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Implementation of Scenario Prospecting Methods in Ecological Footprint Indicators for the Identification of an Environmental Balance in the Production and Global Consumption of Beef

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Abstract: Among the impacts caused by the increase in demand for food production for a world population expected to reach 9 billion people during the 21st century, there is an increase in the demand for beef and consequently an increase in the consumption of natural resources of the planet , resulting in an atmosphere heated by greenhouse gas emissions. In view of this, the search for technological efficiency in the use of resources becomes a target still treated in a secondary way by the segment. Considering the current and future possibilities of global beef production and consumption, this research concentrated on identifying a sustainable global pattern of beef production and consumption by 2040 through an unprecedented methodology, composed of four distinct phases, which resulted in a prospective model, composed of four scenarios for 2040, which involve technology in different ways. In addition, this model contemplates the current levels of production, consumption and technology and prospects for technological advances, evolution in the levels of projection of demand, population and per capita GDP globally.

Key words: prospective scenarios; ecological footprint; beef
JEL codes: Q

1. Introduction

Agriculture changed not only food habits but also human civilization, bringing to men the need to abandon the nomadic life and change to a more centralized life (in the form of villages and future cities) for the planting and cultivation of food. During Prehistory, specifically in the Palaeolithic period (4.4 million BCE up to 10,000 BCE), man was nomadic and depended on what he located to feed, especially plants or part of them, such as fruits and roots. During the Neolithic period (12,000 BC to 4,000 BCE), the fire was discovered and along with it were creations and discoveries of hunting instruments. This allowed the inclusion of animal meat as an item of consumption in food. For this, man began to domesticate animals for his own consumption and began a process that, after degrees of evolution came to be known as agriculture (De Chardin, 2005; Lopes, 2010). During the 8,500 years that followed, agriculture has evolved slowly through trial and error for food and fiber production.

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Tools were replaced so that the work became more efficient, but the work was still slow. In the 18th and 19th centuries, agricultural innovation evolved, starting with inventions that allowed greater efficiency, organization and quickness in planting, such as the first mechanical sowing machine. During the 20th century, new technological advances pushed agriculture forward: machinery (replacing traditional equipment), use of fertilizers, pesticides, and improved seeds (Monsanto, 2015).

From the beginning of agriculture until the middle of the last century, the predominant food production system was based on small, almost self-sufficient family farms, in the so-called “Cutting Livestock”. The vegetables grew in vegetable gardens and orchards, side by side with the raising of goats, chickens and cattle, which supplied milk, eggs and meat. The grains were crushed in stone mills and consumed in the integral form, preserving the fibers and the natural benefits (De Chardin, 2005). However changes occurred after World War II, driven by a new rural image and use of technologies that help to technify beef cattle. One of these changes occurred in the control and regulation of food production and imports in the United States. A liberal, productivist food model called “American” was developed, which was quickly established also in Latin America, Asia and Africa, which depended heavily on beef production and this created an incentive for the industrial production of livestock and crops destined for their food. With the implementation of this model, from the point of view of production, agriculture underwent two fundamental changes: the change from a mixed grains model and cattle production to a regime specialized in grains and intensive operations of livestock raising, with ecological consequences (Belik, Maluf, 2000).

On the other hand, it is possible to observe another element that can also contribute to the cattle raising of the beef cattle to acquire an intensive operation every year - the population increase. It is observed that between 1900 and 2012, the world population grew from 1.6 billion to more than 7 billion (World Bank, 2014f). As cities grew, crops were moved to places farther from urban centers, which made it necessary to build railroads and roads to enable them to transport food. Vegetables and other fresh foods gave way to people's trade and table for products that could be transported more easily and last longer. During the twentieth century, the consumption of industrialized foods was intensified, due to behavioral and routine changes to the lifestyle suffered by the population. But even contemplating behavioral changes, agricultural production was driven to increase its level of production and include in its business model techniques that contemplated the cultivation of a variety of foods and fresh and continuous supply (Monsanto, 2015).

