UNIVERSIDADE DO SUL DE SANTA CATARINA

WELLYNGTON SILVA DE AMORIM

THE PROMOTION OF FOOD SECURITY: CHALLENGES AND OPPORTUNITIES FOR FOOD PRODUCTION AND DISTRIBUTION IN A CONTEXT OF GLOBAL ENVIRONMENTAL AND ECONOMIC CHANGES

Palhoça, 2019

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PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS AMBIENTAIS

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Master's degree dissertation presented to the Graduate Program in Environmental Sciences as a partial requirement to obtain the title of Master in Environmental Sciences.

Advisor: Dr José Baltazar Salgueirinho Osório de Andrade Guerra

Palhoça, 2019

A54 Amorim, Wellyngton Silva de, 1995-
The promotion of food security : challenges and opportunities for food production and distribution in a context of global environmental and economic changes / Wellyngton Silva de Amorim. – 2019.
92 f. : il. color.; 30 cm

Dissertação (Mestrado) – Universidade do Sul de Santa Catarina, Pós-graduação em Ciências Ambientais.
Orientação: Prof. Dr. José Baltazar Salgueirinho Osório de Andrade Guerra

1. Segurança alimentar. 2. Agricultura familiar. 3. Desenvolvimento sustentável. 4. Mudanças ambientais globais. I. Guerra, José Baltazar Salgueirinho Osório de Andrade. II. Universidade do Sul de Santa Catarina. III. Título.

CDD (21. ed.) 353.997

Ficha catalográfica elaborada por Carolini da Rocha CRB 14/1215

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This dissertation was deemed appropriate to obtain the title of Master in Environmental Sciences and was approved in its final form by the Master Course in Environmental Sciences of the University of Southern Santa Catarina.

Palhoça, 2 July, 2019.

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Prof. Advisor José Baltazar Salgueirinho Osório de Andrade Guerra, Dr.
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Prof. Rogério Santos da Costa, Dr.
Universidade do Sul de Santa Catarina

This study is dedicated to all of those who somehow are affected by hunger, poverty and misery. Through this study, I hope to collaborate in the creation of solutions that can answer to the countless challenges related to food security and sustainable development.

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PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS AMBIENTAIS – MESTRADO

ATA Nº03/2019 DE DEFESA PÚBLICA DE DISSERTAÇÃO

Aos dois dias do mês de julho de dois mil de dezenove às treze horas, na sala 115 – Bloco D, da Unidade Universitária Pedra Branca da Universidade do Sul de Santa Catarina, foi realizada a sessão pública de apresentação e defesa de Dissertação de Mestrado de **Wellyngton Silva de Amorim,** como requisito para obtenção do título de Mestre em Ciências Ambientais, de acordo com o Regimento Interno do Programa de Pós-Graduação em Ciências Ambientais - PPGCA. A comissão avaliadora foi composta pelos seguintes professores: - Dr. José Baltazar Salgueirinho Osório de Andrade Guerra, orientador e presidente da banca; - Dr. Rogério Santos da Costa, avaliador interno do PPGCA; - Dr. Pablo Salas Bravo, avaliador externo da Universidade de Cambridge. A dissertação tem como título: **"A promoção da segurança alimentar: desafios e oportunidades para a produção e distribuição de alimentos em um contexto de mudanças ambientais e econômicas globais"**. Área de concentração: Tecnologia, Ambiente e Sociedade e linha de pesquisa: Tecnologia & Sociedade. Após a apresentação, o mestrando foi arguido pelos professores da banca. Feitos os questionamentos e ouvidas as explicações, a banca avaliadora emitiu o seguinte parecer:

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Obs: _____

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Nada mais havendo a tratar, foram encerrados os trabalhos e, após lida, foi a presente ata assinada pelo Mestrando e pelos membros da Comissão Avaliadora.

Dr. José Baltazar Salgueirinho Osório de Andrade Guerra: Baltazar D'Andrade Guerra

Dr. Rogério Santos da Costa: _____,

Dr. Pablo Salas Bravo: _____,

Discente Wellyngton Silva de Amorim: Wellyngton.

ACKNOWLEDGEMENTS

All kinds of work and compositions, when well-structured, require time, dedication and even some obsession. In the backstage of this entire creation process, generally there are caring and comprehensive people, ready to help in whatever is necessary. In order for me to end this dissertation successfully, I counted with the support of endless people who have an immensurable importance in my life. Therefore, nothing more fair than use this section of my study to thank them.

First, I thank my family for all the support and incentives given through out my entire trajectory to my master's degree. My father João Schorne de Amorim, my mother Márcia Silva de Amorim, my sister Jullyana Silva de Amorim and my partner Franciny Amorim Genol, who were the people responsible for supporting and encouraging me in the last years. I thank you from the bottom of my heart for your understanding, patience and care.

I also thank my dear friend and advisor José Baltazar Salgueirinho Osório de Andrade Guerra for his teachings and lessons shared through my entire academic journey, which were essential to my formation as a cientist and citizen. Without doubts, your support guided my career and has opened unimaginable opportunities.

To Unisul, I thank all the opportunies and magnificente moments which only the university could have given me. I also would like to thank the entire team and colegues, students and professors, of the Programa de Pós Graduação em Ciências Ambientais (PPGCA) for the extraordinary experience, and to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for financing my studies and research in the last two years. To the Grupo de Pesquisa em Eficiência Energética e Sustentabilidade (Greens), I thank for being my second home in the last years, providing countless friendships and great knowledge.

At last, but not least, I thank professor Dr. Rogério Santos da Costa and Dr. Pablo Salas Bravo, who accepted my invitation to participate in my defense, contributing to the conclusion and evaluation of this dissertation.

"Tell me, and I'll forget.
Show me, and I may remember.
Involve me, and I'll understand."
(Xunzi)

"Most risk management is really just advanced contingency planning and disciplining yourself to realise that, given enough time, very low probability events not only can happen, but they absolutely will happen."
(Lloyd Blankfein)

"Our very survival depends on our ability to stay awake, to adjust to new ideas, to remain vigilant and to face the challenge of change."
(Martin Luther King Jr.)

ABSTRACT

The effects of population growth, climate change, fast urbanization and the increase in demand for energy, water and food resources have contributed to consolidate a complex and interdependent global scenario. Such complexity, results in global risks and challenges that have no observance for political or economic borders, affecting all the planet. Among many obstacles faced by humanity, food security is a major challenge. In this study, I defend the idea that three pillars must be set as a priority in regional and international agendas to address the problem of food insecurity. Those three pillars are: incentive to family farming and small scale food production; good governance; and technological development. At the end of this study, the conclusion is that better management by decision-makers and public power is needed, ensuring that by creating public policies, increasing the awareness of stakeholders and technological innovation, a new global chain of food supply will be resilient, innovative and sustainable.

Keywords: Food Security; Global Risks; Family Farming; Sustainable Development; Innovation.

SUMMARY

CHAPTER 1 – GENERAL INTRODUCTION

The uninterrupt access to food resources has always been a reason of constant concern throughout the history of humanity. Besides being the foundation to the survaival of species and production of riches, nourishment also brings countless cultural traces which vary from region to region.

After the accelerated development of societies, the emergence of international organizations and a largest distribution of riches and rights assurance, the idea of promoting food security to all has became a high priority of the international agenda. Initialy, the term "food security" was directly linked to economic aspects, reaching a much more inclusive and holistic view nowadays, which takes into consideration four fundamental dimentions: food access, availability, use and stability.

In that sense, it is fundamental for all people, at all times, to have fisical and economic access to nourishment that are nutritious and healthy, answering the needs, nutritive and dietetical preferences that result in an active and healthy life. However, in contrast, despite the countless movimentations that drive the assurance of food to people around the world, it can still be noted the continuous persistence of food insecurity in many regions, affecting mainly the poorest in developing countries.

The situation becomes more chaotic as new challenges emerge in the international scene, such as populational growth in a global scale; behavioral changes in purchase patterns; climate change; competition for resources and land; raise in the middles class and demand for food, water and energy; political deadlock; economic crises and environmental catastrophes.

To assure that there is a distribution and an access of food which is equal and fair to every individual, it will be necessary to use and apply new technologies, theories and moves that facilitate this process. In this sense, through this dissertation, I defend the idea that we need to apply our efforts in three important pillars: i) family farming and smaller-scale food production; ii) good governance; and iii) new technologies from the fourth industrial revolution. Through observing this new reality in which we are living, in the last years, I have dedicated my studies in searching for solutions that assure food security on the long run, bringing with me the knowledge acquired through a deep reading of international literature and the attention given to traditional and modern academic debates.

Therefore, through this dissertation, I intend to answer the following question: how Family farming, urban agriculture and the process of the fourth industrial revolution promote

food security when aligned with public policies and technology in a global risks scenario? To reach the intended result, three objectives must be reached: i) define food security, the Nexus between water, energy and food and global risks, ii) contextualize the food security issue in urban centers; iii) identify in literature the good pracices from technological development which collaborate for the promotion of food security.

To answer to the main questiono f this study, 3 scientific articles were written and published in international journals. These same articles, compiled and organized logicaly in only one narrative, make relevant debates about the challenges of food security, promoting eventual answers and questionings which contribute for the academic debate.

The first study *(Article 1)* refers to the article named "**The contributions of public policies for strengthening family farming and increasing food security: The case of Brazil**", published in "Land Use Policy" journal. In this research, the impacts of public policies in family farming in Brazilian national territory were approached, highlighting the relevance that this kind of production in a smaller scale has in the development of regions, in the distribution of riches and fostering food security.

Within the debated points of this study, it is possible to highlight 3 main ideas: i) the production of food in an smaller scale has countless benefits; ii) it should contemplate food production in a larger scale; and iii) we must study and mitigate the threats and challenges that put small producers at risk. In that article, Brazil was choosen as the case study, due to its relevance in production and exportation of commodities in the international market.

The second article, entitled "**The nexus between water, energy, and food in the context of the global risks: An analysis of the interactions between food, water, and energy security**" *(Article 2)*, published at "Environmental Impact Assessment Review" journal, reveals the intrinsic relations that exist between the management of food, water and energy resources, and the countless global risks which impact countries and industries across the globe. Through the point approached in that study, it can be noted that assuring food security requires not only an integrated resource management and effective public policies, but actions and decision making that lead to the consideration of economic, environmental, geopolitical, social and technological risks which impact food management.

It is important to highlight that until now, the relations between global risks and the nexus between water, energy and food, were new in the academic debate. After perceiving this gap, I opted to write this study, enriching the debate over risks and resources management.

The third and last article, named "**Urban challenges and opportunities to promote sustainable food security through smart cities and the 4th industrial revolution**" *(Article 3)*, published in "Land Use Policy" journal, approaches the last highlight of this dissertation. In this article, we point that technological development and the fourth industrial revolution as essential factors for the promotion of food security, allowing food to be produced in a smarter, faster and more effective way, turning the household into local food producers.

Next, in chapters 2, 3 and 4, the three articles discussed are exposed and organized logically, allowing that, by the end of reading, the reader understand and identifies the pillars which are considered essential for the promotion and guarantee of food security.

CHAPTER 2 – ARTICLE 1

The contributions of public policies for strengthening family farming and increasing food security: The case of Brazil

Land Use Policy

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Abstract

Ensuring food security is one of the main challenges of the 21st century in developing countries. The aim of this study is to analyze how public policies contribute to the strengthening of family farming in order to increase the food security. The study encompasses a literature review of the relations between public policies, family farming and food security and relates them with a review of the main policy framework in Brazil. The results show that the Brazilian policy framework in terms of strategies to strengthen food security is intrinsically focused on family farming and, in fact, these policies contribute to enhancing food security. Thus, family farming, in conjunction with large-scale farming, is crucial to Brazilian and global food security. Even though there are some scientific publications on food security and official reports on the subjects in Brazil, little has been written about family farming as a strategy for public policies to enhance food security in Brazil. Therefore, this paper can potentially contribute to the literature on good governance in terms of agriculture and food security policies by presenting the well succeeded case of Brazil since the early 2000s.

Keywords: Food security; Public policies; Family farming; Sustainable development

Highlight

•Food security is a major global challenge of the XXIst century.
•Good governance is a key player in reducing poverty and increasing food security.
•Family farming, complementary to large-scale farming, is crucial to global food security.

1. Introduction

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996). The need of assuring food resources has been increasingly

discussed in global agenda, since the foreseen population growth to 9 billion people by 2050 will generate larger disputes for food and larger pressures on this resource (McDonald, 2010). This scenario will demand better handling of international actors to deal with the growing scarcity of food and the uncertainties related to this scenario.

Despite their inability to intervene in global markets, national authorities play a key role in ensuring global food security by handling food production between large producers and smallholders, promoting sustainability and social inclusion (Oosterveer et al., 2014; Shete and Rutten, 2015). In addition, strengthening partnerships with non-governmental organizations, academia and other sectors of civil society is equally important and contributes to the formulation of environmentally sustainable food security and nutrition policies, which can promote gender equity and reduce the effects of climate change on agricultural production (Magalhães, 2014).

The formulation of food and nutrition security policies is a complex and dynamic process that is affected by different forces, such as political constraints; additionally, consistent structural policies can modify the social and cultural bases of populations with prevalence of food insecurity (Magalhães, 2014).

Food insecurity, due to its correlation with people's income, affects the poor population more intensely. Consequently, poverty causes food insecurity, hunger and malnutrition, leading to poor physical and cognitive development, which may result in low productivity that perpetuates poverty (FAO, 2008).

Whereas policy interventions are needed to face poverty and food scarcity (Just and Gabrielyan, 2016; Pérez-Escamilla, 2012), good governance is essential to meet global demand related to food security without compromising sustainable development (Lele et al., 2013; Pérez-Escamilla, 2012; Iglesias and Garrote, 2015). Effective governance should rely on strong and stable institutions, policy integration and coordination, but also on good governance criteria (Pérez- Escamilla et al., 2017) and contribution of civil society to food security governance in terms of design, implementation and monitoring of effective policies is essential in this process (Kepple and Segall-Correa, 2017).

Food security is an important component of the 17 Sustainable Development Goals (SDG), implicitly addressed through its major scope aiming to eradicate poverty, a major challenge for food security and sustainable development and directly addressed in the SDG goal 2 ("Zero Hunger") which calls for the elimination of hunger by 2030. This goal has also a specific target addressing smallholders, in terms of aiming to increase the agricultural productivity and income through secure and equal access to land and other resources (UN, 2015).

The other SDG indirectly addresses food security issues by concentrating on socio-economic factors influencing it around the world: health and well-being, education, gender equality, resource availability, employment, sustainable consumption and production, land degradation etc. In this respect, in line with the SDG targets, it is recognized that creating links between the social and agricultural policies is crucial to eradicate the hunger in the world (Pierri et al., 2015).

Global food security is a major challenge that should be addressed regionally (Belesky, 2014). To increase food security locally and nationally, food production should be handled by

smaller and more localized production instead of larger producers, contributing to lower food prices and more local development (Chaifetz and Jagger, 2014; Thornton and Herrero, 2014; Belesky, 2014).

