampa.

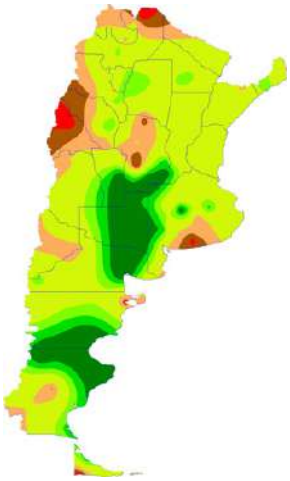
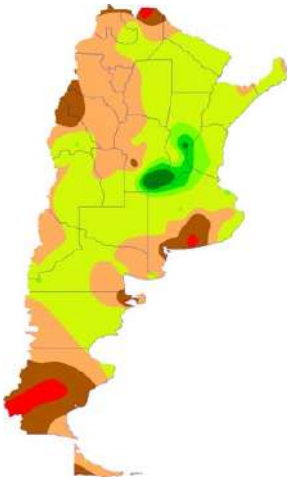
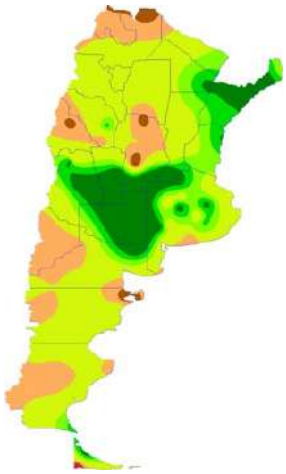
Table 3: Direct losses for soybean crop
Campaign 2016/17, in percentage for the forecasted production value

Buenos Aires	4.4%
Córdoba	4.0%
La Pampa	32.6%
Santa Fe	2.0%
Total	**4.6%**

Source: Compiled

As it can be seen, the state of La Pampa registers, by far, the more significant relative loss. This is consistent with the water excess level recorded in the region, which can be observed in the following table, where the mapping of the Palmer Index, made by the Centro de Relevamiento y Evaluación de Recursos Agrícolas y Naturales (the dark green color implies extreme water excesses) is shown.

Table 4: Palmer Index (PDSI)

January 2017	February 2017	March 2017
		

Source: Centro de Relevamiento y Evaluación de Recursos Agrícolas y Naturales[2]

[2] http://www.crean.unc.edu.ar/files/secciones/monitoreo/pdi_2017/ult_2017.html

5.2 The economic cost of droughts

During the campaign 2008/09, the estimated losses of direct income due to the drought of the soybean crop rises to USD 4,115.88 million, distributed in the following way: Buenos Aires USD 2,478 million, Córdoba USD 679 million, Entre Ríos USD 403 million, and Santa Fe USD 554 million.

During the campaign 2011/12, the loss was USD 2,606.37 million: Buenos Aires USD 293.17 million, Santa Fe USD 574.82 million, and Córdoba USD 1,738.37 million.

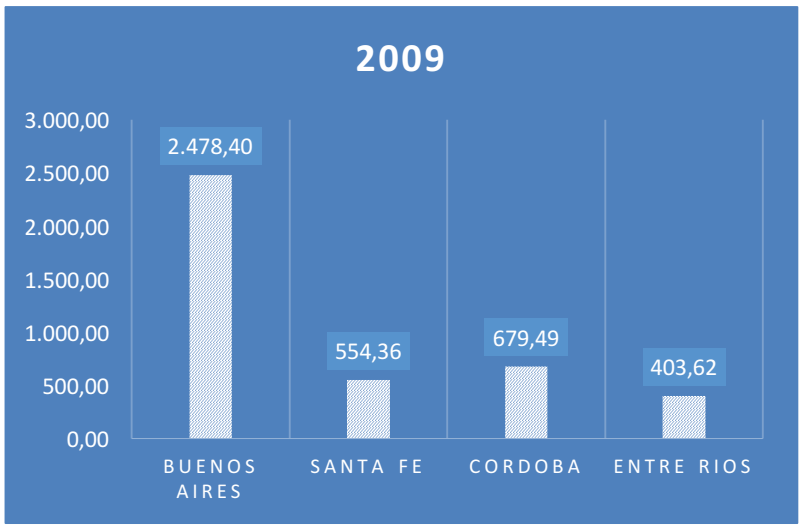
Although in recent years, the water excesses have been the main event, the Argentine agro has not been foreign to severe and extreme drought episodes in the last years. In fact, the droughts are the only events in which there is a dramatic and general drop of the crop yields at a department level. This situation is not observed in other cases, as in the water excesses where the effect is seen in the loss of the area in specific cases rather than in the drop of crop yields. This is caused, mainly, because the geographical and topological aspects do not have a huge impact on droughts as in floods.

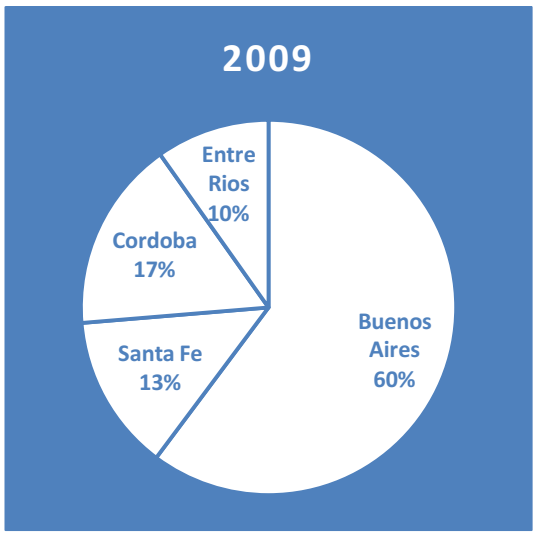
The forecasts correspond to the loss of income in dollars recorded at the department level for the state of Buenos Aires, Cordoba, Santa Fe, and Entre Rios. The number of department analyzed, in which the production of soybean is recorded, are the following:

- Buenos Aires: 99 departments
- Córdoba: 17 departments
- Santa Fe: 18 departments
- Entre Ríos: 17 departments

The model of economic assessment analyzes the evolution of crop yields, sown, harvested, and production area since 1970. Even though there are other cases of droughts, it was focused on the main episodes recorded in the last years. In view of the collected information, the study is based on the drought episodes of 2009 and 2012. The estimates of the direct economic losses are reflected in the following tables:

Figure No 8: Income loss by state due to drought of the soybean crop, campaign 2008/09
In millions of US dollars and in total percentage