According to FAO data (2014a) the world population will grow better by 2030, with 3050 kilocalories per day available per capita, compared to the 2360 daily kilocalories available per capita in the sixties and the 2800 available today. This change reflects, above all, the increase in consumption in many developing countries, where the average will be around 3000 kilocalories per capita in 2030. This increase in consumption generates a tendency towards obesity (or overweight). The World Health Organization (WHO) points to obesity as one of the biggest public health problems in the world. The projection is that, by 2025, about 2.3 billion adults are overweight; and more than 700 million, obese (Abrego, 2015; Carvalho, Rocha, 2011).

Based on the facts exposed so far, a reasoning in another area arises. With the world population expected to reach 9 billion people during the 21st century (FAO, 2013), the demand for food production, especially in livestock, increases and for that, the consumption of natural resources used in the production and cultivation of food also tends to increase accordingly. And because some of these resources are limited, there is a tendency to intensify this depletion, aggravated by increased pollution, resource disputes and the consequences of an atmosphere that is rapidly heating up by greenhouse gas emissions. All these factors can still produce economic impacts, significantly affecting the Gross Domestic Product - world GDP. All these effects will be gradually noticed with accumulated effect for generations to come (Meadows et al., 2004, pp. 53-54).

Concerns are expressed that agriculture may in the not too distant future not be able to produce the food needed to feed a growing world population with levels sufficient to lead a healthy and active life. In the year 1700, only 7% of the land surface was used for agriculture. Currently this area adds more than 40%. However only a remaining part of the land is currently suitable for cultivation (FAO, 2014a). A second concern is with the environment. According to FAO (2013), global health, human health and future food security depend on how we treat the planet and ensuring well-being is synonymous with respect for the environment, so that sustainable prosperity long term is a reality for humanity. In this way, agriculture faces a choice: on the one hand the need for continuous food production, and on the other, the need to conserve limited natural resources for future human generations.

According to data from FAOSTAT (2014), in 2014, 44% of the total cattle population is divided between Brazil (14%), India (13%), China (8%) and the United States (6%). Among the three main commercial cattle herds (Brazil, the United States and China), the Brazilian presented the highest growth rate in the period 1993 to 2014. In the current global scenario, producing sustainable beef can result in generous and positive effects for the mitigation of harmful effects on the environment. This can be achieved through appropriate water and soil conservation, adoption of low greenhouse gas emissions technologies, and integration of crop-livestock, adequate management of production, adequate and adequate production and harvesting of production harvested. However, sustainable beef production is recognized by many producers as a challenge away from the actual realization, especially accentuated by trends in the need for increased production (Monsanto, 2015).

Thus, it is possible to assume that changes are prudent, contemplating the consequences already addressed: change in the processes of cultivation and production of food (especially in livestock) and changes in patterns of production and consumption of food, both aiming at a reduction in the extraction of resources natural resources. (Morilhas et al., 2007; Quirino et al.,1999, pp. 32-33). In order to identify the limit of the natural resources of the planet were made using the indicator Ecological Footprint (Rees, Wackernagel, 1996; Wackernagel, Yount, 1998), but in them an indicator of sustainable food production and consumption was not identified (or specific for beef cattle) that considers current consumption, future growth and the variables that influence it. With all these reasoning presented, the scenario that underlies the objective of this research is created: to identify a level of global sustainable balance of beef production and consumption by 2040.

2. Literature Review

2.1 Earth and Its Natural Resources

The human being can be considered a tenant of the Earth, which depends on the availability of earth, energy, water and air on the planet for its survival. Overcoming the existing limits of these items means walking towards suicide and ecocide. The present situation presents, after 200 years of economic development, significant gains, propitiated by the Industrial Revolution, of reduction of the mortality rates and the growth of the life expectancy. Nowadays, on average, people live longer and better (WHO, 2014; World Bank, 2014e). On the other hand, mankind's average consumption has increased. Between 1800 and 2010, the world's population grew approximately sevenfold (from 1 billion to 7 billion people) (World Bank, 2014f) and the economy (GDP) increased about 50 times (World Bank, 2014d). But the growth of wealth has occurred at the expense of the pauperization of the planet, that is, excessive use of natural resources, especially non-renewable ones (WTO, 2010).