Despite the significant decrease in the number of poor people living in the rural areas their numbers are still higher than in the urban areas. Aiming to reduce poverty in rural areas and to increase food security, public policies need to support small farms by increasing their access to technologies and financial resources (Larson et al., 2016; Devereux, 2016). In this regard, raising household income can be achieved by supporting farmers, and stabilizing incomes can be achieved by reducing seasonal stress and reducing risks by supporting farmers against natural and manmade disruptions in production (Devereux, 2016; Tirivayi et al., 2016).

Social protection and smallholder agricultural interventions often cover the same geographic area and the same householders, making it important to notice that policies to influence one of them usually affects the other, which justifies implementing correlated strategies to both issues (Tirivayi et al., 2016; Nehring et al., 2016). Family farms represent most of the farm systems globally and their sizes vary from 1 há to 10,000 ha (van Vliet et al., 2015), while in Brazil the size of family farms cannot exceed "four fiscal modules" due to state regulations (Brazil, 2006b). The size of a fiscal module in Brazil can vary from 0.5 ha in Southern Brazil to 100 ha in the North (van Vliet et al., 2015), but in average the size of family farms in Brazil is 18 ha (Brazil, 2006a).

Smallholder agriculture, complementary to large-scale farming, is essential to global food security, especially in developing countries, creating more jobs in rural areas and increasing families' income (Tscharntke et al., 2012; Nehring et al., 2016; Larson et al., 2016). Due to the great amount of food produced by large-scale farming, large farmers have more resources to invest in equipment, techniques and technologies, using less human capital, therefore contracting less employees; whereas small farmers employ, proportionally, more people, in more concentrated spaces, contributing to regional development, poverty alleviation and local food security (Shete and Rutten, 2015; Otsuka et al., 2016; Larson et al., 2016; van Vliet et al., 2015).

One of the greatest threats to family farmers and smallholders is the lack of access to resources, which reduces their possibilities to invest in technologies and other mechanisms to enhance their production, productivity and resilience (FAO, 2016b; Tirivayi et al., 2016; Nehring et al., 2016). Hence, stabilizing families' income and food prices is essential to maintain consistent food security, and it can be achieved by increasing insurance to producers, by guaranteeing employment creation, by financial aid to poor people, by food aid (i.e. in extreme cases), and by price interventions and food supply management (Devereux, 2016; Tirivayi et al., 2016; Nehring et al., 2016).

Family farms are recognized as being essential to food security, around the world counting more than 500 million, representing more than 90 percent of the world's farms, and most of the world's food being produced by them (FAO, 2014b). The efficiency of family farming is widely recognized (Bosc et al., 2013), and it achieves high productions levels in using familiar workforce in diversified production systems (FAO, 2014b). Smallholders also represent the population most food insecure and vulnerable to socio-economic and environmental change (HLPE, 2013).

To enhance the quality of life of family farmers, it is necessary to invest in technologies and innovations to improve and increase food production, by implementing more resilient seeds and efficient irrigation methods, biofertilizers, and other technologies and methods, like soil and water conservation techniques (Bizimana and Richardson, 2019). This new approaches can enhance economic growth and poverty alleviation, which results in both socioeconomic and environmental benefits (Poulton et al., 2010), but also helps to design context-specific assistance programs that considers the diversity of small farms situation in each country and region.

To assure food security in this risky scenario, it is fundamental that food sustainably grows. Godfray et al. (2010) explains this healthy growth as a process of "producing more food from the same area of land while reducing the environmental impacts", whose result would be adopting sustainable practices and technological innovation (Kassie et al., 2013; Asfaw et al., 2012). Introducing these practices would doubtlessly represent an important win-win strategy, with wide potential to improve not only food security but also environmental problems, specially to poorer countries (Zeweld et al., 2017).

An additional threat and a major challenge to food security nowadays is represented by climate change, specific mitigation and adaptation actions being needed from the farm to the national level (Campbell et al., 2016), which in an utter way provokes involuntary migrations due to more frequent and intense droughts, desertification, and floods (Berchin et al., 2017; Faria et al., 2016).

Therefore, the aim of this study is to analyze the Brazilian public policies in terms of how they contribute to increase food security and family farming, how they are correlated, and which are the major gaps and challenges for the future, as the basis for further steps to be done to increase the security of this vulnerable population as well as the food security governance.

2. Methods

This study is based on a literature review on the relations among public policies, family farming and food security. In this respect, scientific publications and official reports from agricultural organizations, public legislation, national and regional reports published in national language have been used for documentation.

Even though several studies have attempted to analyze the relations between social protection and smallholder agriculture for reducing poverty and hunger, consequently increasing food security (e.g. Tirivayi et al., 2016; Devereux, 2016; Nehring et al., 2016), little effort has been made however to demonstrate the relationship between social protection, smallholder agriculture and food security in Brazil, a gap where this study aims to offer a contribution.

This paper does not address all the existing Brazilian policies; however, it does attempt to present the main policies and programs regarding food security and family farming; aiming to understand how Brazilian public policies contribute to the strengthening of family farming and to increase food security. The information found in these documents have been supplemented with statistical data collected from national reports and indexes used to analyze

how Brazilian policy interventions regarding social protection and family farming contributed to enhance food security in the country.

Table 1
Main categories of policies stipulations to ensure food security.

Categories	Discussion	Authors
Financial aid	Financial aid policies aim at guaranteeing financial transfers to complement extremely poor families' income, reducing poverty and increasing food security.	UN, 2016a; Devereux, 2016; Larder et al., 2015; Dimitri et al., 2015; von Braun, 2008.
Food aid	Food aid policies aim at supporting poor families living in food insecurity, also improving the quality and quantity of food consumed (e.g. by transferring basic food baskets to poor people and creating food banks).	UN, 2016b; Wilkinson, 2015; Clark et al., 2015; Broussard et al., 2014; Lentz and Barrett, 2013; Ninno et al., 2007.
Technical support	Technical support policies aim to guarantee investments (also appealing to international cooperation) in rural infrastructure, technological development and researches to increase crop productivity. They also provide farmers with mechanisms to produce food in a competitive manner.	UN, 2016b; Vermeulen et al., 2013; Tilman et al., 2011; Lynch, et al., 2000; Gudgeon, 2000; Carvalho, 2006; Rennings, 2000; Welch and Graham, 1999; Foster and Rosenzweig, 1995.
Capacity Building	Capacity building policies aim at training and allowing farmers to produce effectively and through sustainable practices, increasing their productivity and food security.	UN, 2016c; Terry, 2014; Klerkx et al., 2009; Pratley, 2008; Ayele and Wield, 2005; Raynolds et al., 2004; Folke et al., 2002; Collion and Rondot, 2001; Foster and Rosenzweig, 1995.
Land tenure management/food production	Land tenure management and food production policies aim to guarantee sustainable farming practices by supporting practices to increase agricultural productivity while conserving and improving soil quality. Also, they enforce a fair production system, by registering all producers and promoting agrarian reforms.	UN, 2016b; Holden and Ghebru, 2016; Clark et al., 2015; Garnett et al., 2013; Gebbers and Adamchuk, 2010; Godfray et al., 2010; Jakobsen et al., 2007; Sanchez, 2000; Maxwell and Wiebe, 1999.

Identify, categorize and monitor	Policies to identify, categorize and monitor are important to develop databases and increase the efficiency when developing and implementing plans regarding food and nutrition security, poverty alleviation, land use and climate change, for example.	FAO, 2016a; Fritz et al., 2015; Carletto et al., 2015; Brosnan and Sun, 2004; Homewood et al., 2001; Dramstad et al., 2001; Lynch et al., 2000.

Considering that the governmental documents, publications and legislations presented the values in national currency, to convert Brazilian reais to US dollars, we considered the conversion rate as: 1 BRL = 0.30481 USD (Table 2).

To better organize the content of this paper, six categories of policies identified in the scientific literature (Table 1) were used in order to analyse the Brazilian policies for the aims of this paper (Tables 3A–3F). It is important to outline that the selected policies do not incorporate all the existing policies in Brazil, however they are representative of the actions and strategies developed by the government to reduce extreme poverty and increase food security through development and income raising.

Some of these policies are correlated and interlinked with others, adopting similar strategies and, sometimes, using the same funding; however, they are still not unified in one single comprehensive policy, fact that would facilitate its implementation and the measurement of its development.

3. Brazil's framework in terms of food security

In Brazil, family farming is extremely important for agricultural production. A corroboration of this assertion is that family farming corresponds to 84.4% (4.4 million farms) of rural unities in the country, offering 74.4% (12.3 million people) of labor in rural areas and filling about 24.3% (80.10 million ha) of the total area of Brazilian agricultural unities, demonstrating the high productivity of family farming in Brazil, especially in the southern region (IBGE, 2006; Brazil, 2016e).

Historically, family farming has been a part of Brazilian fields from early days (Delgado, 2004), which made the country a major force in polyculture, instead of monoculture. Therefore, small polyculture forms provide food and jobs for rural Brazilian population (Welch et al., 2009). The technological and economic development and the modernization in the 20th Century resulted in land and income concentration, has increased rural exodus and created several environmental problems, which made family farming very vulnerable. This situation worsened with the economic crisis the country faced in the 1980s with high inflations, and in the 1990s when regional integration, privatizations and economical liberations became a reality (Graziano da Silva, 2003; Teixeira, 2005; Bianchini, 2015).

Only in the end of the military government, in the 1980s, social organizations have emerged and drove movements towards agrarian reform and rural interests, which resulted in several political actions which brought more equality, rights and better life conditions for those

who depend on agricultural activities (Ghinoi et al., 2018). Nowadays, data given by the Central Bank of Brazil (2018) point towards reducing, decreasing in the number of contracts and in the value of subsidies paid by government in programs as Pronaf between 2014 and 2017. Then, changes in public policy and in structures become clear, since programs were reformulated, revised or blocked (Niederle et al., 2017). Brazilian agriculture is facing several challenges in political, social, economic and environmental aspects.

Regarding environmental problems, it is known that productivity and agricultural production may decline substantially with climate change (Phillips et al., 2009; FAO, 2014a), affecting rural areas and demanding producers to change their production practices in an attempt to adapt to these changes (Mendelsohn and Dinar, 2003; Mendelsohn and Williams, 2004); thus, compromising the viability of agricultural practices in the affected areas, especially in the northeast Brazil due to extreme droughts, but also impacting in the southern region with increasing rain.

Therefore, the challenges and threats imposed by climate and environmental changes (e.g. droughts, floods, desertification) on agricultural practices urge for more actions for adaptation and mitigation, increasing crop resilience (Howden et al., 2007). This particularly affects vulnerable/poorer producers, usually family farmers who rely mostly on their production for subsistence, due to damages in the farms' crops, equipment and infrastructure, and the lack of resources faced by those producers (HLPE, 2013).

3.1 An effort towards enhancing food security and poverty alleviation in Brazil through family farming

For the past five decades, agriculture has been fundamental to Brazilian economy, representing a large share of agricultural productio globally (FAO, 2018; Borba et al., 2018). Since the 1980s, Brazil became one of the largest agricultural exporting country in the world, by leading global exports of sugarcane, coffee, and orange juice, whilst being the second largest producer of soybeans, beef and chicken meat (Picoli et al., 2018). Between January and November 2018, Brazilian exportation of agricultural products summed up to US$219,967.2 million (Brazil, 2018) and Brazil also made 1.2% of the global international trade share in 2017 (WTO, 2017). The rapid increase of agricultural production in Brazil is due to the creation of the National System of Rural Credit (SNCR) in 1965, which pushed the modernization and transformation of the production methods and technologies (Leite, 2001).

Table 2

Main national policies focused on enhancing food security in Brazil.

Policy/Program/Plan	Aims	Results	Year
National School Feeding Program	To contribute to the growth and biopsychosocial development, learning, and the formation of healthy eating habits of students, through food and nutrition education and the provision of meals to cover	Served 41.5 million students, with an investment of 2.35 billion USD in 2015 - in 2009 it was established that at least 30% of funds must be used to purchase food from family farms.	1955

	their nutritional needs during the school period.		
National Program for Strengthening Family Farming	To finance individual or collective projects, which generates income for family farmers and land reform settlers.	7.35 billion USD invested in 2015.	1995
National Policy on Food and Nutrition	To respect, protect, promote and provide human rights through health and food.	Although there is little data about the results of the policy, it acts through the Unified System of Public Health, with other policies	1999
Zero Hunger program	To guarantee that all people have daily access to food in suficiente quantity and quality to meet their basic nutritional needs	Between 2001 and 2014, poverty fell from 24.3% of the population to 7.3% while extreme poverty felt from 14% to 2.8%	2003
Bolsa Familia Program	To combat poverty and inequality in Brazil	24% of the Brazilian population (42 million people) is benefited by the program, with an investment of 701million USD in 2015.	2003
Single Registry for Social Programs of the Federal Government	To identify, categorize and provide knowledge about low income families in Brazil	27 million families registered in 2015- nearly 81 million people – under more than 20 programs	2003
Program for Food Purchase from Family farming	To encourage family farming, including the distribution of agricultural products to food insecure people, and supporting the creation of strategic stocks.	In 2015, it involved 78 thousand farmers and 10 thousand entities, through 13 million appointments and 142.96 million USD	2003
National Program for Land Credit	To promote development and combat rural poverty.	Since 2003 more than 100 thousand families were benefited by the program	2003
National System on Food and Nutritional Security	To guarantee Brazilians the right to adequate nutrition.	Defined definitions, principles, guidelines and goals towards food and nutrition security governance.	2006
National Policy on Family farming and Rural Family Enterprises	To establish the concepts, principles and tools for the formulation of public policies focused on Family Farming and Rural Family Enterprises, which are grounded in sustainability, equity and inclusion.	Definitions, principles, guidelines and goals towards family farming	2006
National Policy on Food and Nutritional Security	To promote food and nutrition security and ensure the human right to adequate food nationwide.	No empirical results available.	2010
National Plan on Food and Nutritional Security	To promote food and nutrition security and ensure the human right to adequate food nationwide.	101.81billion USD allocated to the plan since 2012	2011

Bolsa Verde Program	To encourage the conservation of ecosystems and raise the income of populations living in extreme poverty	18.5 thousand Families benefited by the program, with 26.67million USD in 2015.	2011
National Plan on Climate Change Adaptation	To increase national resilience to climate change, reducing the risks associated with it, including food security.	Still has no empirical results available.	2016

Dynamic policies related to the "agricultural support package" are essential specially in Brazil (Ghinoi et al., 2018). In the 1960s and 1970s, big landmarks for Brazilian agriculture happened after large state actions which led to agricultural modernization and capitalization of the field, as well as policies with five main focuses: National System of Rural Credit (SNCR), Policy of Assurance of Minimal Prices (PGPM), Brazilian Company of Technical Assist and Rural Extension (EMBRATER), Brazilian Company of Farming Research (EMBRAPA) and the Program of Assurance of Farming Activities (PROAGRO). As a result of these policies, there is an increase in production, economic development and the dependence on imports has decreased (Grisa, 2010). This brought family farmers debt and unemployment, increased agricultural and rural exodus, losses of land and environmental degradation. To meet family farmers' demands and shrink the negative impacts they felt, several specific programs were created to regions in the 1980s, as the Program of Support to Small Rural Producer (PAPP) (Grisa, 2010).

Table 3A

Brazilian policies regarding financial aid.