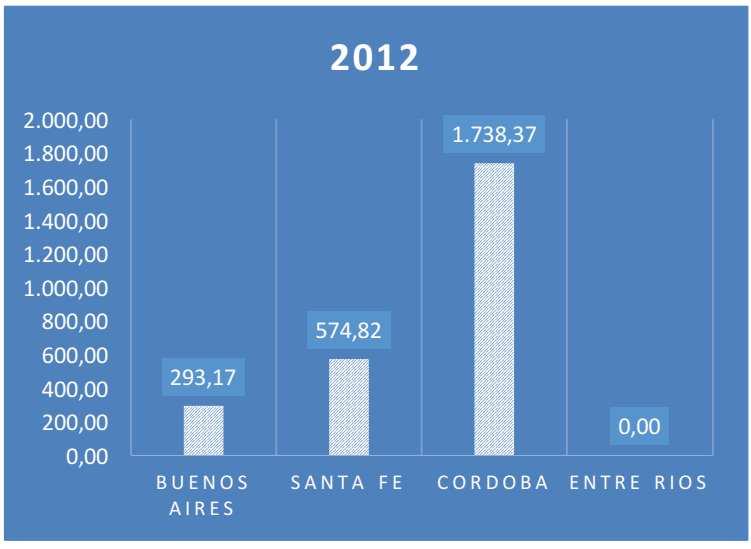


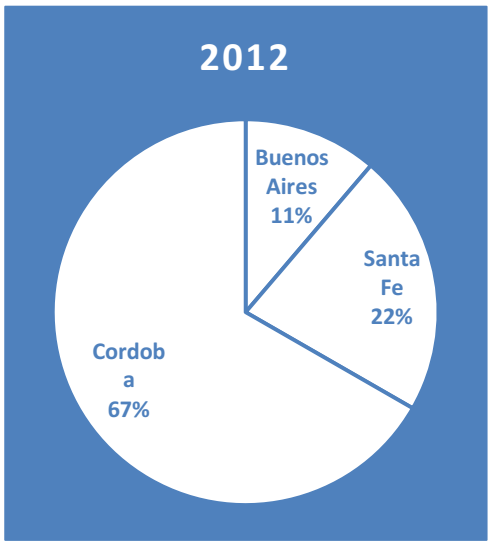


Source: own compilation

As it can be seen, the economic loss of the drought in the campaign 2008/09 rose to USD 4,115.88 million. At a state level, the loss was USD 2,478.4 in Buenos Aires (60% of the total), USD 554.36 million in Santa Fe, USD 679,49 million in Córdoba (17% of the total), and USD 403.62 million in Entre Ríos (10% of the total).

Figure No 9: Income loss by state due to drought of the soybean crop, campaign 2001/12
In millions of US dollars and in total percentage





Source: own compilation

At the same time, in the droughts of the campaign 2011/12, the total loss rose to USD 2,606.37 million. At a state level, the loss was USD 293.17 million in Buenos Aires (11% of the total), USD 574.82 million in Santa Fe, and USD 1,738.37 million in Córdoba (67% of the total).

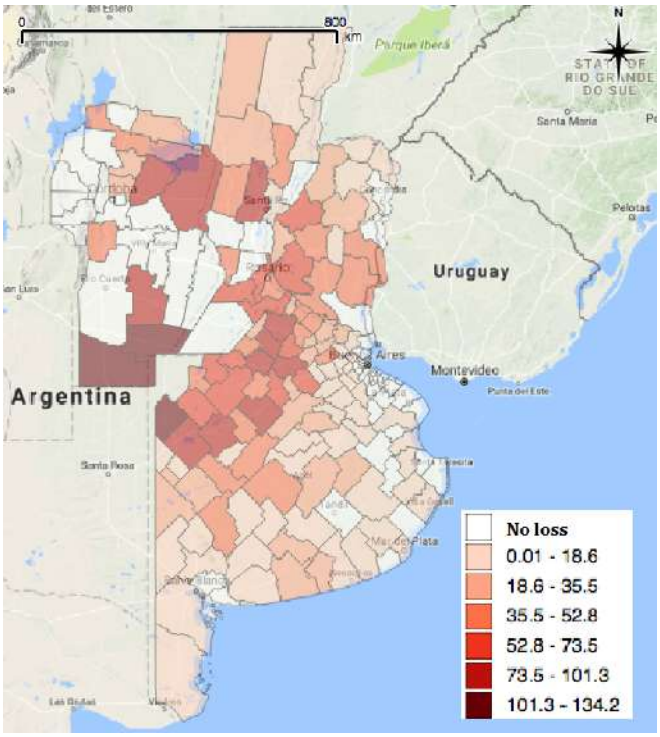
As a first conclusion, it can be inferred that the drought causes higher direct income losses than the water excesses, which its effect is focused on a more limited geographical area. However, it is worth noting that the water excesses may generate other kinds of adverse impact, for example on the social vulnerability or on infrastructure damage, which has not been assessed in this estimation.

In the following figures, the level of absolute and relative loss at a department level is mapped.

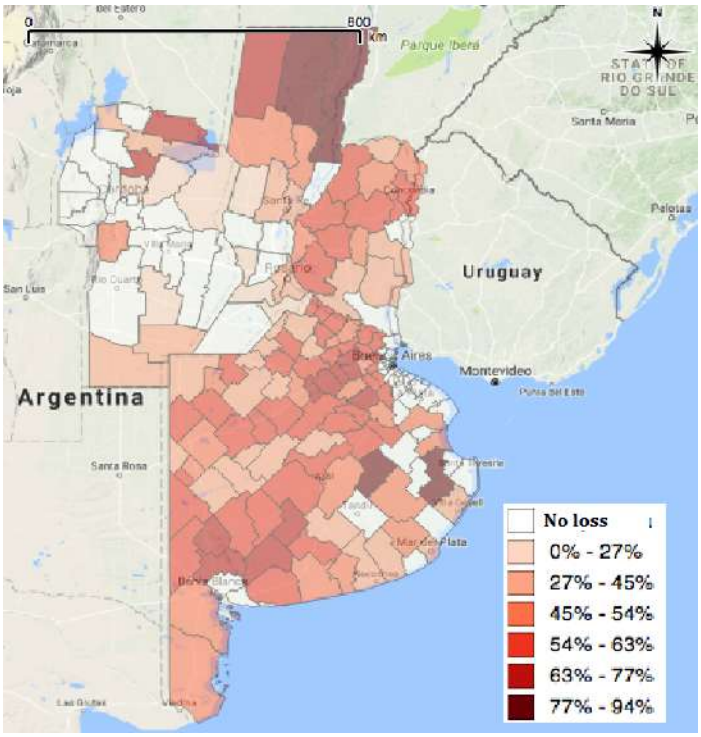
In the first map, it is reflected the scale of the total loss, which by a production volume issue, the higher losses will be seen in departments where there is a higher production volume. Due to this, in the second map, it is reflected the scale of relative loss, in other words: in a percentage of the production volume of each department.