According to Bittencourt (2012), agriculture affects air quality and the atmosphere in four ways: carbon dioxide production due to fires; methane from rice and livestock production; nitrous oxide from fertilizers and manure; and manure and urine ammonia. Biomass burning for the clearing of the soil for planting emits pollutants into the atmosphere and this is a very common practice in tropical agriculture, either to stimulate the development of fodder for the herds or to clear the land for new plantings, mainly in the case of rice, but whose pollution extends to regions beyond the origin of the fires (Bittencourt, 2012, p. 134).

For some countries the emission of greenhouse gases by agriculture represents an important part of total emissions, although this is rarely the dominant emission type. This share of gas emissions from agriculture can grow as emissions from industrial production and energy grow less rapidly. There is also concern about other sources of emissions, such as methane, nitrous acid, and ammonia, which in some countries may account for about 80% of total greenhouse gas emissions from agriculture (Morilhas et al., 2009).

2.2 Ecological Footprint

Within this perspective, possibly the most influential effort to solve or overcome problems of aggregation and economic and environmental weighting through indicators was the methodology of the Ecological Footprint (EF) (or the so-called Ecological Footprint). It has been proposed for about 18 years, both as an approach and a method, which aims to determine the degree of (in) sustainability of activities and regions/countries (Odegard, 2011; Odegard, Van Der Voet, 2014).

The Global Footprint Network is a community that aims to establish international standards for EF methodology in order to establish it as a standard indicator of sustainability. EF applications vary from the study of the demand for resources at the global, national level to regional levels. Recent examples of EF applications at the international level are the “WWF - Living Planet Report 2014” (WWF, 2014) and the “Living Forests Report 2011” (WWF, 2011). Examples of nationally applied EF studies are: Exergy-based Ecological Fo- per Accounting for China (Shao, Wu, Chen, 2013), “Accounting for demand and supply of the biosphere's regenerative capacity: The National Footprint Accounts” (Borucke et al., 2013), “Ecological Footprint Time Series of Austria, the Philippines and South Korea for 1961-1999” (Wackernagel et al., 2004). Under the theme of food and/or agriculture, some EF-based models have been researched to analyze the future of food (Agostinho, Pereira, 2013; Blair, Sobal, 2006; Cerutti et al., 2010; Cerutti et al., 2011; Cerutti et al., 2013; Kissinger et al., 2007; Mózner, 2014; Saravia-Cortez et al., 2013).

The EF compares the biocapacity described by various natural resources (agriculture, pasture, forests, fishing, built area, energy and area required for carbon dioxide absorption) with different classes of consumption (food, housing, mobility and transport, services, government and infrastructure) and aims to assess the pressure of human populations on natural resources and has become an important environmental and urban management tool that allows for mitigation actions that can be taken to reduce impacts. The EF of a country, state, city or person corresponds to the size of the terrestrial and marine productive areas necessary to sustain a certain lifestyle. It is considered a way of translating, in hectares, the extent of territory that a person or a society uses to live, feed, move around, dress and consume goods in general (Rees, 1992, pp. 124-126). EF is popular, not only because it supposedly provides a general indicator for environmental or impact pressure, but also because it resonates with the notion that human activities should not exceed the capacity for assimilation of the environment, everyday decisions generate on the environment (Borucke et al., 2013; Herendeen, 2000).

Currently, the global EF average is 2.6 global hectares per person, while the biocapacity available for each human being is only 1.7 hectares globally. This puts humanity at a severe ecological deficit of 0.9 gha/cap, or, in other words, humankind consumes a planet and a half, thus exceeding the planet's regenerative capacity by 50 percent. Since the mid-1980s, mankind has begun to consume more than the planet naturally offers and remains above the necessary boundary of a planet. Projections for 2050 indicate that if humanity continues to do so, greater ecological capacity will be required to maintain the same pattern of consumption. The EF of mankind has more than doubled since 1966 and currently stands at 2.9 global hectares per capita, indicating that the average consumption of natural resources by the Brazilian is very close to the global RB (Ven Den Bergh, Grazi, 2014, p. 10).