Policy/Program/Plan	Aims related to financial aid
National School Feeding Program	Provides financial resources from the National Government to the implementing entities (states and municipalities). These entities are responsible to operate and execute the Program, guaranteeing food supply to students regularly enrolled in the public system of basic education.
National Program for Strengthening Family Farming	Finances projects aiming at increasing the income of family farmers and agrarian reform settlers. The program has the lowest interest rates on rural finance.
National Policy on Food and Nutrition	Promotes direct transfers of income to families living in poverty or extreme poverty.
Zero Hunger program	Promotes financial transfer to people living in extreme poverty, to complement their income, reducing injustices and increasing their capacity to buy food.
Bolsa Família Program	Promotes direct transfers of income to families living in poverty or extreme poverty. The financial transfers to the families occur when they accomplish some requirements, such as health, education, and social assistance.
Program for Food Purchase from Family farming	Purchases food produced by family farming and delivers it to people living under food and nutrition insecurity and to people under social care programs.
National Program for Land Credit	Finances and gives special financing conditions to rural workers with no land or with small unities, to buy rural unities. The program allows the farmers to finance their houses, crop production, machineries, and goods and also receive training.

National Policy on Food and Nutritional Security	Promotes universal access to food in sufficient quality and quantity.
National Plan on Food and Nutritional Security	Promotes universal access to health and nutritious food, especially to people living in food and nutrition insecurity.
Bolsa Verde Program	Transfers income to families living under extreme poverty in environmental conservation areas. The program gives 300 reais each three month.
National Plan on Climate Change Adaptation	Funds initiatives aimed at increasing resilience to climate change in vulnerable populations (e.g. those families registered in the Single Registry for Social Programs of the Federal Government).

Table 3B

Brazilian policies regarding food aid.

Policy/Program/Plan	Aims related to food aid
National School Feeding Program	Provides food to students regularly enrolled in the public system of basic education.
National Policy on Food and Nutrition	Promotes the reinforcement of healthy and nutritious food to vulnerable populations and to those living with fragile health situations.
Zero Hunger program	Gives basic food baskets to vulnerable people (e.g. those living under extreme poverty and food insecurity and those affected by extreme natural events). The project also stimulates the creation of food stocks to increase food security, preferably using food produced locally.
Program for Food Purchase from Family farming	Purchases food from family farming and allocate it to people living in food and nutrition insecurity, also stimulating the creation of public food stocks with food produced by family farming.
National Policy on Food and Nutritional Security	Promotes the universal access to healthy and nutritious food.
National Plan on Food and Nutritional Security	Promotes the universal access to healthy and nutritious food, particularly to families living in food and nutrition insecurity.

Only in the 1990s, public nationwide policies were develop exclusively to deal with family farmers (Schneider et al., 2004), as National Program for Strengthening Family Farming (PRONAF), Family Farming Insurance (SEAF), Program of Assurance of Prices in Family Farming (PFPAF) and Harvest Assurance Program (Grisa and Wesz Junior, 2010), which have transformed the agricultural situation in Brazil and improved life and work conditions for those who depended on agriculture.

In 2003, the Federal Government's Single Registry of Social Programs was created to identify, categorize and provide information on low-income families in Brazil. The single registry defines low-income families as those with monthly family income per capita of up to a half to minimum wage (Brazil, 2007) - that is, in 2003 the minimum wage was 73.15 USD (Brazil, 2003); in 2016 it was 268.23 USD (Brazil, 2015b).

In 2004, the adoption of the Brazilian Food Security Scale in regional and national surveys enabled the government to identify and measure the number of people living in poverty and food insecure conditions, contributing to the development of policies that resulted in the decrease of hunger, especially in the poorest regions of the country (Pérez-Escamilla, 2012). The identification of 44 million people living in extreme poverty in Brazil (living with less than 1 dollar per day), most of them from rural areas, stimulated the Brazilian government to develop

and implement the Zero Hunger program, aiming to guarantee that all people have daily access to food in sufficient quantity and quality to meet their basic nutritional needs (FAO, 2010).

In an analysis of the Zero Hunger Program, it is understood that in the Brazilian scenario, there is not only unavailability of food in some regions, but in some places, people are incapable of buying food due to poverty. For this reason, the program is organized into three categories: structural policies, aiming to reduce families' food vulnerability; specific policies, aiming to promote food security and fight hunger and malnutrition; and local policies (FAO, 2010). The Zero Hunger program adopts and supports several other national programs, policies and plans to enhance food security and eradicate poverty, based on four main strategies: access to food, raising income, supporting family farming, and social care.

Also, with the aim to combat poverty and inequality in Brazil, the *Bolsa Familia* Program was created in 2003. The program operates in three main areas: financial aid, to complement families' income; families that benefit from the program might attend to some obligations to end poverty in the long term, related to education, health and social assistance; and the articulation with other policies and programs to increase the national efficacy in ending poverty (Brazil, 2004). The program defines extreme poverty as a situation where a family's monthly income is 21.34 USD or lower.

Supported by governmental programs, the income of family farming increased by 33% in the 2003–2009 period (Silva et al., 2010). One of the incentives is the National Program for Strengthening Family Farming (PRONAF), established in 1995, that offers credit lines and tax benefits to family farmers (Grisa, 2010; Petrini et al., 2016). PRONAF is a program potentially complementary to *Bolsa Família*, particularly in its line of financing directed to family farmers within group B. This group coincides with the families assisted by the *Bolsa Família* and offers lines of credit for investment and finance the agricultural, livestock production, and of non-agricultural rural activities, such as handicrafts and tourism.

PRONAF attempts to promote the development of the rural environment in the Brazilian territory based on actions aimed at increasing productive capacity, maintaining and generating jobs, and increasing income through the provision of flexible financing lines. Accordingly, it is intended to improve the quality of life and to provide complete access to citizenship rights to family farmers (Souza et al., 2011).

Table 3C

Brazilian policies regarding technical support.

Policy/Program/Plan	Aims related to technical support
National School Feeding Program	Promotes healthy and nutritious food habits by using nutritionists to prepare school menus.
National Policy on Food and Nutrition	Supports states and municipalities to promote healthy food and nutrition habits to the population. The program encourages the promotion of awareness regarding food habits, obesity, and malnutrition, also supporting vulnerable people.
National Program for Strengthening Family Farming	Promotes technical support to people aiming to apply for financing,
National Plan on Food and Nutritional Security	Promotes the sustainable and healthy food production, structures family farming and supports

	agroecological production systems. The program also aims at increasing water availability to people, particularly in rural areas.
National Program for Land Credit	Supports the infrastructure's structure needed for food production and technical support.
National Plan on Climate Change Adaptation	Gives technical assistance to states and municipalities to develop their climate change adaptation plans and reduce people's vulnerability.

Table 3D

Brazilian policies regarding capacity building.

Policy/Program/Plan	Aims related to capacity building
National School Feeding Program	Promotes healthy and nutritious food habits by using nutritionists to prepare school menus.
National Policy on Food and Nutrition	Supports states and municipalities to promote healthy food and nutrition habits to the population. The program encourages the promotion of awareness regarding food habits, obesity and malnutrition, also supporting vulnerable people.
National Plan on Food and Nutritional Security	Promotes the sustainable and healthy food production, structuring family farming and supporting agroecological production systems.
Zero Hunger program	Encourages quality education at all levels, particularly in basic and fundamental levels, transferring income to families with children in scholar years. The program also promotes advertising campaigns and lectures about food education and education for consumption.
Bolsa Familia Program	Emphasizes the importance of education, and has education as a condition for the families to receive financial support.
National Policy on Food and Nutritional Security	Promotes the implementation of the process of education, capacity building and research development focusing on the human right to adequate and healthy food and food and nutrition security.
National Plan on Food and Nutritional Security	Encourages the healthy and sustainable production of food. The program also promotes food and nutrition education.
Bolsa Verde Program	Capacitates the population to produce food according to agroecology principles.
National Plan on Climate Change Adaptation	Develops platforms (including online platforms) to share and disseminate knowledge about climate change adaptation. Informs the public sector (states and municipalities) and the society (including vulnerable groups of the society) about climate change, though awareness raising and training.

In 2015 the resources available for PRONAF were equivalent to 7.35 billion USD, 14.7% higher than the equivalent harvest in the 2013/ 2014 period due to the 2014/2015 Harvest Plan, which "further stimulates the production of food, aims at producer income security and stability of consumer prices" (Brazil, 2015a). In addition, Family Farming Financial Insurance guarantees the protection of production through a multi-risk insurance that "covers losses caused by weather, pests and diseases without known control" (Brazil, 2015a).

Regarding sustainable and inclusive production systems, Brazilian policies support sustainability and family farming; “of the total funds transferred by the National Fund for Education Development under the National School Feeding Program, at least 30% should be used in the purchase of food directly from family farms and rural family entrepreneur or their organizations” (Brazil, 2009).

In this regard, Tirivayi et al. (2016) and Afridi (2010) argue that programs to increase child nutrition, through feeding programs at school, are essential to put children as the focus of welfare programs, reducing hunger and enhancing food and nutrition security. In addition, smallholder farmers participating in the programs will benefit by increasing their market access and income (Lentz and Upton, 2016). Thus, the National School Feeding Program could be more effective by integrating the concept of school gardens managed by families or cooperatives of producers, using idle areas into productive ones, increasing local food production and availability, while increasing students’ knowledge, awareness and learning (Belik and Souza, 2009).

Together with the Program for Food Purchase from Family farming (PAA) and the 2015 National School Feeding Program, purchases from family farming totaled nearly 457 million USD (Brazil, 2016e). The PAA encourages food production by ensuring the purchase of family farmers' production and stimulating the diversification of cultivated products and acts as a strategy to increase the family income of farmers who have approved their projects by providing people with food and nutritional insecurity the possibility of buying family agricultural products. The credit limits are about 1463 USD per year per family farm (Brazilian Ministry of Agrarian Development, 2012).

As another strategy to enhance food and nutrition security through food aid, there are currently 81 Food Banks, 1444 Distribution Units from family farming, 101 Popular Restaurants, and 164 Community Kitchen, operating as tools for the National Secretariat for Food Security and Nutrition (Brazil, 2016d). Complementarily, the National Policy on Food and Nutrition aims at improving the conditions of food, nutrition and health of the population by promoting appropriate and healthy eating practices, food and nutrition surveillance, and prevention and comprehensive care of health problems related to food and nutrition (Brazilian Ministry of Health, 2013).

Through a land tenure perspective, the National Program for Land Credit aims to facilitate access to land and increase rural workers’ income by financing rural unities for food production, benefiting smallholder and subsistence agriculture (Brazilian Ministry of Agrarian Development, 2013). Land administration by governments is an essential tool to increase food security, promote local development, and reduce poverty and conflicts over land (Rockson et al., 2013).

To financially compensate environmental services provided by farmers, including preservation and forest recovery, the Bolsa Verde program aims to: encourage the conservation of ecosystems; raise the income of the population living in extreme poverty exercising natural resource conservation activities in rural areas; and involve the beneficiaries in environmental training and capacity building (Brazil, 2016b).

Table 3E

Brazilian policies regarding land tenure management/food production.

Policy/Program/Plan	Aims related to land tenure management/food production
National School Feeding Program	States that at least 30% of the total budget transferred by the program must be invested in purchasing goods from family farming.
National Program for Strengthening Family Farming	Finances projects aiming to create and/or increase family farmers and agrarian reform settlers' income.
Zero Hunger Program	Defends a massive process of land distribution as a structural development policy, aimed at redistribution of income, expansion of sources of income for families, food production for self consumption, and promotion of regional economies. The project also supports family farming as a strategy to increase food production and raise families' income.
Program for Food Purchase from Family farming	Purchases food produced by family farming and distributes it to food and nutrition insecure people.
National Program for Land Credit	Finances and gives special financing conditions to rural workers with no land or with small unities, to buy rural unities. The program allows the farmers to finance their houses, crop production, machineries, and goods and also receive training.
National Policy on Food and Nutritional Security	Promotes fair production systems based on agroecology and sustainability, from production to processing and food delivery.
National Plan on Food and Nutritional Security	Promotes food security in rural areas by supporting food production, especially promoting productive inclusion of vulnerable people.
Bolsa Verde Program	Supports people living in environmental conservation areas to use the land in sustainable ways.

Table 3F

Brazilian policies regarding identify, categorize and monitor.

Policy/Program/Plan	Aims related to identify, categorize and monitor
National Policy on Food and Nutrition	Promotes the continuing evaluation of food and nutrition habits of people.
Bolsa Familia Program	Identifies the profile of families registered in the Single Registry for Social Programs, regarding health and education.
Zero Hunger Program	Identifies and monitors extreme poverty and food insecurity.
Single Registry for Social Programs of the Federal Government	Identifies, monitors and generates information about low-income families.
National Policy on Food and Nutritional Security	Identifies and disseminates the factors determining food and nutrition insecurity, and monitors food and nutrition security and the right to adequate food.
National Plan on Food and Nutritional Security	Identifies and monitors extreme poverty and hunger; and analyzes the climatic risk of target populations of the Single Registry for Social Programs.

The *Bolsa Verde* program consists of a 91.44 USD financial aid from the Brazilian federal government directed toward families in extreme poverty living in environmental conservation areas (Brazil, 2016b). In 2015, the program covered more than 980 rural unities, assisting 71,759 families with nearly 26.67 million USD (Brazil, 2016d).

Considering the predicted loss of about 2.26 billion USD by 2020 from the agricultural sector due to the economic effects of climate change in Brazil, which shall lead to food insecurity, especially in lowincome families, the Agricultural Policy of the Ministry of Agriculture was created to support farmers, focusing on production, financing and insurance planning, divided into: risk management in rural areas, credit, and marketing (Brazil, 2016c).

Among the effects of climate change on tropical regions and for the agricultural sector (Porter et al., 2014) are increases in average temperature and the intensity and frequency of extreme weather events (IPCC, 2014), changes in the land use and land cover (The World Bank, 2012; PBMC, 2014a,b), changes and impacts on ecosystem services (La Notte et al., 2017) and loss of ground water storage capacity (Kustura et al., 2008). These trends of climate change have impacts on agriculture, which consequently affects the economy and social systems, since agriculture employs millions of people, providing food, income and other services (PBMC, 2014b; Camargo et al., 2017).

These policies contribute to the expansion of family participation in national production, increasing family income and rural development and ensuring the improvement of product quality, generating benefits for human health (through healthier products and financial aid to complement families' income) and the environment (though agroecological and sustainable practices). Table 1 summarizes the main food security policies previously presented.

These policies, active until nowadays, have brought large advances to ensure food security in the country, specially to more vulnerable populations, which started to enjoy better life conditions, preserving their dignity and human rights, since everyone have the right to be free from hunger and to have access to nutritional food in enough quantity and quality, therefore meeting food availability, stability, accessibility, sustainability and adequacy (FAO, 2014c). The right to food security also correlates to the human right to water, since it is a fundamental resource for nutrition, cooking, food production, hygiene and health; the right to property, related to the access to land and other resources necessary for food production and housing; the right to health, since the proper alimentation and nutrition impacts health; and the right to decente work, since it enables access to food (OHCHR, 2010; FAO, 2014c). Several of these policies to ensure food security and the right to food, were developed or expanded between 2003 and 2016.

In order to organize these policies, Tables 3A–3F illustrate how Brazilian policies are classified under the six categories identified in the literature (presented in Table 1).