Figure No 10: Geographical distribution for each department of the loss due to the drought of the soybean crop, campaign 2008/09

Absolute 2009



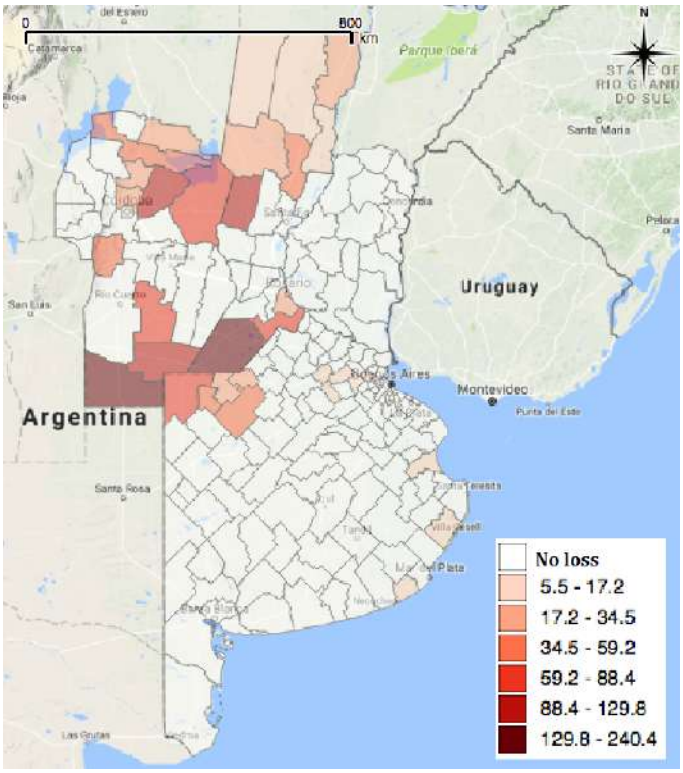
Relative 2009



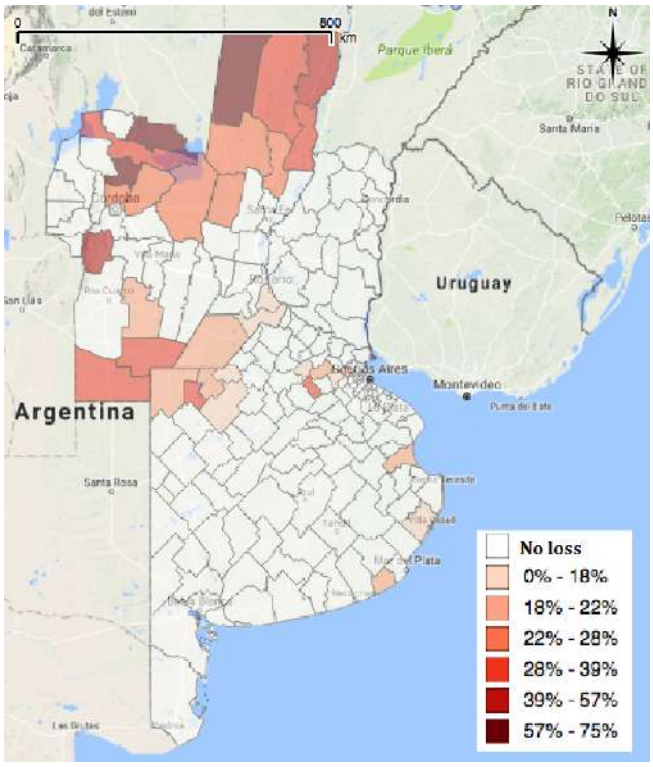
As it can be seen, in absolute terms, the higher loss due to the drought in the campaign 2008/09, is recorded in the core area of the states of Buenos Aires and Córdoba. Meanwhile, in relative terms, in other words: regarding the production volume of each department, the areas most affected were the south of the Province of Buenos Aires, the north of Santa Fe, and a considerable part of the Province of Entre Ríos.

Figure No 11: Geographical distribution for each department of the loss due to the drought of the soybean crop, campaign 2011/12

Absolute 2012



Relative 2012



Regarding the geographical distribution of the losses due to the drought 2011/12, in absolute terms, it can be observed that the significant losses were in the south of Córdoba, south of Santa Fe, and northeast of the state of Buenos Aires. As to relative terms, the most damaged area was in the north of Santa Fe and Córdoba.

Apart from the levels of past losses, the **question is what will be the magnitude of the future loss**. This is the crucial question since the current value of the income loss is what may justify, or not, the financial-economic viability of the investment in adaptation infrastructure. This subject will be developed in the following chapter.