An example of this is that in 1961 only 63% of the Earth was needed to meet human demands. But by 1975, 97% of the Earth was needed. In 1980, 100.6% of the Earth was required, so more ecological capacity was needed. In 2005, the figure was 145% of Earth. This means that it takes almost one and a half Earth to live up to the general consumption of humanity. In 2011 humanity approached 170% of the Earth. So close to two Earth planets. Following this rhythm, statistics indicate that by the year 2030 at least three Earth planets will be needed equal to the one that mankind lives on. If hypothetically if it wanted to universalize for all humanity the level of consumption that rich countries like the United States, the European Union and Japan enjoy, biologists and cosmologists say that it would take five Earth planets, which becomes irrational (WWF, 2014, pp. 32-33). The main objective of the EF methodology is to answer the question concerning the necessary condition for sustainable consumption: “Is human demand within the planet’s regenerative capacity?” (Kitzes, Wackernagel, 2009; Schaefer et al., 2006; Van Den Bergh, Grazi, 2014).

EF measurement is divided into two parts: the demand on nature (or Ecological Footprint, EF) and the ecological supply (or Biocapacity, BC), estimated for a defined period of time. On the demand side, there is the EF utilization feature (built-up areas, energy consumption and renewable resources), which is expressed in units of space or global hectares. On the supply side, BC aggregates the production of several ecosystems in a given area (such as arable land, pasture, forests or productive seas). The weighting factors harmonize influences or heterogeneous components and convert them into different units: (tonnes (t) or hectares (ha)) in standard units (Global Hectares, gha). Each global hectare equals an equal amount of biological productivity (Lazarus et al., 2014; Rees, 2001; Schaefer et al., 2006).

The measure translated into EF is the productivity of the resources needed during the specified time period (eg one year), the product selected (eg crops, animal product and etc.) and the type of land bound (eg, pasture, pasture, fishing area). In short, EF is a measure of the consumption (or demand) of renewable resources (crops, animal products, timber and fish) through the result of energy consumption and the use of urbanized areas converted into standardized production units — global hectares — gha (Lazarus et al., 2014).

The equivalence factor (in gha/ha) translates a specific type of land (such as arable land or forest) into one hectare. This equivalence factor represents the average potential productivity of the world of a given bioproductive in relation to the world average potential productivity of all bioproductive areas. For example, the average productivity of agricultural land is higher than the average productivity of all other land types, which are converted by applying their corresponding equivalence factor to be expressed in global hectares. Equivalence is the same for all countries, but varies from year to year due to changes in the relative productivity of ecosystem types or land use by environmental factors (such as weather patterns) (Lazarus et al., 2014). The equivalence factors are derived from the Global Agro-Ecological Zones adequacy index — GAEZ, which consists of an Agriculturist Model of Income (FAO, IIASA, 2000).

Biocapacity - BC is a methodology that answers the question: "How many renewable resources have been made available by the regenerative capacity of the biosphere (or are they produced by the various ecosystems)?" (Schaefer et al., 2006). BC represents most of the capacity regeneration of the biosphere.It is an aggregation of production of several ecosystems in a given area (e.g., arable land, pasture, forest, sea), some of which may also consist of built or degraded land. biological and with higher productivity per unit of area (Lazarus et al., 2014, WWF, 2011, 2014, 2015).

In 2004, Earth had 11.4 billion hectares of biologically productive land and sea for approximately a quarter of the planet's surface (2.3 billion hectares of oceanic and terrestrial water, 1.5 billion hectares of cultivated land, 3.5 billion hectares of pasture, 3.8 billion hectares of forests on planet Earth and 0.2 billion hectares of urban land). On the basis of this, it is vitally important to remember that one hectare (gha) is a unit of land that contains the average productivity of the Earth, ie it is a biologically productive universal unit, which includes its waste absorption capacity (Lazarus et al., 2014; Schaefer et al., 2006).

It should be noted that biocapacity depends not only on natural conditions but also on prevailing land-use practices (e.g., agriculture, forestry, etc.) (Galli et al., 2014). It is possible to identify in the specific income factor of a country discrepancies, which can be attributed to different levels of productivity of a land type and technological advances (Kaimowitz, Smith, 2001). In this way, each country can have its own set of income factors that suffer oscillations year after year. And again, the equivalence factor (in gha/ha) translates one hectare of a specific land type (such as pastures, forest areas, marine waters or built-up areas) into a global hectare. (Lazarus et al., 2014; Schaefer et al., 2006).