Generally, programs presented in Table 3A focus on reaching people who live in poverty or extreme poverty, paying higher attention to rural and/or vulnerable areas, where health, education and social assistance are unsatisfactory. In this regard, initiatives, funds and transfers of income are put in action for financial help services to get into those who need.

Regarding food help, we conclude that six policies, programs or plans fit in this goal (see Table 3B). Those efforts are in direction of reaching to most vulnerable or insecure population, promoting safe and nutritive food.

For technical support, the government takes six actions, helping specially in preparing food, encouraging healthier and more sustainable eating habits (Table 3C).

To help related to capacitation, we perceived that nine actions are being taken, helping healthier food production, nutritional education, platform development to disseminate knowledge, among other actions (Table 3D).

To support management of land management and food production, eight actions are being taken, focusing in redistributing wealth and land, helping rural workers in small units to buy rural units with special financing conditions, promoting production systems that can be fair and sustainable (see Table 3E).

Regarding help in categorizing and monitoring, six actions exist, and they benefit mainly low-income families promoting the generation of valuable information for decision-making (see Table 3F).

The programs and policies presented in this paper have particular characteristics and point to agriculture and food security; however, some of them diverge and/or converge in their guidelines for implementation. For instance, some policies prioritize the support and engagement of the youth. The National School Feeding Program mostly focus on youth at all levels of basic education and high school, contributing to their development, growth, learning, and for the development of healthy alimentary habits through school meals, and nutrition and alimentary education (FNDE, 2017).

Thus, the National Program for Strengthening Family Farming also demonstrates a concern for the integration of the youth by creating the National Program for Strengthening Family Farming for Youth, which offers especial credit lines and lower tariffs and interest rates for the youth (mostly sons and daughters of farmers), also after the PRONAF investments in family farming in 2015/2016 all public calls for technical assistance and rural extension have a minimum of 25% of Young people among their beneficiaries (Brazil, 2017a, a).

The Zero Hunger program also emphasizes the importance of nutrition to the youth, putting them in the center of discussion in their structural programs - e.g. through the Program for the education of young people and adults in areas of agrarian reform (FAO, 2010). Additionally, National Program for Land Credit creates the opportunity for sons and daughters of farmers and/or students of agrotechnical schools to become beneficiaries of the program (Brazil, 2017b). Finally, the National Program for Land Credit straighten the participation of Young people in the program, based on an additional support of 914 US$ to develop specific projects of the program's interest (Brazil, 2017c).

Another common area of interest among the policies and programs is gender equality and women's rights; for example, the National Program for Strengthening Family Farming, the National Program for Land Credit, and the *Bolsa Familia* Program. PRONAF supports women farmers through its especial credit line and tariffs called PRONAF Women, which enables credits for construction, reforms and improvements in the farms' facilities (Brazil, 2010). The *Bolsa Familia* Program improve the autonomy and empower women benefited by the program, increasing their power of decision in their houses, and enabling the exercise of their citizenship

(UN, 2017). Thus, the National Program for Land Credit also contributes to empower women through an especial line of credits, the National Program for Land Credit for Women (Brazil, 2017c).

The National Policy on Family Farming and Rural Family Enterprises, the Bolsa Verde Program, the National Program for Strengthening Family Farming, and the National Program for Land Credit are examples of policies and programs to ensure credits and financing to promote development and to fight poverty in rural areas, also supporting the sustainable use and management of natural resources and lands where the producers are settled (Caixa, 2017; Brazil, 2006b, c; Brazil, 2017a).

Both the National Plan on Climate Change Adaptation and the Single Registry for Social Programs of the Federal Government are distinguished from the other policies due to their aim to produce, gather and disseminate information, knowledge and create forecasts to achieve their goals. Finally, in general, all policies and programs aim to promote human rights to food (food security), poverty reduction, health improvement, and inequalities reduction in the national territory.

4. Results and discussion

The literature review indicates that poverty is one of the main causes of food insecurity and poses a challenge to sustaining food supply and accessibility. According to FAO (2014a), Brazilian policies are key contributors to enhancing food and nutrition security in the country, promoting social progress, poverty alleviation, stimulating and supporting family farming, and improving access to health and education. These programs include the Zero Hunger program, the Brazilian National System on Food and Nutritional Security, the Brazilian National Policy on Food and Nutritional Security, the Brazilian National Plan on Food and Nutritional Security, supported by the inter-ministerial Chamber on Food and Nutrition Security and the Brazilian National Council for Food and Nutritional Security.

These policies and programs support food security in Brazil, resulting in poverty alleviation and access to food in enough quality and quantity. Beyond benefits gained in implementing state actions, we realize other fundamental factors for wealth growth, productivity and diversification is the rise in participation of family farmers in associations and cooperatives. One of Brazil's main strategies for enhancing food security is to support family farming, which contributes to increased access to food and generates extra income for families, promoting local development and financial independence to families. Although economic growth contributes to increasing family income and therefore food security, if poorly managed, can affect natural resources (e.g. increased deforestation, pollution and stress of water resources), triggering food insecurity (Ozturk, 2015). As a consequence of the impact these policies had and have in agricultural Brazilian sector, a vast literature discusses and analyses the subject (e.g. Gazolla and Schneider, 2013; Grisa et al., 2014; Leite, 2015; Garcias and Kassouf, 2016; Resende and Mafra, 2016).

However, progress in food security in Brazil occurs not only because of the adopted public policies, but also because of the increase in wages and salaries of workers, the increase of pensions, and economic growth (Hoffmann, 2006). According to Paes de Barros et al. (2007),

the reduction in poverty, especially extreme poverty, and consequent increase in food security, is a direct consequence of the concomitant reduction in income inequality. This reduction in poverty rates is illustrated in Table 4 (which was based on data from FAO, 2014a; and Brazil, 2016e).

Despite large farmers being responsible for most land use in Brazil, sustainable practices are more often observed in small unities devoted to family farming. Family farming is considered an important strategy in reducing social inequalities and poverty in many Brazilian regions and is responsible for the wide variety of agricultural products in the Brazilian domestic consumption market.

It receives government support to integrate families in a social and economic way, also increasing income in rural areas through sustainable practices, encouraging ecological production with practices that are less aggressive to the environment and the soil, promoting the conservation of ecosystems, agroforestry practices, and reducing deforestation. These practices strengthen food security and increase social inclusion, contributing to better practices in agriculture, preparing family farmers to produce more sustainably, also preparing them to adapt to the effects of climate change.

It is worth noting that domestic consumers and the international community, acting as stakeholders, are increasingly demanding agroindustry to adopt more sustainable practices, with less environmental impacts. In the context, government support programs are of paramount importance in supporting family farming, encouraging agroecological practices, and reducing the risks of climate change.

With the contribution of these government's programs and policies, food insecurity is unlikely to be an issue in Brazil in a long-term, due to the social protection created by them, but also through the support to increase families' resilience. Programs like the Bolsa Verde and Zero Hunger initiatives provided good results as well as an alternative path for the future of the country. The country can gather economic, social and environmental benefits through family farming:

- Socially, by pulling people from misery and engaging them in agriculture production.
- Economically, by offering these people subsidies through credit lines and therefore expanding employment in all rural areas, since it was already pointed out that family farming employs largely more than regular agriculture.
- Environmentally, by producing and planting using different Technologies that promote sustainability, therefore self-sustaining the production areas.

Considering the above-presented data and analysis, National Policy on Food and Nutrition Security, National Policy on Food and Nutrition and National System on Food and Nutrition Security, as well as other government new policies and services in the 21st century were fundamental for the reduction of food insecurity overall. Their implementation affected a great number of families and regions and the possibilities seem optimistic for the future. For those reasons, the budgets for all programs regarding family farming should be strongly increased, making family farming no longer an alternative farming choice, but instead the main one.

The attention on the topics of food insecurity and family farming must be addressed until these policies become a bigger part of the government's agenda, aiming at specific solutions to problems such as hunger, poverty and unsustainable agriculture, eventually including many more issues, like climate change, economic crises, land use and industrialized food supply chains. This political effort has been strongly supported by the civil society participation, Brazil being an example on how to coordinate this process, although more organization is needed to ensure a qualified and effective participation (Kepple and Segall-Correa, 2017). In this respect, institutionalized participation of civil society has been recognized as being a key factor in better formulated policies, family farmers being involved in the consultation process of the strategies elaborated by the state (Pierri et al., 2015).

Table 4
Reduction of poverty in Brazil based on FAO, 2014a; and Brazil, 2016e.

Extreme poverty		Poverty	
2001	2014	2001	2014
14% (nearly 24.8 million people in Brazil)	2.8% (nearly 5.7 million people in Brazil)	24.3 % (nearly 43 million people in Brazil)	7.3% (nearly 14.8 million people in Brazil)

There are some issues that could not be addressed by this study due to several reasons: the lack of formal information about the performance of the programs and policies, lacking transparency and data about the distribution of national resources and the lack of monitoring the progress of each action. Future studies should focus on the realities of each Brazilian region, generating more local data and observing local strategies to increase peoples' wellbeing, reducing poverty, enhancing food security and supporting smallholder production, also considering the influence of climate change on food security. Also, a stronger connection with agricultural stakeholders to identify their specific needs and concerns would offer a more accurate view on the contribution and implication of the public policies to food security.

5. Conclusion

Brazil has developed an integrated effort to reduce extreme poverty and increase food security both in terms of providing financial and food aid to the poor and by stimulating their development and social and economic inclusion by integrating agricultural production systems through family farming. Although there are still several challenges to be faced in order to implement the right to adequate food, there are concrete governmental actions designed to encourage agricultural production that observe the sustainability parameters in several aspects: environmental, cultural, social and economic. However, adherence and evaluation of these actions should be carried out in each social context separately in order to better understand the nature and complexity of the food and nutritional issue, and to advance in the design of new political strategies.

Government incentives to family farming can be considered a viable alternative to food production that guarantees food security, with greater respect for the environment. Support for family farming has several social benefits, many of which are indirectly related to food security,

such as better production conditions and higher quality of life due to poverty reduction, extra income generation, and financial Independence of families. Family farms also contribute to the adoption of less aggressive practices in the environment and the soil by using local inputs for production, such as manure.

Studies on food security issues mention that good governance, comprehensive and differentiated policies, increased wages and salaries of workers, and economic growth are key to reducing poverty and increasing food security nationally and integration of the policies is essential to address the complex issue of food security. In this respect, the Brazil experience is very useful and relevant, adopting a holistic view and strategy that aimed at integrating financial aid, food aid, technical support, capacity building, land management, food production, and tools to identify, categorize and monitor the policies and performance of programs.

The Brazilian effort towards reducing poverty and increasing food security was effectively implemented, resulting in the diminishing of national food insecurity and poverty. In this regard, the strategies developed and implemented in Brazil could be replicated and adapted to other developing countries, contributing to the enhancement of global food security. This could be the case for some regions in Africa in which family farming can be supported to increase local food production and raise income of poor families. In this context, women play a critical for the production.

This adaptation of the Brazilian framework in other regions would be beneficial, however to correlate the national efforts with those existing at the regional and local levels, as there are many territorial discrepancies and “one size fits all” approach is not the best option. The national policies should establish the major guidelines; however, adapted regional and local strategies, with civil society participation, are needed to meet the needs of larger groups.

Finally, as shown in the Brazilian case to increase national food security, other developing countries could build their national systems to enhance food security based on these major pillars: 1) Financial aid, to complement extreme poor families’ income; 2) Food aid, to support poor families living in hunger conditions, also improving the quality of consumed food; 3) Technical support/technological aid, to provide farmers with mechanisms to produce food in a competitive manner, also increasing their resilience; 4) Capacity Building, to educate producers towards sustainable practices and efficient production; 5) Land tenure management/food production, to enforce a fair production system, and register all producers; and 6) Identify, categorize and monitor, to contribute to global food security, through a development strategy, to promote social and economic inclusion though development, and to evaluate the performance and effects of these initiatives.

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CHAPTER 3 – ARTICLE 2

The nexus between water, energy, and food in the context of the global risks: An analysis of the interactions between food, water, and energy security

Environmental Impact Assessment Review

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Keywords: Water security; Energy security; Food security; Global risks; Water-energy-food Nexus; Sustainable development

Abstract

The purpose of this article is to analyze the interactions between water, energy, and food security, referenced in this study as the nexus between water, energy, and food, and the impacts of global risks using the World Economic Forum's, 2017 Global Risks Report as a guideline. In this analysis, the authors reveal that water, energy, and food are interdependent and essential resources demanding sustainable, integrated and inteligente management. These vital resources are susceptible to many global risks which are maximized by extreme weather events, mass involuntary human migrations, and other hazards that predominantly endanger the vulnerable communities of less developed countries. In conclusion, policies carried out by the international community, decision-makers, civil society, and the private sector, must align to target and mitigate global risks, specifically, water, energy and food security.

1 Introduction

The international community is tasked with solving a variety of complex and interrelated issues which disproportionately affect vulnerable nations most and include many challenges linked to management of water, energy, and food resources (Bazilian et al., 2011). If these problems are not effectively administered, human civilization could face major threats (Diamond, 2005). The world's population is expected to reach 8.5 billion people by 2030, rising to 9.7 billion in 2050 and to 11.2 billion in 2100 (UN, 2015). Thus, the increase in water, energy, and food demand, combined with population growth and economic development, has the potential to result in a shortage of resources

Aside from the challenges mentioned above, humanity faces several risks, acknowledged as “global risks” which have been deeply analyzed by the World Economic Forum (WEF) in its annual Global Risks Report. These risks not only affect people and

companies around the globe, but also have potential impacts on water, energy, and food security.

In this context, the nexus between water, energy, and food security emerges from a different perspective which aims to promote the understanding of the interconnections between the management of natural resources and the importance of ensuring universal rights such as water, energy, and food (WEF, 2011; OECD, 2014; Scott et al., 2015; Mohtar and Lawford, 2016; WEC, 2016).

The main objective of this article is to understand how the global risks impact the nexus between water, energy, and food. Through a systemic analysis of the global risks, this article examines the interdependencies and vulnerabilities among these resources; moreover, it facilitates the comprehension of today's chaotic reality, promoting the development of new adaptation strategies in academia, civil society, politics and other sectors. These actions may not only diminish threats but also stimulate the development of a more secure and sustainable world.

To adequately analyze the nexus between water, energy, and food and the threats they face concerning the Global Risks Report, this paper aims to demonstrate that these resources are: a) essential, b) vulnerable, c) interdependent and, d) demanding of sustainable management.

1.1 Water security

Ensuring permanent access to water is becoming increasingly difficult due to global transformations in today's economy, climate, and society (Hope et al., 2012). It is estimated that about 40% of the world's population will live under water-stressed conditions by the middle of the next century (OECD, 2013). Nowadays, less than 3% of the world's water is potable, and 2.5% of this freshwater is frozen (WBCSD, 2005; UN Water, 2013), creating a global scenario of vulnerability and insecurity.

According to the Global Water Partnership (GWP, 2010), water security is connected to integrated water resources management among all sectors (agriculture, energy, health…). Researchers from the Program on Water Governance (PoWG, p. 17, 2012) state that water security exists when there is “sustainable access on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health”. The UN Water (2013) states that water security is associated with sustainable accessibility and availability, moreover, is essential for responding to other development problems like malnutrition and child mortality.