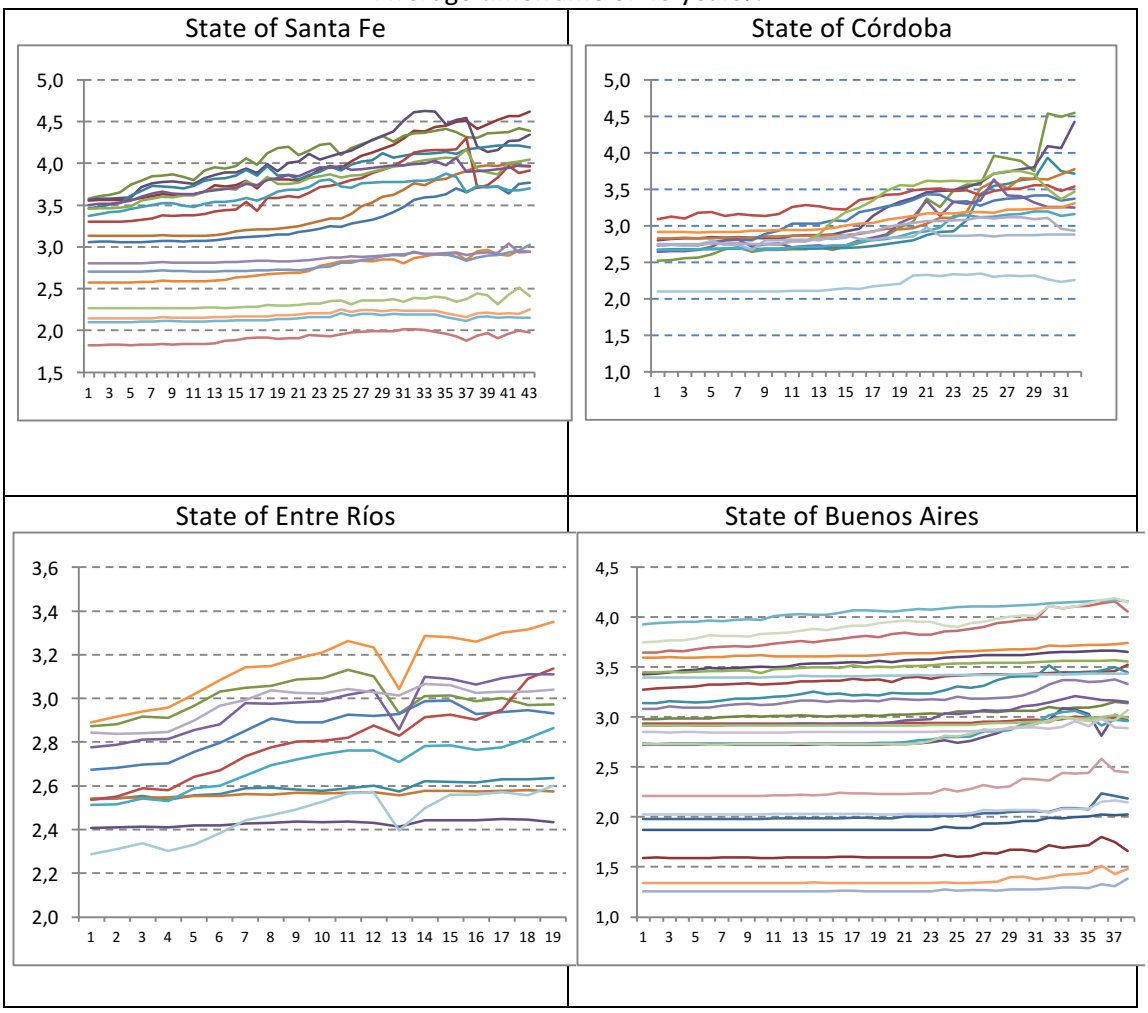
5.3 Forecasts

The current value of the direct loss of soybean production forecasted due to droughts rises to an amount of USD 22,985 and USD 3,339 million, depending on which valuation rate is applied. The higher the macroeconomic risk, the higher the rate will be and the less the financial feasibility to invest in adaptation infrastructure.

The forecast implies to make countless models and projections: future crop areas, yields, climate events, behavioral changes of the agricultural producers, international prices, and interest rates.

For this work and due to the high complexity of this task, which does not guarantee accurate results, a pragmatic solution is provided. The same frequency and intensity of the past episodes are repeated, forecasting them to the future with the current level of the sown area, keeping the last trend of the yields and applying the previous data of the international price. For example, in the figure No. 12, different simulations of crop yields for the provinces analyzed in this work are provided.

Figure No 12: Simulations of crop yields
-Average timeframe of 40 years%-

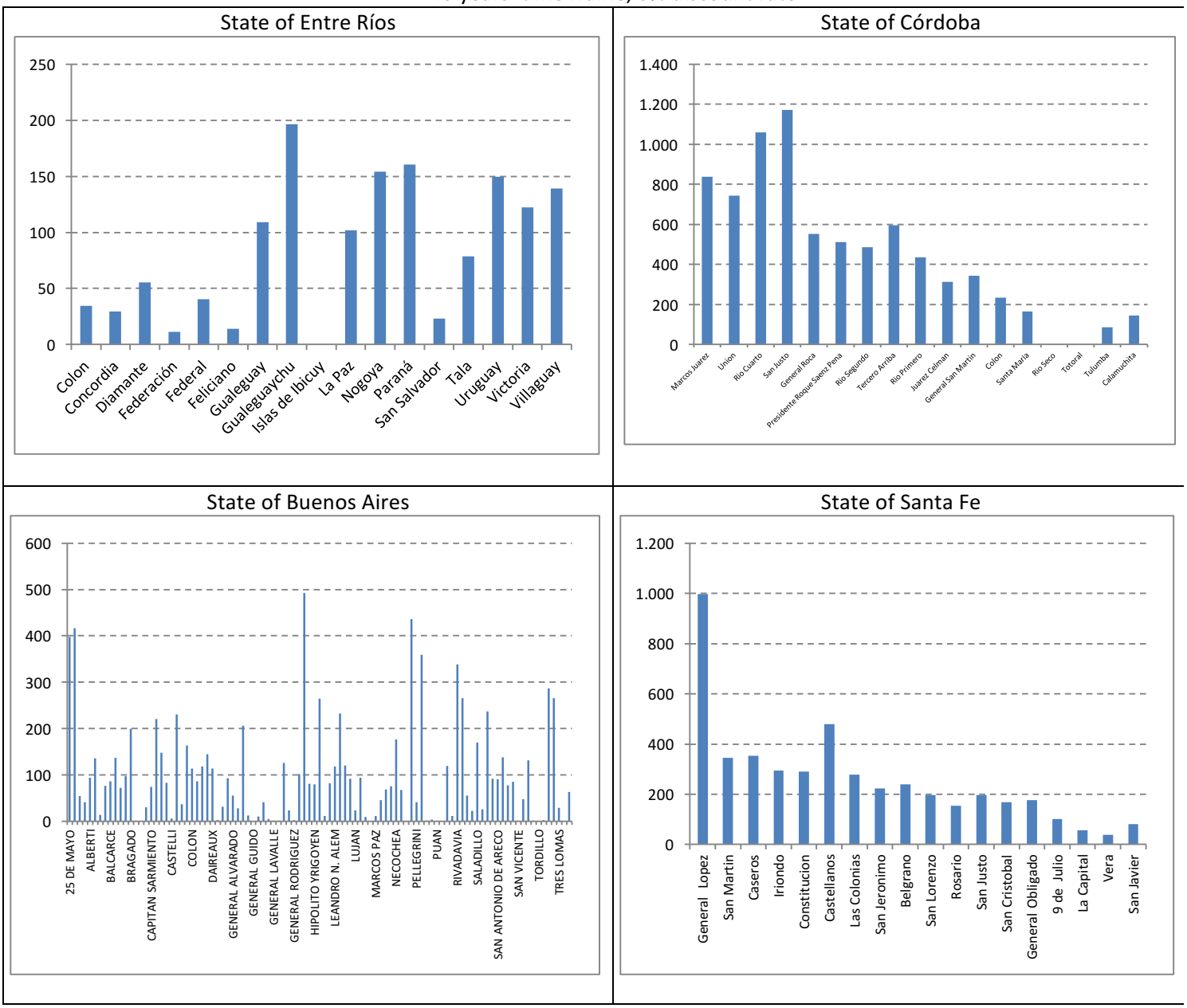


Source: own compilation

Taking as a starting point, the sown area in 2016 and replicating the behavior of the history of crop yields, within a forecast timeframe of 40 years, the nominal value of the loss, in other words: it does not contemplate the time value of the money, and it rises to **USD 22,985 million**.