3. Methodology

The choice of methodological tools may seem to a layman in the subject, or even to an inexperienced researcher, a mere formality that every author must comply with, otherwise scientific texts will be considered incomplete or deficient. The fact is that the inadequate description of the methodological scope actually compromises the quality of the research, since it does not allow the reader to understand the essence of what the researcher intended when elaborating his work, much less if what he actually obtained is in agreement with the objectives. According to Dubé, Paré (2003), methodological rigor alone is not a sufficient element to guarantee the quality of the research, but there is also a need to meet minimum requirements to develop a research with quality and a high degree of relevance for the scientific community and society as a whole. In this sense, Marconi, Lakatos (2010) present fundamental conditions in the choice of methodological tools, among them the type of research, which will depend on several factors related to the research, ie the nature of the phenomena, the research object [...] and other elements that may arise in the field of research. The phases that constituted this research, along with its procedures are described in detail in the following subsections.

3.1 First Phase

Since researchers do not have in-depth knowledge on the topic of Natural Resources, this phase was based on the collection of information about the subject, together with the environmental consequences of the production and consumption of cattle. In addition, sustainability indicators for global production and consumption were analyzed and among those investigated, it was considered as preponderant to answer the research question initially defined the EF methodology. For this purpose, renowned sources on the subject, both national and the Brazilian Agricultural Research Corporation - Embrapa, were used as international sources, such as FAO, Global Footprint

Network, among others.

3.2 Second Phase

This second phase was composed of analyzes of the phases that compose the beef cattle (breeding phases, types of feed, appropriate soil and etc.). In addition, quantitative data on world production and consumption were verified. Initially, the Pareto Principle (Sanders, 1987), which is also known as the “80-20 rule”, was used to determine which countries account for 80% of world beef production (United States, China , Brazil, Argentina, Russia, Mexico, France, India, Italy, United Kingdom, Germany, Australia, Canada, Japan, South Africa, Colombia, Spain, Pakistan, Korea, Egypt, Uzbekistan, Venezuela, Ukraine, Indonesia and Vietnam) and 80% of world beef consumption (United States, China, Brazil, Argentina, Australia, Mexico, Russia, France, Germany, Canada, Italy, India, United Kingdom, South Africa, Colombia, Pakistan, Uzbekistan, Ukraine, New Zealand, Spain, Ireland, Japan, Venezuela and Uruguay) in historical series from 1980 to 2011. From this, these countries become the focus of the research. Data were collected from FAO (2014a). Next, production levels of beef (in tons), production per head (per arroba), of each of these countries were identified in the same historical series (1980 to 2011). Data were collected from FAO (2014a).

As social variables, data on consumption (in ton), consumption (grams/person/day), population size and GDP per capita of each of these countries were identified in the same historical series (1980 to 2011). The data used were collected in FAO (2014a); World Bank (2014e, 2014h). In addition, applying the EF methodology as the initial basis of the model (explained in Chapter 6), the analysis/inclusion of EF of only one ecosystem: Ef_Grazing or Pasture was defined as more appropriate to the study. These data in the same historical series (1980 to 2011) of EF used in this research were obtained through the Global Footprint Network (Global Footprint Network, 2016), which includes EF data of area, biocapacity, production, consumption, import and export converted into Global Hectare - Gha.

3.4 Third Phase

The third phase is initiated by the use of statistics to investigate issues. The question investigated is the consumption of beef by analyzing the relations between two variables (consumption and GDP per capita) in each of the countries in the same historical series (1980 to 2011). According to Hair Jr et al. (2005), when there is a coherent and systematic link between variables, it can be said that there is a relation and this relationship can be evaluated through associative techniques such as correlation and multiple regression. For all countries, the associative technique of regression was performed, remembering that the relationship sought is not necessarily causal, but the presence of it among variables and probable trend lines (Hair Jr et al., 2005, p. 310).