According to the GWP (2014), sustainable water management will improve the quality of life around the world. However, considering the dynamic changes in the world's physical and economic conditions, such as population growth and modifications in climatological conditions, which demand continuous attention and water systems adaptations, water security will never be achieved entirely.

1.2 Energy security

In the early 20th century, studies related to energy security arose in the political realm due to demands for coal and oil for use by naval fleets and armies (Yergin, 1991). In 1970, as a result of the beginning of the oil crisis, many academic institutions initiated studies analyzing

the energy field (Hancock and Vivoda, 2014). In recent years, the term “energy security” has gained prominence as a consequence of terrorist threats, instability among oil-exporting countries, geopolitical conflicts, and demands to increased energy supply and boost economic growth (Yergin, 2006; Löschel et al., 2010; Cox, 2017).

The International Energy Agency (IEA, 2016) defines energy security as “the uninterrupted availability of energy sources at an affordable price”. According to IEA, energy security is composed of three main categories a) long-term energy security, which mainly concerns long-term investments planned to provide energy according to a country's economic development and sustainable environmental needs; b) short-term energy security, which focuses on the ability of the energy system to respond promptly to sudden changes in the balance of supply and demand; and c) lack of energy security, which is linked to its economic and social impacts, as a result of price volatility and noncompetitiveness.

Energy security is essential to support basic human needs and economic necessities (Kruyt et al., 2009) and represents a critical feature regarding systems planning in the environmental, technical, political and social realm (Augutis et al., 2017). However, energy security may be vulnerable to climate change and other global risks, increasing tensions around this resource.

1.3 Food security

The definition of food security has been widely discussed by the academic field (Godfray et al., 2010) due to its global significance and its social and economic impacts on the development of nations (Gentilini and Webb, 2008). The concept of food security encompasses a broad scope, allowing different interpretations of its definition (Maxwell and Smith, 1992).

The need to create a particular concept for the term arose in 1974 when the World Food Conference defined food security as the global availability of food supply resources to sustain the increasing demand for food and to recompense market prices (UN, 1975). The World Food Summit (1996) declared that “food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for na active and healthy life”. These definitions reinforce the multidimensionality of food security (accessibility, availability, stability, and utilization).

Food insecurity, on the other hand, occurs when people do not have social, physical and economic access to food (FAO, 2009). According to Gundersen and Ziliak (2015), this insecurity also significantly impacts public health, making it challenging to fight off chronic diseases, diabetes, asthma, and insomnia.

Many world leaders recognize the need to minimize the adverse consequences of food production on the environment. As a result, agricultural producers face greater competition for land, water, and energy (Godfray et al., 2010; Lal, 2010). This paired with population growth, which will increase demand for food by 60% by 2050, creates a complex and chaotic scenario (Alexandratos and Bruinsma, 2012) that demands global cooperation and exhaustive research regarding food security and adaptation strategies to promote environmental protection.

1.4 The Nexus between water, energy and food

The Integrated Water Resource Management (IWRM), formed in 1971, is a sustainable development process that aims to promote awareness concerning the issue of global water security through education, investigations, and the exchange of information between countries (Mohtar and Lawford, 2016). The establishment of the IWRM represents the acknowledgment of the interconnections between water, energy, and food. The IWRM recognizes water as a fundamental resource for social and economic development. At the Bonn 2011 Nexus Conference, the term "water, energy, and food security nexus" was popularized and diffused internationally, especially among academic, political, and business fields (OECD, 2014).

Water, energy, and food are inseparable resources (WWAP, 2014; Wolfe et al., 2016). Many regions face significant water, energy, and food security challenges (Miralles-Wilhelm, 2016; ESCWA, 2015). Understanding the relationship between these resources allows countries to establish effective sustainable development strategies and policies based on accurate and systemic data, avoiding and mitigating interconnected risks (IRENA, 2015).

The establishment of food, water, and energy security is a global challenge. Thus, as the demands for these resources rise, it is becoming increasingly necessary to fully understand the interdependencies between them. The adverse consequences of climate change, in addition to political, social and economic obstacles, intensify these difficulties, affecting the management, availability, allocation, and usage of resources (Miralles-Wilhelm, 2016).

Analyzing the nexus between water, energy, and food not only ensures a better understanding of these resources and their interconnections but also allows for the comprehension of their production and distribution systems. The importance of this study also arises from legal, social and economic matters, which share a deep connection with these resources. Hence, the profound and sensitive interactions between water, energy, and food, demand attention and awareness to the risks and unexpected consequences that faced by society (King and Carbajales-Dale, 2016).

The interdependencies concerning the nexus between water, energy, and food are the result of an extremely complex system. Thus, developing a viable solution that provides stability for these resources simultaneously is extremely challenging (Meadows, 2008).

As shortages in natural resources increase and economic and population growth rates rise, the significance of the nexus becomes evident. The demand for a profound examination regarding the interrelations between water, energy, and food is urgent (Hoff, 2011). It will not only stimulate sustainable objectives and stability between resource users, but will also facilitate the transition to a globally integrated ecosystem through encouraging strategic and integrated management (Mohtar and Lawford, 2016).

2. Methodology

First, a broad analysis of the 2017 WEF Global Risks Report was conducted. The Annual Global Risks Report (2017) focuses on the global risks impacting countries and large companies and assesses the risks to each type of security (water, energy, and food). This article seeks to study the direct interconnections between these risks.

According to Jackson (2000), a system represents more than the sum of its parts. This statement can be applied to nature as well since nature cannot be divided into isolated sections;

it requires connectivity between its components instead. Bider et al. (2011), analyzes that three concepts must be examined for a full-comprehension of systemic analysis: a) the interrelation: the way things are connected and their consequences; b) the perspectives: the form in which scenarios of different global visions are overseen; and c) the limits: prevention of a system that reaches everyone.

Finally, an analysis contemplating examples of each of the risks and its impacts on water, energy, and food security was conducted. This study, using scientific methodology, describes how extreme weather events, large-scale involuntary migrations, large-scale terrorist attacks, natural catastrophes and other risks impact water, energy, and food security.

3. The global risks

The global risks are linked to specific events which negatively impact security, health, environmental, economic or technological matters. According to Cutter et al. (2015), Engel and Strasser (1998), the global risks are connected to the globalization process and to society's individualization, which leads to instability and insecurity. According to the WEF (2014), the global risks are events that cause significant negative impacts to countries and industries over a 10-year period.

The global risks are “systemic risks”. This concept implies that when something impacts one portion of an interdependent system, there is a high probability that the entire system will be consequently affected since it is composed of interconnected parts (Kaufman and Scott, 2003).

The impact of global risks on water, energy, and food security is different for each of the sources. Among the 30 risks introduced by the 2017 Global Risks Report, 26 of them may impact water, and/or energy, and/or food security. Concerning these 26, only 9 risks manifest direct impacts on the nexus between water, energy, and food security simultaneously, as shown in Table 1. Cases and examples will support the explanation of how the global risks impact these securities.

Analysis of the global risks impacting food, water and energy security, shows that the geopolitical and environmental risks are the most threatening risks concerning the nexus. The demand for elaborating a more detailed reflection of how each risk impacts these resources is urgent. Below is a detailed analysis, describing how each global risk can impact the nexus between water, energy, and food.

3.1 Economic risk

Among the current economic risks, only failure of critical infrastructure impacts the nexus. The lack of investments in infrastructure affects key sectors, such as transportation, electricity, telephony, and sanitation. The degradation of these services disturbs economic and social development. The table below (Table 2) presents some potential impacts of economic risk on food, water, and energy security.

3.1.1 Failure/Shortfall of critical infrastructure

Failure/Shortfall of critical infrastructure impacts many regions globally. For example, in Africa food security has been deeply affected due to this matter. In order to address the continent's problem, it is crucial to understand the founding reason for this enormous vulnerability concerning food insecurity. First, food insecurity arises when: a) there is a shortage of food production due to weather events (droughts, flood etc.); b) when the food supply production is smaller than the population it reaches; and c) when these food prices are expensive due to high oil prices, transportation, and commodities market fluctuation. In order for countries to mitigate and adapt from these vulnerabilities, traditional living methods must be substituted by highly technological approaches and increasing infrastructure investments in rural areas, consequently rising food production (AfDB, 2012).

Failure or shortfall of critical infrastructure is probably the most significant risk concerning water security. The lack of investments towards adequate water infrastructures, especially in developing and underdeveloped countries, generates many adverse consequences, including discrepancies in basic services (Van Leuven, 2011; OECD, 2014a).

Failure or shortfall of critical infrastructures (lack of investment in energy, transportation, and communication) influences energy security by increasing fuel costs, raising the price of commodities, and causing potential debts for consumers. A failure of a major financial mechanism may intensify the energy crisis or ensure its persistence (O ECO, 2007; IPEA, 2015; WEF, 2016).

3.2 Environmental risks

Two of the five global risks listed on the 2017 Global Risks Report display direct connections to the nexus. The extreme weather events and the failure of climate-change mitigation and adaptation significantly threaten the nexus between water, energy, and food, as shown in the following table (Table 3).

3.2.1 Extreme weather events and failure of climate-change mitigation and adaptation

The extreme weather events consequences regarding food security are historically recognized. In 2011, a drought struck East Africa, triggering a regional food crisis, which affected 13 million people. In Somalia, more than a quarter of a million people died of starvation (WEF, 2016). In 2015, in the United States, the ten disasters and damages related to climate change issues exceeded over $ 1 billion each in expenses (NRDC, 2016).

Failure of climate-change mitigation and adaptation affects food security in a diverse range of ways. When governments and companies do not promote preventative and adaptive actions, companies are affected, lose protection, and the global community is negatively impacted (WEF, 2016).

In South America and Central America, projections predict several risks concerning water security triggered by extreme weather events. Because of the reduction of the Andean glaciers, a decrease in rainfall, and an increase in evapotranspiration in South and Central America's semi-arid regions, these semi-arid zones and the tropical Andes are becoming extremely susceptible to water shortages (IPCC, 2014).

These events directly impact energy security. The demand for energy is proportional to increases in temperature. In the United States, if temperatures increase to 1 °C, the demand for

energy will rise by 5–20% (for cooling environments) and demand for energy to heat will drop to 3–15% (CCSP, 2008; EPA, 2016). The increase in temperatures will limit our capacity of power generation and ability to reliably deliver electricity (EPA, 2016). Warmer weather reduces the efficiency of nuclear power plants due to an increased need for cold water to cool generators. Hence, warmer air and water reduces the ability of power plants to convert oil into electricity (U.S. Global Change Research Program, 2014).

Table 1
Main global risks impacting food security, water security and energy security.

	Risks	Water	Energy	Food
Economic	**Failure/shortfall of critical infrastructure**			
	Asset bubbles in a major economy			
	Deflation in a major economy			
	Failure of a major financial mechanism or institution			
	Severe energy price shock			
	Unmanageable inflation			
	Fiscal crises in key economies			
	High structural unemployment or underemployment			
Environmental	**Extreme weather events**			
	Failure of climate-change mitigation and adaptation			
	Major biodiversity loss and ecosystem colapse (terrestrial or marine)			
	Major natural disasters			
	Man-made environmental damage and disasters			
Geopolitical	**Failure of national governance**			
	Failure of regional or global governance			
	Interstate conflict with regional consequences			
	Large-scale terrorist attacks			
	State collapse or crisis			
Societal	**Failure of urban planning**			
	Rapid and massive spread of infectious diseases			
	Water crisis			
	Food crises			
	Large-scale involuntary migrations			
Technological	**Adverse consequences of technological advances**			
	Breakdown of critical information infrastructure and networks			
	Large scale cyberattacks			

Table 2
Economic risk.

	Water security	Energy security	Food security

Failure of critical infrastructure	Lack of investments in infrastructure, sanitation, and maintenance of water supply (Dickson et al., 2016; Hanjra and Qureshi, 2010; Grey and Sadoff, 2007).	Energy is both a determining and limiting fator for economic growth and development (Goldemberg, 2000; Kessides and Wade, 2011; Vosylius et al., 2013).	Infrastructure is crucial for food production and processing (Godfray et al., 2010; Hanjra and Qureshi, 2010; Shively and Thapa, 2017).

3.3 Geopolitical risks

Table 4 shows that of the six geopolitical risks mentioned in the 2017 Global Risks Report, four directly impact the nexus. Interstate conflicts and large-scale terrorist attacks threaten food, water, and energy security on a global level resulting potential failures regarding national, regional or global governance in the international community. These are delicate risks which could jeopardize society and thus demand global awareness.

3.3.1 Failure of national governance and failure of regional or global governance

According to Bakker et al. (2008), failure of global and regional governance regarding water management causes: a) decrease in consumer rights to essential services; b) lack of political rights; c) neglection of poor communities by a government focused on serving the elite; and d) economic hindrances which connect more impoverished families.

Failure of national, regional or global governance arises when problems related to famine and food insecurity occur. Sovereign governments are responsible for developing programs and policies that stimulate agricultural business and lead to food security (Paarlberg, 2002).

Some researchers believe that global and local energy governance is the most important part of energy security (Goldthau and Witte, 2009; Mckenzie, 2011), while others prefer to focus on the "deficiencies" of energy security (Florini and Sovacool, 2009, 2011). Failure of national governance, in this scope, could result in energy distribution instability, increased monopolies, market disruption, and price volatility (Karlsson, 2007; Goldthau, 2012).

3.3.2 Interstate conflict with regional consequences

Interstate conflicts significantly impact energy security by reshaping urban and rural areas, raising the likelihood of humanitarian crises, increasing countries vulnerabilities, affecting populations, industries, and the transportation sector (Cornelius and Story, 2008; USAID, 2010). "Resource wars", especially concerning the global oil industry, will transform future international dynamics. For example, Africa, a significant producer of oil, will be drastically affected by this conflict. Additionally, since oil extractions typically occur in regions secluded from hostile territories, resource wars will be more likely to occur in depopulated or marine areas (Colgan, 2013).

The connections between food insecurity and interstate conflicts are less prominent; however, these impacts occur on different levels caused by increasing food prices, forced migrations, the spread of diseases, social collapses and violence; thus, the outcomes of interstate conflicts trigger food insecurity, especially in the most vulnerable countries (WFP, 2011).

Toset et al., 2000 identifies that "the previous war in the Middle East was about oil, the next war will be about water". This statement represents a real concern to interstate conflicts

on water security which will certainly have regional consequences. Wars in some regions will occur more frequently due to disputes over water access; therefore, water supply will become a war instrument. Many countries with high population and economic growth will increase their demands for and reliance on water resources, potentially under another nation's control, generating conflicts and disagreements (Gleick, 1993).

3.3.3 Large-scale terrorist attacks

The concept of "agroterrorism" suggests the development of terrorista strategies focused on agriculture with the potential to endanger food security (Laqueur, 1999; WFP, 2011). Damaged infrastructures lead to contamination of water reservoirs through chemical or biological agents, interrupting fresh water supply, and threatening humankind, the environment and water security (Gleick, 2006; Copeland, 2010). Water has been used throughout history politically and militarily as a strategic resource; thus, when water demand increases, the value and vulnerability of water advances proportionally (Gleick, 2006).