In the following figure, an example of nominal losses at the department level of the provinces of Entre Ríos, Córdoba, Buenos Aires, and Santa Fe is provided.

Figure No 13: Total loss forecasted due to droughts
- 40 years' time frame, 0% discount rate-



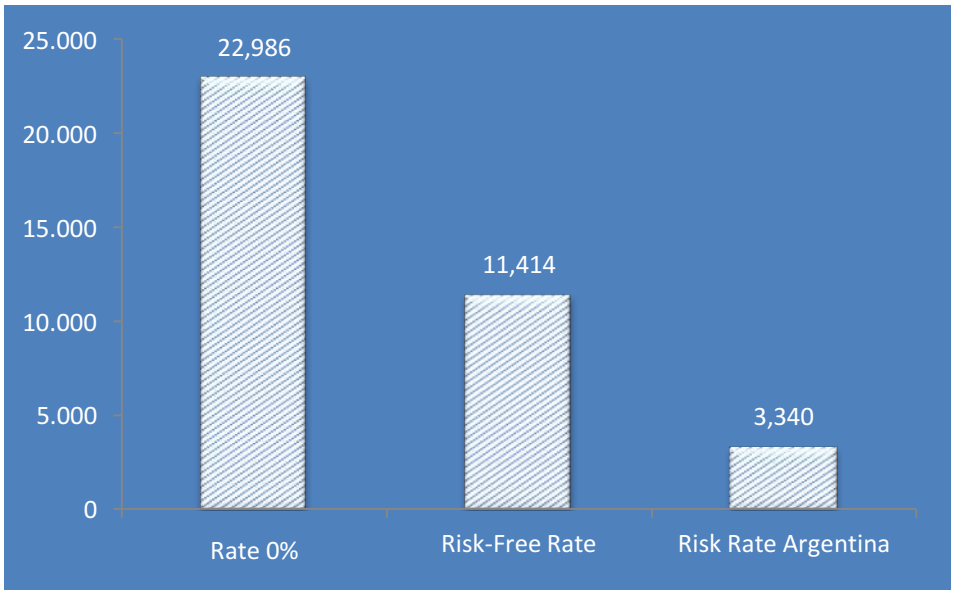
Source: own compilation

Even though the applied focus in the renowned Stern report (2001) was to value the loss in nominal values, that is to say with a 0% discount rate; it does not prove to be the most viable approach, especially in emerging countries with a significant macroeconomic risk. For this purpose, the same loss event is valued under two forecasts of interest rates hereunder:

- Applying the risk-free rate, the current value of the loss rises to **USD 11,414 million**.

- Finally, if the intertemporal losses are discounted to the current level of the average risk rate of the Argentine market, the present value of the loss descends to **USD 3,339 million**.

Figure No 14: current value of the forecasted losses due to droughts according to three discount scenarios.



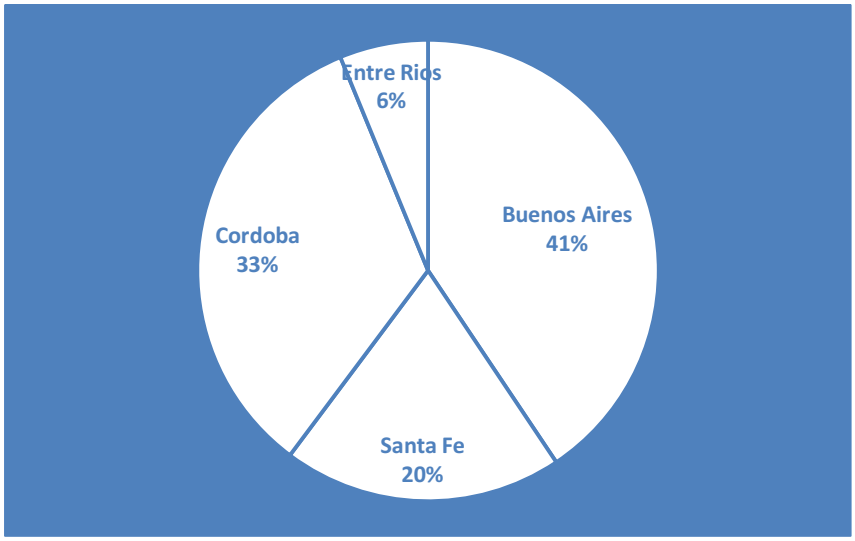
Source: own compilation

In financial-economic terms, investment in adaptation infrastructure, which its cost is less than the current loss value would be profitable, economically. However, as it can be seen, the current value of the loss does not depend only on the complexity of the climate forecast and its impact, but also on the interest rate, which represents the cost of the project,'s financing. **Due to the higher rates that the emerging countries have, the funding of adaptation infrastructure to the risk climate results non-viable in financial terms**.

This is one of the most critical issues of the investment on adaptation to climate phenomena in emerging countries: the high cost of the financing causes future losses to have a small relevance in present terms, allocating few or none resources to the sector. Even though the benefits of this infrastructure project are generated in long-term, the uncertainty of the climate projections becomes an additional problem.

Irrespective of the value of the forecasted loss, it will be distributed in the following way in the analyzed states: Buenos Aires 41%, Córdoba 33%, Santa Fe 20%, and Entre Ríos 6%.

Figure No 15: States percentage distribution of the economic losses forecasted due to droughts in the soybean production



Source: own compilation

Given the impact of the extreme climate episodes being straightly linked to the adaptation infrastructure, in the following paragraph, a preliminary and exploratory analysis on the perceptions that the agricultural producers have regarding climate events and infrastructure is introduced.

"…Vision may drive great projects but
FINANCING is the fuel that powers them…"

6. Climate Risks and Infrastructure

Survey to the farmers: the 64% considers climate events as the significant risk to their crops. From this, the 58% are highly concerned about floods and 39% about droughts. The higher demand of public works is for roads and hydraulic works. Within the hydraulic works, the 78% considers more critical the containment of floods. The 80% would be willing to be part of public investments plans (PPP)

Throughout this document, it has been emphasized the complexity of the estimation of an economic valuation of extreme climate events. The available tools for adaptation and mitigation are not exempt from a high degree of discrepancy. They require the coordination of multiple individuals with different incentives and various time frames. However, there is a general agreement that the investment in infrastructure whether in existing improvements or new projects, is noted on the available tools set. In this paragraph, it is intended to reply to the critical point in which there is no general agreement, how to implement adaptation infrastructure to the climate risks?