After the association analysis (multiple regression), an overall trend of bovine consumption was developed as a function of per capita income, based on consumption data for 2011. At the same time, the multiple regression equations of each country were used for projecting its future per capita demand, with the proviso that if projected per capita demand for 2040 were lower than current per capita consumption (2011), the current consumption should be maintained for projected per capita demand. Based on this calculation, the total country demand was projected for 2040. For the projected population and GDP per capita indices, data from studies developed by Coopers (2015) for 2050 were used. The biocapacity data used in the simulations were obtained by through the Global Footprint Network (Global Footprint Network, 2016) and was maintained in all simulations.

3.5 Fourth Phase

Based on the data collected and projected, some simulations were carried out for the year 2040, with the special objective of identifying a sustainable scenario, that is, reserve or equalization of biocapacity. The first simulation was based on the current global scenario of beef production and consumption, together with the resulting impacts. The second simulation followed the premise of projecting data on population, GDP per capita, per capita demand and total demand for 2040, making use of the efficiency of the use of natural resources used in 2011 and its resulting impacts. The third simulation aims to identify levels of consumption and production of beef that are sustainable or environmentally friendly by 2040. The fourth simulation is based on the application of a moderate level of efficiency to reduce the impacts of global beef production and consumption. After the simulations, global scenarios were developed for the production and consumption of beef. According to the methodology of elaboration of scenarios selected for this research, one of the stages consists in the validation by specialists of the scenarios developed. This validation was performed through interviews, conducted through a structured questionnaire. The selection of the interviewed specialists was done by searching for curricula in the Lattes Platform (http://lattes.cnpq.br/) by the key term of production “bovine beef cattle”, with researchers doctors of Brazilian nationality. A non-probabilistic sampling technique was used to obtain a suitable sample of respondents.The interview was conducted online, through a structured questionnaire, which addressed central issues concerning the production and consumption of beef in Brazil and in the World.

4. Conclusion

Considering the objectives of the research and the theoretical reference, this research gave rise to a construct of analysis, which subsidized the proposition of a prospective model that contemplates global scenarios and identifies a sustainable pattern of production and consumption of beef, through the combination of use of natural resources, economic variables, technological trends and global patterns of food consumption. Figure 1 represents the model of constructs adopted for this research, incorporating the elements that delimit its scope into five groups:

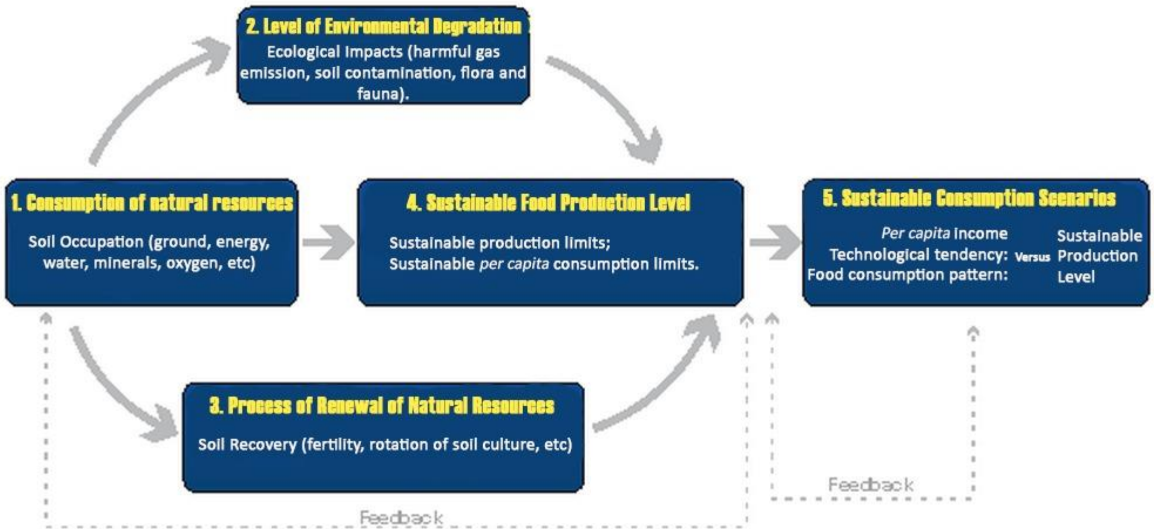

Figure 1 Research Constructs

Source: developed by the authors

1) Consumption of natural resources - in this quadrant were characterized the fundamental resources associated with the evolution of beef production: occupation of soil, energy, water, minerals and oxygen (explained in chapter 2 of this research and considered in the methodology Ecological Footprint).