Terrorist attacks on oil processing facilities, transportation, tanks and oil terminals (especially in the Middle East and the Pacific) may have several negative outcomes: millions of oil barrels could be destroyed; millions of barrels will not be able to be shipped by traditional routes; and countries, such as the United States, will demand increased production from other refineries and increase importation rates to compensate for gas shortages (Cohen et al., 2011). The attacks on Nigeria's oil facilities by the terrorist group MEND (Movement for the Emancipation of the Niger Delta) in 2007, for instance, caused about 61 million dollars losses per day, inducing massive disruptions in the oil supply industry (Giroux, 2010; Toft et al., 2010).

Table 3

Environmental risks.

	Water security	Energy security	Food security
Extreme weather events	Floods, landslides, heavy storms and earthquakes trigger environmental and socioeconomic consequences, affecting rivers and increasing the probability of the spread of infectious diseases due to the degradation of sanitary conditions which obstructs water accessibility for the population (Mata-Lima et al., 2013).	Storms, landslides, floods, and forest fires, for instance, could affect the production and distribution of energy globally (IEA, 2015).	Intensification of extreme weather events (IPCC, 2001, 2007) can negatively impact the food supply and food security of vulnerable regions (Schmidhuber and Tubiello, 2007).
Failure of climatechange mitigation and adaptation	Failure of climate change mitigation and adaptation will affect river flows and cause sealevels to rise, impacting all people and all sectors related to water, such as the energy and agriculture business. This directly endangers water	Rising temperatures will require more energy production to cool homes, reduce the efficiency of nuclear power plants, and hinder the production and distribution of energy	Climate change, which impacts and changes society's habits, will spread water scarcity around the world. Additionally, extreme weather events will become more frequent, affecting agriculture. This will risk

	security. Additionally, as temperature intensifies, water evaporates which results in more droughts (GRACE, 2016).	(CCSP, 2008; EPA, 2016; U.S. Global Change Research Program, 2014).	global security and result in involuntary migrations (University of Oxford, 2016; Nature Climate Change, 2016).

Table 4
Geopolitical risks.

	Water security	Energy security	Food security
Failure of National Governance **Failure of Regional or Global Governance**	The lack of integrative water management approaches on local and regional administrations (Bigas, 2012; Bakker et al., 2008; Pahl-Wostl et al., 2008; Moss, 2004).	Instability of energy distribution, increased monopolies, Market disruption, and price instability (Karlsson, 2007; Goldthau, 2012; Florini and Sovacool, 2011).	Hinderance of the development of policies that lead to food security (Paarlberg, 2002; Ericksen et al., 2009; Windfuhr and Jonsén, 2005; Godfray et al., 2010).
Interstate conflict with regional consequences	Poor distribution of water and contamination of water can both arise from a conflict and be the cause of the conflict itself (Molen and Hildering, 2005; Toset et al., 2000; Gleick, 1993; Link et al., 2016; Petersen-Perlman et al., 2017).	Energy resources, especially fóssil fuels, can motivate conflicts and lead to infrastructure breakdown when these disputes increase (Månsson, 2014; Colgan, 2014; Mercille, 2010; Giordano et al., 2005).	Destruction of sources of food can cause increases in food prices as well as food shortages (Scanlan and Jenkins, 2001; Hendrix and Brinkman, 2013).
Large-scale terrorista attacks	Interruption of the supply of basic services, threatening human life, the environment, and water security (Haimes, 2002; Gleick, 2006; Copeland, 2010).	Attacks on energy infrastructures threaten energy supply, affecting energy security (Yergin, 2006; Toft et al., 2010; Cohen et al., 2011).	A potential threat to food security is the socalled agroterrorism, attacks which compromises agricultural infrastructure. These attacks could be carried out through concentrated viruses, entomophilic (disseminated by pollinating insects), botanical or bacteriological viruses against birds, livestock and agricultural production itself (Foxell Jr, 2001; Casagrande, 2000; Prescott, 2016).

3.4 Societal risk

Regarding all of the societal risks, only failure of urban planning has a prominent impact on the nexus. The following table (Table 5) suggests that the failure of urban planning might pose an even greater challenge to food, water, and energy security, since these resources are already undergoing an increasing demand due to climate change and population growth.

3.4.1 Failure of urban planning

Providing healthy and nutritious food to a growing urban population is a challenge that requires efficient urban planning and an inclusive agricultural and food supply system, promoting an eficiente network between rural producers and urban markets (FAO, 2015). The interconnections between urban areas and food security are critical to securing sustainable international development (Dickson et al., 2015).

Failure of urban planning is a significant threat to water security. A vast part of the world's population lives in urban areas (in 2014, 54% of the world's population lived in urban areas). Urban life demands substantial amounts of water resources. Thus, resource abundance, as well as efficient urban management, is necessary to supply these demands (GWP, 2015).

More than 60% of the global energy demand comes from cities where half the world's population is concentrated (ICLEI and UM HABITAT, 2009; IEA, 2012). Studies estimate that by 2050, two-thirds of the global population will inhabit urban areas. Cities are fundamental for local and regional development and poverty reduction. Cities are also important for economic, governmental, commercial and transportation activities (UN, 2014). Urban planning techniques must be innovative, and should respond proportionally to population growth (Barnett, 1989). Therefore, urban contexts are ideal locations to implement efficient and sustainable energy practices (Cajot et al., 2017).

3.5 Technological risk

After analyses of the four different technological risks acknowledged in the 2017 Global Risks Report, it was found that only one has an impact on the nexus: the adverse consequences of technological advances. The table below (Table 6) provides an analysis of the impacts of this risk on food, water, and energy security.

3.5.1 The adverse consequences of technological advances

Aside from the increasing risks caused by the acceleration of technological processes, radical technological transformations, such as nanotechnology and intelligent machines, may also impose unprecedented threats to humanity, endangering food security (Bostrom, 2002).

The adverse consequences of technological advances also offer significant dangers to global water security (WEF, 2016). The WEF (2017) and highlights the importance to the survival of humanity, of studying the potential impacts of emerging technologies, such as biotechnology, artificial intelligence robots, geoengineering, and other Fourth Industrial Revolution (4IR) innovations which will cause major changes in vital water infrastructure networks (e.g. supply, wastewater treatment, flood protection, etc.).

Different forms of energy production influence the environment and energy security differently. While nuclear fusions pollute the water with radioactivity, hydroelectric plants destroy habitats and alter water flow (CMU, 2016). Therefore, it is important to increase awareness concerning these vulnerabilities among powerful policy makers (WEF, 2016).

Table 5

Societal risk.

Water security	Energy security	Food security

Failure of urban planning	Overall, water security has been under great pressure in various urban areas as a result of population growth, poor wastewater and sanitation management, lifestyle changes, and water demand conflicts. Water consumption is expected to double until 2025 (GWP, 2015).	Population growth, especially in urban areas, will put pressure on energy resources, inducing potential risks to several regions of the world (ICLEI and UN HABITAT, 2009; IEA, 2012).	Climate change, summed up with unhealthy lifestyles in urban centers and increasing pressure on food resources, provokes societal challenges which must be defeated through intelligent planning (Dickson et al., 2015; FAO, 2015).

Table 6

Technological risk

	Water security	Energy security	Food security
The adverse consequences of technological advances	The limitless increase in production and consumption, combined with technological advance, can impact soils, ecosystems, and water. There is a possibility Existential Risks might occur, threatening water security (Bostrom, 2002, 2013; Jebari, 2014; CSER, 2016).	The Fourth Industrial Revolution will dramatically change how we understand logistics, communication, and transportation systems. Na interdependente world, which requires more energy, must be prepared to guarantee energy security (UCS, 2016; WEF, 2016; CMU, 2016).	The increasing population and demand for food will drastically change the way we produce food, which directly impacts food security (Bostrom, 2002; Bernauer and Meins, 2003).

3.6 Trends, future shocks and their impacts on nexus

The Global Risks Report describes certain global tendencies which will reshape the global agenda in the next following decades “that could contribute to amplifying global risks and/or altering the relationship between them” (WEF, p. 62, 2018). Furthermore, the report provides a special session regarding the “future shocks”, an innovation available in the 2018 Global Risks Report. These shocks are analyzed as “dramatic disruptions that can cause rapid and irreversible deterioration in the systems we rely on” (WEF, p. 5, 2018). Trends and future shocks are not as tangible as the global risks since most of these challenges have not occurred yet, mainly due to its complex, speculative and future nature, demanding strategic measures to impede them from materializing. This study analyses these movements as indirect risks concerning their impacts on the nexus between water, energy, and food.

The Grim Reaping, for instance, is considered one future shock which is triggered by the increase of environmental tensions, extreme weather events, plant pests, and political instability. The consequences and impacts of this shock encompass key food producing regions provoking food scarcity, price increases, demand increases, and disputes concerning food, water, and energy supply inducing political, economic and geopolitical crisis. Therefore, the Grim Reaping's impacts on the nexus between water, energy, and food are evident, considering that these resources demand favorable climatic conditions and stability to be appropriately distributed and delivered globally (WEF, 2018).

Regarding future tendencies, there is an undeniable variety of challenges concerning the nexus between water, energy, and food. Rapid urbanization, for example, will stress these resources and might induce conflicts concerning demand and supply. Climate change will modify the composition of earth's atmosphere, resulting in a diversity of obstacles especially

concerning vulnerable communities and the countryside, regions that rely on favorable climate conditions for their subsistence and growth. Finally, among the various trends addressed by the WEF, the growing middle class in emerging economies will unquestionably demand reliable water, energy, and food infrastructures guaranteeing the accessibility and availability of these resources (WEF, 2018). The aforementioned risks will be systemically analyzed throughout this paper particularly regarding its interconnections between the nexus of water, energy, and food.

4. A systemic analysis of the global risks regarding water, energy and food security

As previously analyzed, the global risks drastically impact water, energy and food security. By emphasizing the global risks systemic complexion, this study concentrates on analyzing two specific aspects stated on the Global Risks Report: how likely a phenomenon is to occur; and its potential implications. Fig. 1 represents the global risks that impact water security, energy security, and food security.

Concerning the thirty global risks, nine simultaneously impact the nexus, four of which remain among the ten most likely to occur. Other four global risks are among the most impactful risks for business and society. The Global Risks Report methodology aims to assess and rank the risks regarding probability and impact. The following measures are used to qualify the potential impact: minimal, minor, moderate, severe and catastrophic. The probability scale uses a score from 1 to 7. Overall, 745 interviews were conducted in order to gather the data analyzed by the report.

Systemic challenges and global instabilities increasingly jeopardize water, energy, and food resources. Over time, humankind has learned to mitigate traditional risks separately; however, it is still incapable of coping and preventing complex and interconnected risk systems rooted in the modern world (WEF, 2018).

Failure of climate-change mitigation and adaptation as well as the increase of extreme weather events such as floods, storms, hurricanes and intense droughts, severely impacts water security. Dramatic consequences rise when water potability or supply infrastructure is affected (Vörösmarty et al., 2000). Irrigation and water distribution challenges might also impact food production and biofuel generation (Berchin et al., 2018). Biofuels are important energy resources that play a prominent economic role in many countries such as Brazil and China, which hold the world's largest hydroelectric plants (Hamududu and Killingtveit, 2012). These countries tend to suffer serious damage when extreme weather events affect their existing infrastructures through a failure of critical infrastructures.

Examples of the failure of critical infrastructures include failure in hydroelectric lines, thermoelectric lines, transmission cables and goods distribution lines, which impact the entire production system. These failures impact the flow of food and distribution of water and energy for irrigation or for the population itself. Regarding technology, equipment to mitigate the detrimental impacts of climate change can also be affected. The challenge of failure of critical infrastructures is characterized by a lack of investments, upgrades, or protections of infrastructure networks and strategic activities, which has implications for the entire system (Evans et al., 2017).

These impacts are profoundly connected to the failure of regional or global governance and failure of national governance, which represent the inefficiency of governments and institutions in developing and implementing risk reduction and mitigation strategies on a local and global level. Deficiencies in policies regarding water management, such as lack of basic sanitation, pollution of rivers, and low navigability, might impede the generations of sustainable hydropower (Moe and Rheingans, 2006), representing failure of governance in terms of water security. Policies centered on the generation of biofuels might increase competition for land between the food production and energy industry resulting in increased prices and rising water and energy demand due to the increased need for crop irrigation and energy for transportation (Harvey and Pilgrim, 2011). Thus, policies must be developed systemically regarding local, national, and global systems.

A failure of global governance can lead to interstate conflicts with regional consequences. Increasing water demand and its consequente scarcity results in conflicts between countries, inducing food and energy crises in several regions since water is an essential resource concerning food and energy security (Wolf, 1998; Swain, 2015).

Failure of urban planning produces several impacts and challenges to social, health and environmental development (Andrade et al., 2016). Efficient urban planning prevents water pollution and electrical overloads and increases waste and resource management which is essential for society's livelihood. Disregarding new energy consumption patterns, inefficient urban planning with inadequate water supply systems and a lack of innovative energy production methods not only affects each sector separately but also puts the entire system in jeopardy (Berke, 2016) since water, energy, and food are interconnected and dependent resources.

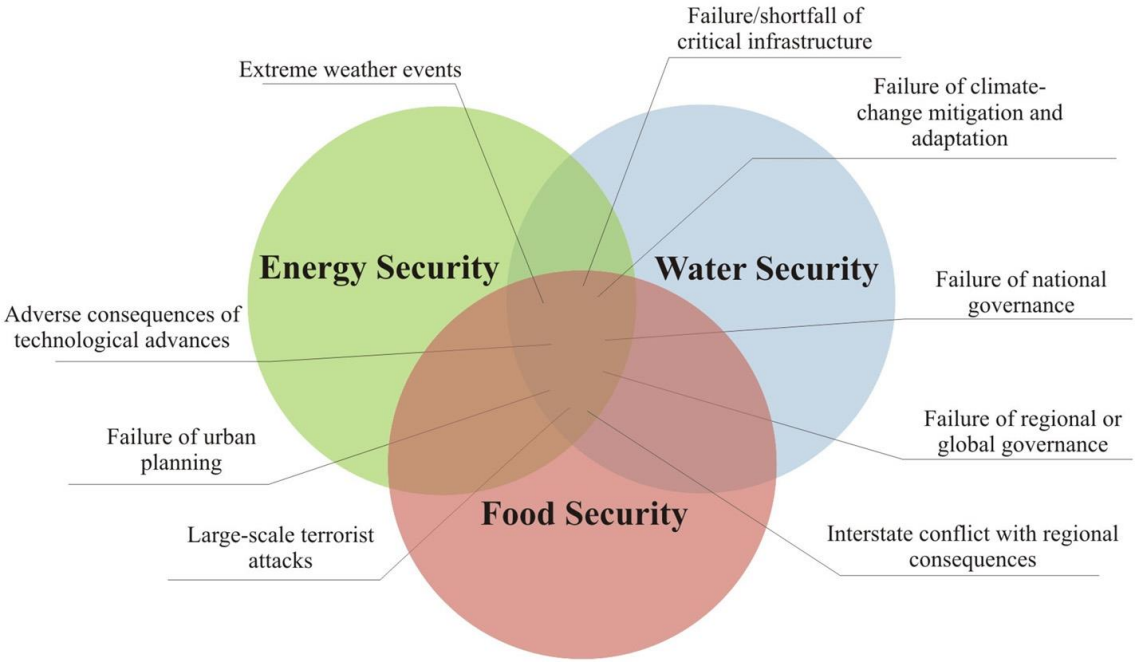

Fig. 1. Global risks impacting the nexus between water, energy and food security.