Usually, this kind of infrastructure projects shows unique features, which differentiates them from traditional investments. Amongst them, it can be highlighted the difficulties in making the future cash flows due to the high uncertainty, intertemporal problems of transferring the cost-benefit through generations of the growing risk, long-term projects with limited uses and generally, irreversible (Colgan 2016, Stern 2015, PPIAF 2016). Given this issue, the public and private sector are required to participate in these projects. Within this framework, it is vital to identify the sectorial priorities correctly in the planning process as well as to guarantee the increase of social benefits.

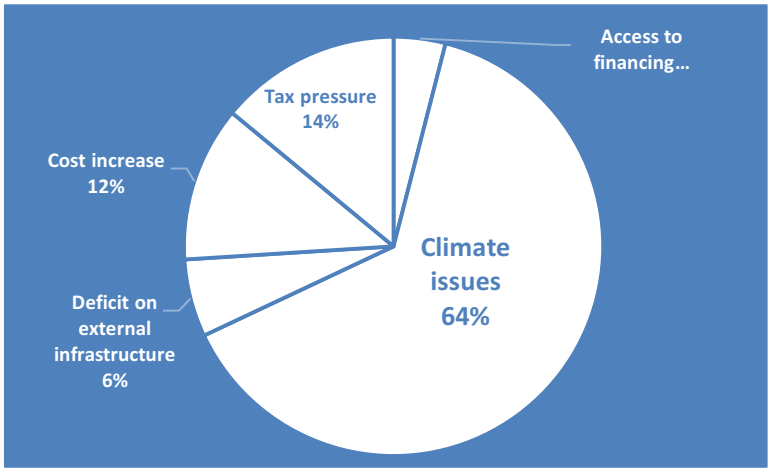
6.1 How to implement the adaptation infrastructure to the risk climate?

To answer this question, a first exploratory study was made trying to search for an approach the look and perception of the agricultural sector regarding infrastructure. 50 agricultural producers were interviewed in the Provinces of Buenos Aires, Córdoba, Santa Fe, Entre Ríos, and Salta. The main issues affecting the crops, the determinants of the investments, and financial mechanisms of infrastructure were enquired. From the set of the questions made, the following questions were selected to exhibit this work:

- Question 1: which has been the main risk your production has faced in the last 5 years?
- Question 2: Identify the main climate issue, which represented a risk for your production.
- Question 3: State the importance you give to the following alternatives: roads, energy supply, hydraulic works, telecommunications, irrigation systems.
- Question 4: which adaptation work to the climate risk seems more important?
- Question 5: in which adaptation measure to climate risk would you invest in, privately, if you have long-term financing?
- Question 6: Would you participate in a private-public participation framework to finance, in a shared manner, the adaptation works to the climate risk?

The results are shown hereunder.

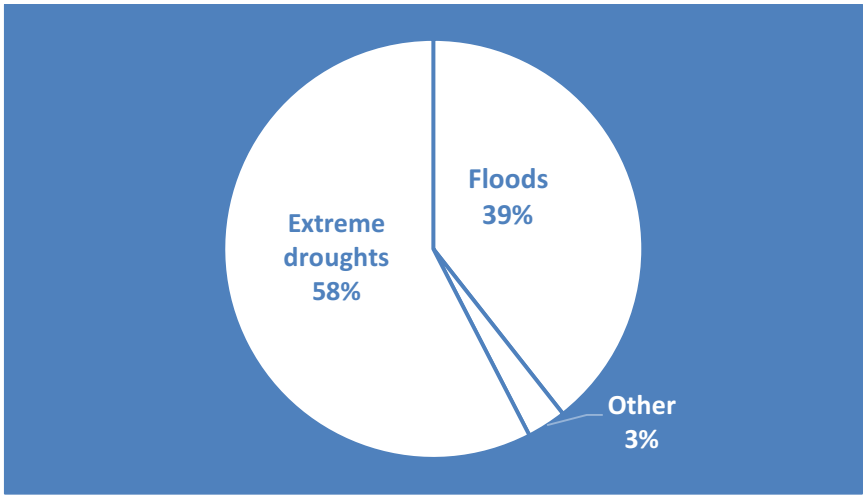
Question 1:
Which has been the main risk your production has faced in the last 5 years?



Source: own compilation

As it can be seen in the figures, there is a high incidence of the climate issues as the main risk of the production above the economic factors, as the Access to financing, tax pressure, or the cost increase.

Question 2:
Identify the main climate issue which represented a risk for your production.



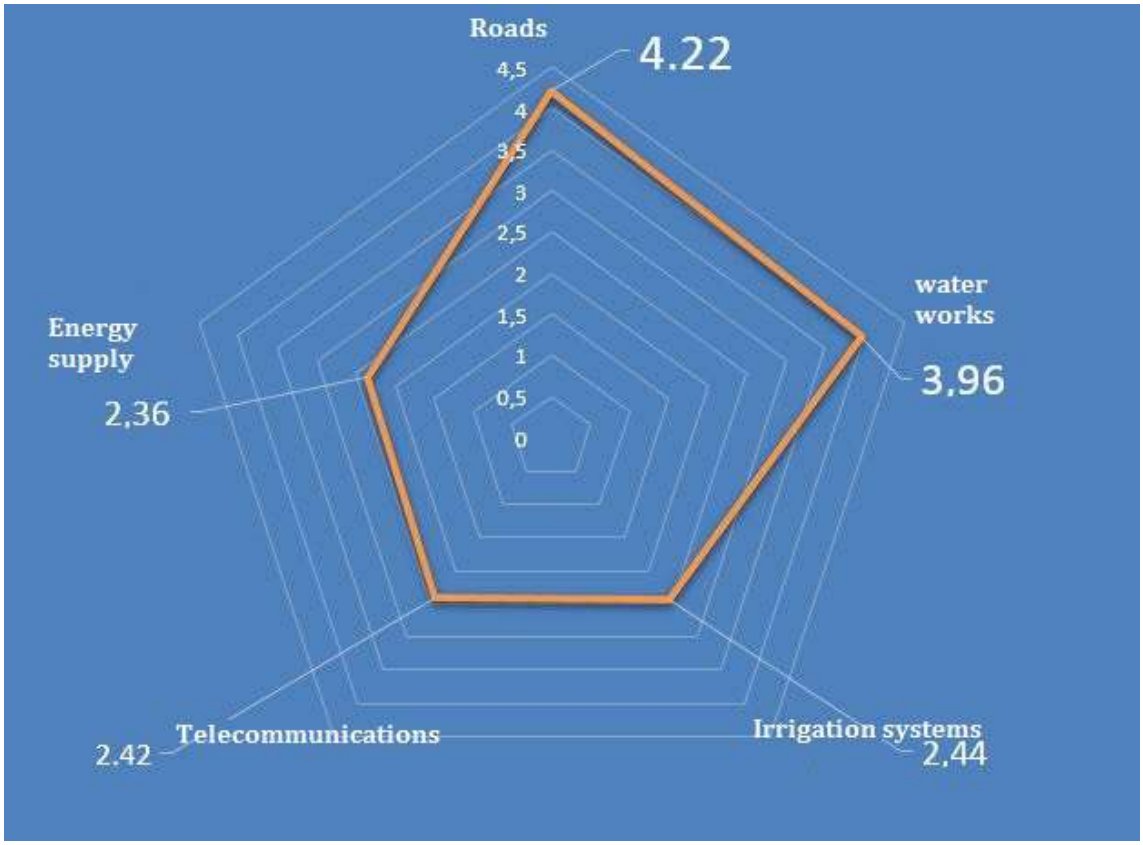
Source: own compilation

It is also emphasized the importance given to the drought as well as the floods justifying, in this way, the in-depth study of both events.

Regarding the public infrastructure situation, most people believe there is a deficit regarding the provision for their agriculture production. It was inquired about the

importance of the following alternatives to infrastructure: roads, energy supply, hydraulic works, telecommunications, and development of irrigation systems.

Question 3:
State the importance you give to the following alternatives: roads, energy supply, hydraulic works, telecommunications, irrigation systems.



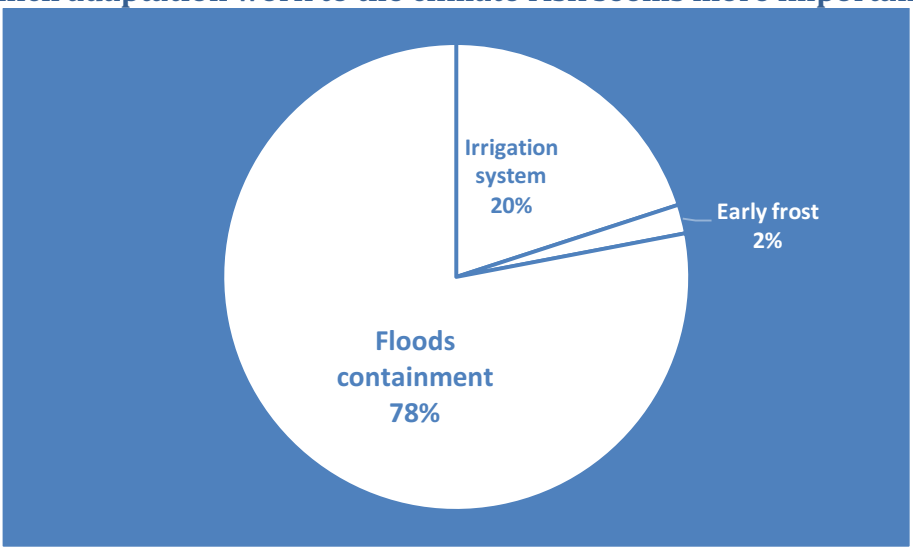
Source: own compilation

It is especially interesting to note that the alternative of **roads** is one of the most important followed by **hydraulic works**. Even within the context of the floods phenomenon, the option of roads being registered as one of the most important shows a necessity. It is worth noting that the rural roads may become impassable, even without an extreme event of flooding. This makes it impossible to access the farm or its exit, if the machinery had already entered, delaying the harvesting due to the impassable roads. It is worth noting, for example, one of the answers "… the way up to the nearest road from my field is of 7 kilometers. When it rains intensely, it becomes impassable…".

In respect of which government level should oversee the running of the implementation of the infrastructure works, the 58% chose the national government, the 36% the provincial government, and only the 6% the municipal. Once again, a clear majority answered, affirmatively, whether they considered a priority the public investment regarding other adaptation works to climate risk even considering its high cost. Later, they were asked

which adaptation work was considered the most important, is it the containment of floods as a first choice.

Question 4:
which adaptation work to the climate risk seems more important?

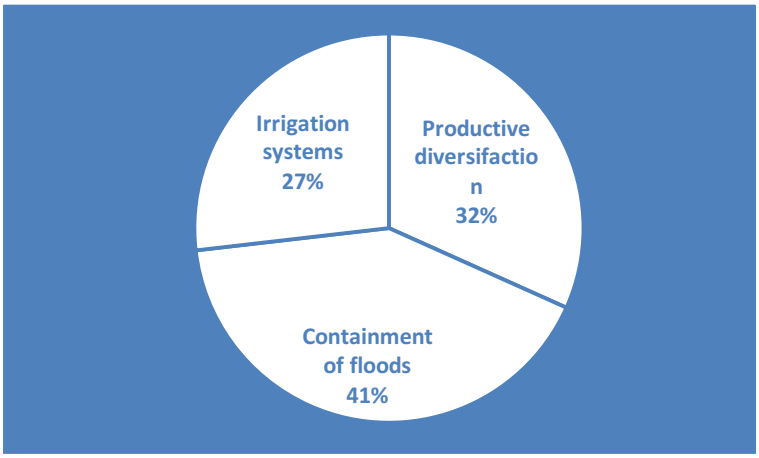


Source: own compilation

As it can be seen, a clear majority chose the works linked to the floods containment. However, it is worth noting that this question may be biased due to the current context. Despite this, it is highlighted the fact that the 20% answered the irrigation systems, linked to the droughts.

Subsequently, it was consulted, mainly, on which adaptation measure to the climate risk would they invest privately, in case of having a long-term, stable an in right conditions financing. It is interesting to see that from the private sector's point of view; the answers vary more. In this case, 41% would invest, privately, in the containment of floods while the 78% believes this work to be the most important at a public level. At the private level, there appear a productive diversification and irrigation systems as feasible alternatives, if they had the appropriate financing.

Question 5:
In which adaptation measure to climate risk would you invest in, privately, if you have a long-term financing?