Lack of governance implies governmental and institutional failure regarding social, political, economic, geopolitical and environmental concerns, producing a delicate institutional scenario

which can lead to many crises and destructive events, including large-scale terrorist attacks. According to Copeland and Cody (2003), terrorist attacks or infrastructure failures could profoundly affect water security concerning the vulnerability of water as a resource regarding these risks in particular. The partial or entire destruction of infrastructure used for national water supply, for instance, could cause a shortage in primary resources, threatening public health, the environment, transportation, industrial activities, energy supply and food production (Hua and Bapna, 2013; Nickolov, 2005).

The adverse consequences of technological advances are another set of future challenges requiring adaptation by society. Shocks such as the "Precision Extinction" and the technological advances englobing artificial intelligence, geoengineering, and synthetical biology might cause unprecedented environmental, human, and economic calamities (WEF, 2018). Processes such as management, extraction, and transportation involving water, energy, and food resources continuously demand careful proceedings in consideration of their vulnerabilities. Therefore, innovative technology might stimulate and facilitate these mechanisms; however it may also produce and increase risks and generate more vulnerabilities to these resources. Computing systems develop and manage relevant functions associated with water, energy, and food resources such as controlling water and nuclear power plants, controlling different levels of food production and overseeing the signaling of mass transportation. These considerations imply a potential scenario for systems vulnerabilities and failures regarding the interconnections between these three resources.

Technology allows the creation of genetically improved species; the development of innovative and powerful machines, and the generation of devices capable of replacing manual crop labor; however, through the expansion of plantation land into forest habitats, it induces deforestation, modifying microclimates and increasing the demand for water in growing planting areas (Marques et al., 2007). These new Technologies in the agricultural world transform it into a significant energy consumer, leading to disputes over energy resources between the other sectors.

Recognizing how the risks interact and impact the nexus offers na opportunity to develop mitigation strategies, create new technologies, and stimulate cooperation among the international community. According to Morin and Lisboa (2007), complexity arises in environments where simplicity seems to fail. Thus, the complex nature of the systemic analysis promotes the understanding of the interactions between different fields, which are often disjointed by disjunctive thinking.

A global risk that impacts three resources simultaneously (i.e. nexus) is naturally more alarming, precisely because of its systemic complexity and interdependencies. Studying different risks (economic, environmental, geopolitical, social, and technological) that affect several resources (water, energy, and food) requires the construction of complex solutions and strategies. The international community along with decision-makers, and other stakeholders must work collectively towards strategic natural resources management. The global risks featured in this analysis should be top priority compared to those risks that impact only one or two resources.

The risks that impact the nexus between water, energy, and food (Fig. 1) are not necessarily related to each other, even though all global risks "communicate" and share a strong

interdependence; however, this connection does not justify a possible similarity between them. A terrorist attack (a geopolitical risk), for instance, may impact other risks, such as the failure of critical infrastructure (an economic risk). The correlation between those risks does not imply that they are similar. It is important that this relationship between interdependence and "singularity" among the global risks is understood. Moreover, decisionmakers (public or private agents) can plan a more efficient management of resources through acknowledgement this pattern of data crossing and through observation of resource supply and availability. Risk management can contribute to a more effective governance, which will pragmatically improve the daily lives of people and their relationship with the environment.

5. Conclusions

The purpose of this article is to analyze the impacts of global risks on the nexus between water, energy, and food, based on bibliographical and qualitative research regarding the 2017 Global Risks Report. The report required extensive analysis concerning the concepts of global risks, the nexus between water, energy, and food, and the security of each resource.

First, a definition regarding the nexus between water, energy, and food was established. Then, the global risks stated on the current WEF Risks Report were identified and clarified. Afterwards, an analysis was developed regarding the potential impacts of the thirty global risks on water, food, and energy security.

The analysis led to the conclusion that: a) 22 risks impact food security, b) 16 risks impact energy affordability and supply availability, c) 14 risks threaten water security, and d) 9 risks can cause significant short or long-term effects on the nexus between water, energy, and food.

The impacts of the global risks on the nexus are evident but complex. In order to overcome the various challenges these resources encounter (political; economic; social; technological; environmental; geographical - local, national and regional; and historical - current and future), countries must collaborate and implement strategic and integrated policies to improve the management of natural resources.

This research subject importance is apparent since it predicts future difficulties concerning water, energy, and food security that countries and great corporations will face. Considering it is a relatively innovative subject, these issues have been carefully discussed in international settings in conferences among chiefs of state and decisionmakers.

The cooperation between multi-stakeholders to stimulate sustainable development regarding the global risks and nexus is also of great significance. Important events discussing the management of sustainable resources such as the 2017 Dresden Nexus Conference; the Paris 2015 Climate Change agreement; the Bonn2011 Nexus Conference, and the development of the United Nations Sustainable Development Goals raised awareness for discussion and empowered governments and societies to develop policies, sustainable management plans and resolutions in order to ensure food, water, and energy security. Thus, agentes must work together to manage specific resources sustainably as well as in providing suggestions on how to incorporate the nexus or manage resources more sustainably.

Throughout this article, water, energy, and food security are examined as highly interconnected and interdependent resources. Therefore, the recognition of the nexus and its relationship to global risks should inspire the mitigation of adverse climate change consequences and stimulate sustainable development processes. Moreover, the development of adaptation strategies is required to avoid the global risks negative consequences, preserving water, energy, and food security.

It is reasonable to recognize that countries must overcome existing challenges and obstacles to ensure sustainable management global resources. Thus, decision-makers, heads of state, stakeholders, academics and the civil society must commit to developing relevant measures, policies, and resource management strategies considering the variety of global risks, the alarming data and projections for the future.

Acknowledgments

The authors would like to thank Issa Berchin for his contributions to the revision of this paper. This study was conducted by the Research Centre on Energy Efficiency and Sustainability (Greens), from the University of Southern Santa Catarina (Unisul), in the context of the project: Building Resilience in a Dynamic Global Economy: Complexity across scales in the Brazilian Food-Water-Energy Nexus (BRIDGE) funded by the Newton Fund, Fundação de Amparo à Pesquisa Inovação do Estado de Santa Catarina 2016TR557 (FAPESC) and the Research Councils United Kingdom (RCUK).

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CHAPTER 4 – ARTICLE 3

Urban challenges and opportunities to promote sustainable food security through smart cities and the 4th industrial revolution

Land Use Policy

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Abstract

The several changes happening in environmental, social, economic, technological and geopolitical spheres of our society result in countless risks, challenges and opportunities for human development. The global population crosses 7.7 billion with the loss of biodiversity, increasing pressure on food, water, and energy resources. The migration of people from rural to urban in large scale is a matter of concern; as the global urban population will almost reach 68% by 2050, approximately 6 billion. A very high concentration of people living in urban areas and growth projection pose a serious challenge for large cities for vulnerability. Amongst the several challenges, food security will be a serious issue for the future of cities. In this context, the Fourth Industrial Revolution and movement towards creating Smart Cities have to provide solutions and opportunities to deal with those challenges. In this opinion paper, we seek to discuss the future of cities, with a holistic vision of several actions to deal with food security challenges in urban centers.

Keywords: Food Security; Climate Change; Industrial Revolution; Smart Cities; Sustainability

1. Introduction

The fast-paced development of humanity in this industrial era has resulted in several risks and challenges, creating systemic issues in our economies, societies and in the environment, locally as well as globally (World Economic Forum, 2019). As the 21st Century begins, we experience a fast population growth, accelerating deforestation in rainforests, land degradation and desertification, growing demand for food, energy and water resources (Amorim et al., 2018), and an increase in the concentration of greenhouse gas (GHG) in the atmosphere and climate change (Lal, 2016).

It is considered that by 2050, 68% of the world population will live in urban areas (UN DESA, 2018), so infrastructures in cities will be under pressure (Satterthwaite, 2009) and GHG emissions will increase in urban centers (Glaeser and Kahn, 2010). This scenario of insecurity, unpredictability and global environmental change creates a situation of risk and vulnerability to cities, which are considered to be factors which represent the largest and most dramatic manifestations of human action in the environment (Ridd, 1995). Cities allow the creation and spread of ideas, culture, science and social development (Ribeiro et al., 2018), and their importance is such that the 21st Century is considered to be the "century of cities" (Carrillo et al., 2014).

Until recently, there was little discussion regarding food issues and urban studies. However, in the days we live, problems related to food became extremely integrated into cities, making it impossible to ignore the role that food plays in urban centers (Maye, 2018). In this sense, cities are increasingly engaging in practices aimed at food and agriculture through social movements and actions from authorities and city councils (Deakin et al., 2016; Derkzen and Morgan, 2012). These movements are necessary to find solutions demanded by this scenario we live in, using technological advances, political expressions, and other initiatives, making cities more sustainable, resilient and smart (Vilajosana et al., 2013).

In this opinion paper, we seek to reflect on this outlook which can unfold uncontrollably on a global scale leading to larger negative impacts on the climate change; as well as a bigger pressure in resources, critical infrastructures, and accelerated technological development. Thus, the critical question arises, "How it is possible to ensure the large urban centers to provide safe and healthy food in such a complex scenario, for today and in the future?"

2. Challenges and opportunities for promoting food security

In 2017, roughly 821 million people were victims of starvation and malnutrition, which means approximately one person to every nine people in the world (FAO, IFAD, UNICEF, WFP and WHO, 2018). The challenge for humanity is to achieve worldwide food security — a concept that means there is safe, nutritive and sufficient food for all (FAO, 2006). This challenge is made harder since the world population is expected to grow to around 9.1 billion people by 2050, creating a demand for a substantial increase in food production and consequently dealing with an increase in GHG emissions and in the use of resources (Romero-Lankao et al., 2018; Carvalho, 2006).

Food insecurity is a worldwide problem with impacts in several countries, especially in urban centers, but its impact is uneven. Around 50 million children globally live in a situation of food insecurity, but half of them live in South Asia, and an additional quarter live in sub-Saharan Africa (FAO, IFAD, UNICEF, WFP and WHO, 2018). In the 2018 Global Food Security Index, 34 out of the 35 countries considered to be the most food insecure were from Asia or Africa (The Economist Intelligence Unit, 2018).

The consequences of food insecurity in urban centers can also be seen in developed countries, as the United States. Food insecurity is more common in households of minoritarian groups, such as Africans, Afro-Americans, hispanics or single mothers, orphans, *etc*. Children

compose a vulnerable group since food insecurity has a long-standing impact on their lives and development (Hobbs and King, 2018).

As a result of challenges and concerns coming from large urban centers, there is an appeal for urban feeding systems to be more active locally (Matacena, 2016), engaging activities and actors that supply food for urban areas (Dubbeling et al., 2016). However, current urban food systems are characterized for a lack of urban-rural links, and cities depend heavily on industrialized food supply chains, which possess global sources and are generally based on mass production (Forster et al., 2015; Sonnino, 2009). There are several studies on literature regarding challenges and opportunities on urban farming, peri-urban link farming, rural-urban link farming, and urban food loops to achieve food security in cities (Diehl et al., 2019; Ritchie et al., 2018; Knorr et al., 2018; Margenat et al., 2019; Del Ángel-Lozano et al., 2019). Gu et al. (2019) put forward their idea that food security in urban areas can be achieved by combine pockets of rural land, reduce food waste, improve farming and encourage urbanites to eat less meat.

There is a consensus that there will be a need to increase food production, but the amount needed is still in discussion. The FAO report "How to Feed the World in 2050" (FAO, 2009), one of the first to address the issue, says an increase of 70% in food production is needed (Popp et al., 2013). Prosekov and Ivanova (2018) believe the needed increase should be between 50% and 75%. In any scenario, the biggest problem is to understand how to make this production possible, since it needs to happen in a stable environment, different from the one we have today, clouded by uncertainties as climate change (Carvalho, 2006).

3. Climate change and the cities

Recent studies confirm that climate change and extreme events (e.g. floods and sea level rising) are predicted to become more intense and frequent in the coming years, bringing large impacts and new challenges for urban sustainability (Mi et al., 2018). These impacts are heightened in cities and urban areas, making them exposed and vulnerable to climate change (Revi et al., 2014; Weyrich, 2016).

Generally, climate change affects urban sectors in several ways, putting cities in a state of vulnerability due to fast urbanization and complex patterns of assets, infrastructure and urban economic services (Geneletti and Zardo, 2016; IPCC, 2012). In attempting to mitigate these risks and impacts, a broad movement is expected to create local food systems, bringing producers and customers together in the same region (Stagl, 2002), improving work and life conditions for small-scale farmers, who not only use local agricultural inputs, but also encourage a diversity of cultures and redefine relations between producers and customers by creating more confidence between them (Marsden et al., 2000; Fraser, 2006).

Another solution may be observed coming from the idea of Climate-Smart Agriculture (CSA). According to Lipper et al. (2014), CSA identifies synergies and trade-offs between food security, adaptation, and mitigation, serving as a base for formulation and guidance of policies to react to climate change. In achieving their three main goals (increase agricultural productivity sustainably to promote food security, income, and development; adapt and build resilience to climate change from farms to global sphere; and develop opportunities to reduce GHG

emissions in agriculture), CSA seeks to provide a climate and food security in all levels, creating global and local actions concerning research, policies, and investments, acting in synergy with public and private players, as well as the civil society.

Cleveland et al. (2017), carried out a model to mitigate GHGs by alternative household vegetable gardens (AHHVGs) in Santa Barbara County, California, in the United States. Lee et al. (2015) report a reduction in GHGs from the urban agriculture in Seoul, South Korea to support food supply and to mitigate climate change. There are studies on links between food-energy-water-waste for carbon neutral sustainable governance in smart city concept have been reported for climate change mitigation (Covarrubias, 2019; Miller, 2019).

Cities have a central role in developing mitigation global actions in climate change and the development of low-carbon strategies (Mi et al., 2018). Despite answering for three quarters of global energy consumption and emissions of GHG (Gouldson et al., 2016), cities are centers for promoting innovation and wealth, ensuring resources and tools needed to combat negative impacts and other challenges coming from climate change (Rosenzweig et al., 2010).

4. Population growth and smart cities

Since they concentrate a significative share of human activity, cities play an important role in economic and social spheres of society (Mori and Christodoulou, 2012). Life in cities is associated with better levels of health, education, life expectancy and political involvement (UN, 2014), and people are attracted to these centers in searching for better work and life conditions (Eurostat, 2018) — cities like London, Paris, Tokyo, and New York have enormous populations, but are still seen as attractive to inhabitants and people who would like to live there (Newman, 2006).

In the other hand, cities are largely responsible for environmental problems, such as air and water pollution and massive use of non-renewable energy (Grimmond, 2007; Guerra et al., 2016), which have effects on climate change (Choucri, 2007). In addition, the rapid urbanization brings other challenges to sustainability, as an expansion of poverty, social instability, shortage of natural resources and spacial dynamics (Ibrahim et al., 2018).

Having this in mind, it becomes necessary to develop smarter alternatives to reduce existing problems and face the new challenges which will threaten environmental, social and economic sustainability in cities, in order to improve people's quality of life and promote sustainable development (Bătăgan, 2011; Ibrahim et al., 2016; Kumar et al., 2018; Zawieska and Pieriegud, 2018). In this context, the idea of "smart cities" emerge.

Smart City is a term commonly used to refer to convergence between technology and cities (Yigitcanlar et al., 2018). However, as there is no unique framework for smart cities, nor a unanimous definition, it becomes clear that this concept must not be limited to the diffusion of Information and Communication Technology (ICT), but it also looks at people and community needs (Albino et al., 2015; European Parliament, 2014).

In this sense, Smart City models are based in strategies to use advantages of technologies of information and communication in areas as city administration, education, healthcare, public safety, real estate, transportation, and utilities. This is made in order to optimize city infrastructure, offering advanced and innovative services to their citizens, improving quality of

life whilst increasing prosperity and competitivity in the region (Bakıcı et al., 2012; Chen, 2010; Washburn et al., 2010; Piro et al., 2014).

One example is the city of Barcelona, in Spain, which has invested in implementing technological systems to become a Smart City since 1990, and intends to compete in the global knowledge-based economy while creating a sustainable environment and providing a high quality of life for its population (Bakıcı et al., 2012). Other models of smart cities are emerging around the world: according to 2013 data, there were approximately 143 ongoing or completed self-designated smart city projects. In Europe, cities like Amsterdam, Berlin, Manchester, and Edinburgh can be cited for having put in place smart city actions (Albino et al., 2015).

Despite some advances promoted by Smart Cities models, cities are responsible for 80% of the world's consumption of resources (Yigitcanlar et al., 2018). The increasing demand for capital and the consumption of goods in the globalized world requires opportunities for the realization of advanced manufactures which could provide a true transformation in producing goods and services (Maynard, 2015), as well as significative effects on how people live, and consequently might bring deep changes in a global scale, in all spheres of life in society (Chung and Kim, 2016; Feshina et al., 2019).

5. Fourth industrial revolution

During several hundreds of years, industrialization processes have been shaped so manufacturing processes are increasingly more complex, automatic and sustainable (Lu, 2017; Carvalho et al., 2018). Keeping environmental factors in mind, the changes in business sectors and requirements for manufacturing companies to remain internationally competitive, the world now walks towards the next step of industrial revolutions, the so-called "Industry 4.0" (Navickas et al., 2017; Simonis et al., 2016; Stock and Seliger, 2016).

The concept "Industry 4.0" was formulated in 2011 by the President of the World Economic Forum, Klaus Schwab, during the annual Davos meeting (Feshina et al., 2019) as a propose for the development of a new concept of German economic policy based on high-tech strategies (Mosconi, 2015; Lu, 2017) powered by nine foundational technology advances: Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, Internet of Things, Cyber-security and Cyber-Physical Systems (CPS), The Cloud, Additive Manufacturing and Augmented Reality (Rüßmann et al., 2015).

This new orientation of industrial policies seeks to promote interaction between information and decisions made by people, processes and objects, which will communicate with each other via the internet with a certain autonomy; work in progress products, components and production machines will collect and share data in real time as cyber-physical systems (CPS), being monitored and synchronized between the physical factory floor and the cyber computational space. The goal is to remove planning, control and decision centralization in decisions regarding production and consumption, introducing the Internet of Things (IoT) concept in industrial application scenarios (Gilchrist, 2016; Lee et al., 2015; Shrouf et al., 2014; Wollschlaeger et al., 2017).

This fourth wave of technological advancement will not only be useful in manufacturing industries. The advances it promoted increase productivity by answering to customers' needs,

so it is applicable in any industry where there are several variants of products, especially food (Manavalan and Jayakrishna, 2018), reshaping the modern food supply chains with promising business prospects and innovations (Pang et al., 2012) which may significantly contribute to human health and well-being (Pang, 2013).

Cities have been recognized as the ideal scale for food policy innovation; however, one of the most distinctive features of food policy is its fragmentation, which fails to recognize the structural interdependence between food and other resources and sectors (Sonnino et al., 2018). In this sense, the use of smart technologies in urban food systems presents potential to improve food chain performance in terms of supply, production and distribution, improving logistics systems, and food waste management, using pillars from the Fourth Industrial Revolution (El Bilali and Allahyari, 2018; Maye, 2018; Pang et al., 2012; Pires et al., 2018; Rüßmann et al., 2015; Wang and Yue, 2017).

The Fourth Industrial Revolution brings various urban farming technologies such as spatial farming, roof-farming, vertical farming, hydroponics, aeroponics, LED-based artificial farming, etc. promoting progress to achieve food production and supply in urban areas (McDougal et al., 2019; Rahdriawan et al., 2019; Salim et al., 2019; Olivier, 2019; Taufani et al., 2017; Pölling et al., 2017; Fang, 2019; den Besten, 2019; Lu, 2017). Recently, the internet things of using network mobile technologies, smart city planning link with the urban food system, smart city-food links to provide a solution to the urban food supply system (Wantchekon et al., 2019; Maye, 2019).

Incentives to use elements from the Fourth Industrial Revolution such as robotics and automation can significantly contribute in increasing food production and reducing food waste in all the process, especially in harvesting (Sewald et al., 2018). According to Carthy et al. (2018), roughly 40% of the United State's agricultural production is wasted in harvesting and transporting. New solutions such as IoT and implementing microchips in containers could help avoiding waste, therefore promoting food security. A machine learning process could also provide a better control of temperature inside containers, allowing for a better conservation of foodstuffs until the point they arrive at urban centers, where they are consumed (Badia-Melles et al., 2014).

To divert threats as a growing tolerance of plagues, diseases and weeds and deal with an unsustainable pressure on labour supply, there is a movement to automatize and robotize aspects of the cultivation process (Baizid et al., 2015; Grieve et al., 2019). In the context of industries, robots are nowadays considered as integral part of processes (International Federation of Robotics, 2015). Keeping this in mind, it is understood that robots are being used for tasks including sowing, water spraying, food processing and packaging, transport, and automatic quality decision — meaning, from rural areas to consumer's homes (Iqbal et al., 2017; Sun, 2016).

For a long time, ICTs have been used to improve resource efficiency and productivity in food systems, for example, communication, information exchange, transactions, and knowledge transfer are fundamental in nearly every aspect, thus placing the digitization of agriculture and food chains high on the political agenda (Bilali and Allahyari, 2018). Technological innovations in big data and data analytics applied to food production are being

developed and adopted in order to optimize both business as well as environmental efficiency (Bronson, 2018).

In agriculture, for example, communication, information exchange, transactions and knowledge transfer are fundamental in nearly every aspect (El Bilali and Allahyari, 2018). Another area in which this recent data explosion can contribute to food security is in developing personalized diets and food, fulfilling the consumers' right to know and help to guarantee the right to make informed choices, while at the same time providing big data services for companies to help them produce the food that consumers need (Kwon, 2017).

Introducing IoT-based mechanisms assisted by centralized data collection and analytics may help improving food security conditions by reducing significantly food waste, improving transport and distribution (Regattieri et al., 2007, do Nascimento Nunes et al., 2014). IoT also has potential to act in identifying vulnerabilities and pre-warning about issues along the farm-to-fork chain, helping to remove quickly contaminated or spoiled products from the fresh food supply chain, for instance (Pal and Kant, 2018; Wang and Yue, 2017). However, the biggest challenge for wide-scale adoption of IoT and associated smart data analytics solutions for the global food chain is still the cost of implementation (Carthy et al., 2018).

Uncertainties regarding demand, process, and supply represent a challenge for supply chains in their goal to create planning and choose tools which will better meet needs and decisions made. However, such characteristics must be considered to elaborate a plan of control of resources and diminishing problems. To answer "what-if" questions which emerge with variations in factors that interfere in supply chains and predict proper means to proceed in several scenarios, we can try and run simulations (Pires et al., 2018).

Other technological advances might revolutionise food industries, such as 3D printers, whose goals are to make any person able to be a food manufacturer, creating foodstuffs according to their needs and individual desires in controlling shapes, textures, color, flavour, and nutrition. This versatility in domestic kitchens has the potential to improve efficiency in delivering high quality and freshly-prepared food products to consumers since these processes have environments and food safety management systems (King et al., 2017; Sun et al., 2015a; Sun et al., 2015b).

The initiatives of the industry 4.0 have a great opportunity to realize the creation of sustainable industrial value in all three dimensions of sustainability: environmental, social and economic (Carvalho et al., 2018; Stock and Seliger, 2016). Thus, it becomes even more important to ensure governments, companies and population are involved in discussions about challenges and opportunities that technological development provides so that we can assure a safer and more sustainable future for all (Carter, 1997; Chourabi et al., 2012).

6. Discussion: Challenges and opportunities for promoting food security in urban centers

Our cities have to develop in a sustainable way for providing welfare and security for all. Urban centers were created and designed to support a context which is no longer the same, since we have new demands and needs to satisfy our comfort/luxury. The world today is well connected, and we live in a complex, interdependent system which has great potential to bring benefits to society as a whole. However, for this development to happen, we need decision

makers, civil society, academia and the private sector to act in synergy, considering the complexity of cities acting holistically. This is the only pathway to provide food security in urban areas.

It is worth reinforcing that current food production levels will not be enough to support the food demand of the estimated population in 2050, and cities and urban centers are at the center of this risk. One of the ways to overcome this challenge would be increasing cultivated areas, but most of the arable land is already being used, and most of the land available is concentrated in Africa and South American, regions that find themselves under geo-climatic severe consequences, capable of preventing their use in agriculture (Tyczewska et al., 2018). Another solution, which looks more feasible, is to use technology and tools capable of bringing producers and customers together, focusing on local food systems inserted in large city communities. To address the above-said complex system, the Fourth Industrial Revolution and Smart Cities emerge as possible solutions to promote fair and sustainable development.

The Fourth Industrial Revolution is very different from the previous three, since it is being foreseen, while all benefits that came from the others were perceived later. This allows_us to shape actively the way it changes our world, and gives governments and enterprises a chance to take specific action to implement it in their manufacture models efficiently (Almada-Lobo, 2016; Gilchrist, 2016).

To create a significant change in our society and consequently in our urban centers, we need drastic changes in the way we live and see cities. Changes from the Fourth Industrial Revolution will create new ways for us to live, work and interact with each other. We need to work in an integrated, comprehensive manner if we want to seize this opportunity and want to cooperate and adapt to global environmental change. The number of things to do and possibilities coming from the connection of billions of people through mobile devices and unlimited knowledge are unprecedented. We must use these new tools to create bridges between us, in order to promote a safer feeding and more sustainable world.

7. Conclusions

The global environmental changes and the new social movements, economic, political and technological change are bringing a new dynamic into the urban centers. We live in the cities designed to withstand a reality that no longer exists. The high population growth, migration, the consequences of climate change and the emergence of new global risks are just a few challenges faced by us for our survival. The increase in the demand for essential resources such as food, water, energy, medicine, materials, etc. also raise concerns. Hence, it is necessary the creation of direct and persistent answers that assimilate the complexity and interdependence that exists in the current scenario. For this, it is vital that through a holistic vision, we have to develop techniques, actions, social movements, and policy tools that interact with decision makers with the scientific community, industry and civil society. Therefore, we have to create and use new solutions to integrate all pillars of the Fourth Industrial Revolution, i.e, bringing new technologies, ideas, and tools to promote food security in urban areas.

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CHAPTER 5 – FINAL CONSIDERATIONS

The raise in awareness concerning the impact of human actions in the environment and global risks in society and industries has resulted in an alarming perception over the present situation that we are inserted in the beginning of this century. In the attempt to find solutions for the countless challenges faced in most parts of the globe, scientists, decision makers, international organizations and civil society, look for answers that are practical and sustainable, trough collaboration and union of knowledge.

Between the many obstacles faced in the present context, it is important to ensure food security. Through a deeper reading of international literature, I was able to attest that food production in a smaller scale, allied to good governance and technological innovations from the fourth industrial revolution, will be able to help reaching the path to assure food security. Through family farming and public policies which encourage production in a smaller scale (local production), it will be possible to increase food security both locally and nationally, resulting in a direct development of small regions, lowering the prices of food, diminishing external dependencies of national economies, assuring sustainability and social inclusion. For that, strategies and initiatives adaptet to local realities will be needed, always aligned to global partnerships to support them.

In this sense, it is fundamental that the status quo is altered and faced, since the present measures and strategies adopted by governments to increase food production do not attend global needs. This means profound shifts in production, transportation and consumption of food patterns; as well as the creation of resilient food system and the strengthening of critical intitutions and infrastructures responsible for assuring food.

Another measure related to local production is urban agriculture, that has revolutionized current food systems, mainly in developing countries that are highly dependent on rural production. Besides contributing for a smarter and more efficient production, urban farms lower the disposition of organic waste, improving the functionality of urban ecossistems and assuring a low carbon economy, since supply chains, when shortened, many times demand a lower amount of fossil fuel for transportation.

Since urban centers house a large share of the global population, they have become fundamental spaces for the creation of problems as well as solutions for the food security issue. Directly impacted by climate change, environmental catastrophes, economic challenges, inequality and social conflict, urban centers will need a fast adaptation.

Through the fourth industrial revolution, which we are going through, it will be possible to enlarge the scope of actions, business and infrastructures that have information technology and communication as their guiding pillars. If applied to production and distribution of food, it will be possible to assure that food security is preserved in many regions, mainly in urban centers. For that, decision makers and political actions must be constantly aligned to fundamental ideas such as smart cities; intelligent technologies; Big Data; simmulations; autonomous robots; artificial intelligence and cyber security.

Alongside innovation, local food production aligned to good governance, as well as a holistic and complex vision and administration of food, water and energy resources, that beside being interdependent, are essential for the promotion of development and well-being. Adding

prevention of global risks to the nexus between water, energy and food, we have a powerful tool for the promotion of sustainable development and increasing security of resources and systems.

Through family farming, small scale food production, good governance and innovation, technology and information, it will be possible to create a global food chain that is healthier, transperent, resilient and efficient, enabling us to answer to the endless demands that are fundamental to assure well being and sustainable development.

From the result of the three articles discussed in this dissertation, the objectives of this study were reached, and the research question (how family farming, urban agriculture and the fourth industrial revolution promote food security when aligned to public policies and technology in a global risks scenario?) has been answered.

About the challanges faced during this research, I highlight the lack of articles which relate food production to technological innovation in urban centers in the context of the fourth industrial revolution; as well as the absence of discussions that relate the nexus between water, energy and food to global risks. However, this gap has allowed that the articles discussed here to be published and presented to the scientific community as something truly relevant. I hope that this study leaves behind a legacy in the academia, as an intrudutory discussion which cooperates for debate and deepens issues that are fundamental for the creation of new solutions to food security challenges, in Brazil as in other countries. Hence, it is hoped that based in this dissertation, practical actions will be implemented in order to bring benefits to civil society. For the author of this dissertation, the legacy that will be left is focused on countless knowledge and experiences acquired in these two years of research, which resulted in personal and intellectual growth which will be the base as well as encouragement for the rest of my academic career.

For future research, I suggest that the new studies link the use of land, the nexus between water, energy and food, to the technology development process, what will help in the discussion and improvment of fundamental ideas for assuring food security to future generations.

To assist and direct new studies focused on the theme of this dissertation, I chose to select the 5 most relevant articles for this academic work:

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