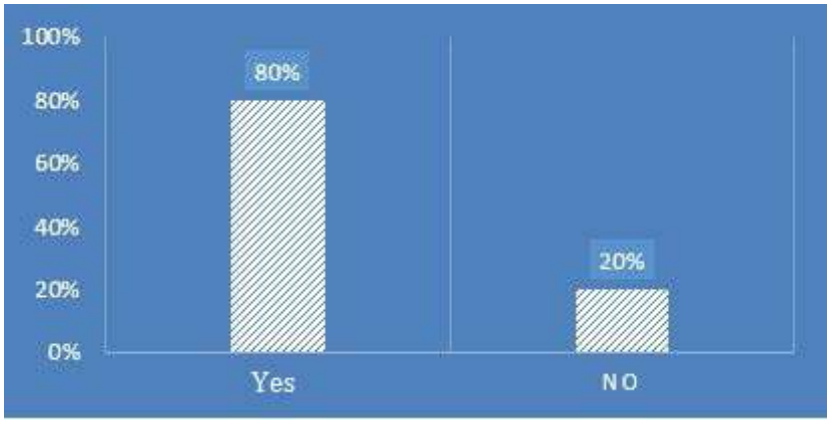


Source: own compilation

Finally, it was consulted on the viability and interest in participation in private-public partnerships (PPP). This kind of structure constitutes an alternative to financing which is becoming more relevant in developing countries where the climate vulnerabilities are increasing, and it is necessary the participation of all the actors to finance and implement adaptation strategies. In this kind of projects when they turn out successful, the climate risk is not allocated to only one part but distributed. The PPP projects also allow, in case they are correctly designed, the incentives to be precisely aligned to reach mutual benefits.

As it can be seen in the following figure, it can be thought about joint projects between the private sector and the public sector since 80% answered that they would participate in a PPP framework.

Question 6:
Would you participate in a private-public participation framework to finance, in a shared manner, the adaptation works to the climate risk?



Source: own compilation

7. Perspectives for planning

How to finance infrastructure under uncertain events? Adaptation to climate risk can be understood as one of the most significant challenges in theory and practice of planning. It implies dealing with long-term scenarios, a high uncertainty regarding the magnitude and the timing of the crystallization of events, great economic impacts and high costs of investments.

The science shows the dynamic and nature of the climate episodes is exceptionally complex and consequently, hard to predict, as different models may generate from mixed results to opposing ones. There is a relative consensus about the increase of the climate variability of specific events and the average increase of temperature. However, its particular distribution and momentum are highly uncertain.

Consequently, a question is raised as to how to plan adaptation measures before an unpredictable natural phenomenon and entirely exogenous for the mid-term human action. Even more, these investments imply generating resources that compete with other policies objective with accurate and current impacts, as in education, health, and security. Within this framework, the question arises as for how to make costly policy decisions based on a forecast of events (for example, a drought or floods map) for a long-term time frame in which its estimations may show a high level of uncertainty.

In this sense, the adaptation to the climate risk may be understood as one of the most significant challenges in the theory and practice of modern public policies. It implies dealing with long-term scenarios, a high uncertainty regarding the magnitude and the timing of the crystallization of events, great economic impacts and high costs of investments. Additionally, the investments in adaptation to attend future events compete with other policies, which must attend current issues, and at the same time, those investments may affect the behavior of the stakeholders, altering the economic activities, insurance costs, and assets valuation.

Irrespective of the fact that the climate science will keep evolving and will provide new answers in the future, **planning specialists, currently, face the problem with multiple points of view. Following an incremental approach, apply flexible strategies, and combine the investments in adaptation with investments in adaptation with current economic development requirements, increasing the co-benefits**. However, this focus has its limits in huge infrastructure projects of a long-life cycle, as well as in social vulnerability problems in populations of high risk, which, ultimately, should be relocated.

In general terms, progress should be made with a new design of valuation of projects. This one should consider the high uncertainty of the climate forecasts, the holistic effect of the events, the current and future level of the socio-economic vulnerability, the tolerance of various sectors and activities, and the relationship vulnerability/cost of different actions.

The right valuation of the socio-economic impacts and the design of plans of private-public participation are fundamental to finance adaptation strategies within an implementation context within an implementation context of public policies based on the data-driven policy-making paradigm.

8. Summary

Macroeconomic impacts, the valorization of the agricultural sector and private-public financing: the extreme climate episodes may generate macroeconomic impacts in the Argentine economy. This is not only due to higher frequency and intensity of the climate events but also due to the valorization of the agricultural production, given the increase of the international prices, the rise in the productivity, and expansion of the agricultural frontier.

Due to the shared risks, there is space to explore instruments of private-public participation to finance adaptation infrastructure projects. The right forecast and monetization of the future losses and its financial discount are significant elements for the correct distribution of the risk between the parties.

This document tried to provide a summary and a first approach to the problem of the economic valuation of extreme climate events in the agricultural sector in Argentina.

In the first place, the definition of climate change and climate variability was differentiated, emphasizing on the second phenomenon for a mid-term time frame. In the second place, the problem and the limitations to the economic valuation were laid out. Regarding this, a methodology was applied which allowed being applied to a vast geographical area to give the first step at the scale of the issue and reply to the query whether the economic impacts are a macroeconomic, regional or local.

Droughts generate more significant losses than the floods when evaluating the direct losses of the soybean crop. Also, its geographical extension is much more significant, and the scale of the loss turns it into almost an event with macroeconomic impacts.

Meanwhile, the floods cause a loss problem much more focused on a geographical extension much smaller. However, although the direct loss is low, this even may cause other economic impacts, which were not valuated in this work[3], could turn into observable and unobservable Also, while in the past the floods were a local problem, in the last campaign (2016/17), it became almost regional problem.

Even though currently, the Argentine situation is marked by the floods, it is important to remember that in the last decade, there were two extreme droughts with significant economic losses. This fact affirms the perception of the producers, where the majority answered as the main concern the water excesses (58%), the 39% chose the droughts. The central question is which event will take place frequently in the future.

[3] The indirect effects and the hidden costs shall be contemplated in a second phase of estimation.

The results of the soybean exhibited herein must be considered as the minimum, not only for not including other crops like corn, wheat, livestock and dairy business but also for not estimating the indirect costs.

However, due to the high weight of the soybean industry, the results are robust enough to obtain the scale of the phenomenon.

Within this framework, we find that the scale of the loss magnitude due to extreme climate events deserves the research of adaptation measures to the climate risk. The higher international prices, after the Asian Miracle among other factors, has increased the cost of events significantly. In this way, the different ranges of the available financial instruments for the financing of infrastructure must be researched. Especially, the private-public partnerships (PPP) constitute, provided that they are well-planned, a risk distribution mechanism between the parties.

The expansion of the agricultural frontier, the valorization of the crops, and thereby, the value of the soil, probably, has not been followed by an increase of the infrastructure associated to the sector. In this way, although the climate variable causes the dominant shock, the rise in the scale and valorization of the sector generate the losses measured in economic terms to be significantly higher than in the past.

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