2) Level of Environmental Degradation — In this quadrant, environmental implications were identified for the production of bovine meat: emission of harmful substances and gases, soil contamination, flora and fauna (explained in Chapter 2 of this research).
3) Process of Renewal of Natural Resources — based on the implications identified in the previous quadrant, ways to mitigate and renew the natural resources used in beef production were identified: recovery of degraded biomass, soil fertility, crop rotation and reuse/capture of water resources (explained in Chapter 2 of this research and partially considered in the Biocapacity of the methodology Ecological Footprint).
4) Sustainable Production Level — based on the analysis of the three previous quadrants, this level of the model is intended to identify a sustainable production limit associated with sustainable per capita consumption of beef. This is one of the objectives of the Ecological Footprint methodology — to be an indicator of sustainability, but it is applied in a general way and in this way the research is intended to carry out a direct application in cattle production.
5) Sustainable Consumption Scenarios — as a final part of the model and based on the implications of beef production and consumption, social (population), economic (per capita income and consumption pattern) and sustainability (biocapacity) indicators are analyzed along with indices of associated technological development to agricultural productivity (resource efficiency) versus sustainable levels of beef cattle production projected for 2040.

The use of natural resources (finite and non-renewable) of the planet Earth in a sustainable manner in the production and the global consumption of bovine meat are the guiding theme of this research. In order to answer and identify the proposed research question, a qualitative exploratory research related to beef production was carried out (with the objective of identifying the natural resources used in the project, consequences of the use and sustainability indicators), together with a qualitative and quantitative descriptive research concerning the phases of production, global consumption and variables influencing it. After the research, the development of a prospective model of sustainable level of cattle production and consumption was followed, followed by the phase of simulations and elaboration of predictive scenarios, which passed the validation of specialists, as contemplated in the methodology of Wright Jtc, Spers (2006).

In general, one can cite the main considerations regarding the constructs of this research:

1) Consumption of Natural Resources — it was possible to perceive, especially through the model created from the Ecological Footprint methodology that the fundamental resources associated to the evolution of beef production (such as occupation of soil, energy, water, minerals and oxygen) in fact, employed in the production and consumption of beef and have consequences that may jeopardize the future of the generations. However, even if we were aware of this, it was identified in interviews with experts that beef cattle raising does not have the practice of carrying out any method of measuring this or the preoccupation with adopting techniques that aim at reducing the consumption of natural resources, unless these are accompanied by gains in productive efficiency.
2) Level of Environmental Degradation — by the estimated trend in the research, it is possible to notice that the level of degradation tends to increase, if no changes are made in processes and production levels, adoption of new technologies or change of consumption habits. The developed model predicts, through the simulations, an increasing level of degradation, which is greatly reduced by technological advances aimed at increasing efficiency in the use of natural resources.

3) Natural Resources Renewal Process — ways to mitigate and renew the natural resources used in beef production were identified: recovery of degraded biomass, soil fertility, crop rotation and reuse/capture of water resources. These measures were contemplated in the scenario that provides for the application of advanced technology to the productive process of beef. According to experts interviewed, this process can be applied in parallel to the level of environmental degradation. However, there is still a need for producer awareness and government support for the application of advanced technologies.
4) Sustainable Production Level — based on the Ecological Footprint methodology, the model developed in the research presented a sustainability indicator, through some simulations, which indicated different levels of production and consequences for the biocapacity of the countries analyzed. The method indicated the need for some changes in the economic and social way of dealing with beef production and consumption so that a sustainable level is achieved.
5) Sustainable Consumption Scenarios — through the elaboration and analysis of scenarios constructed for the global production and consumption of beef, it was possible to identify different optics, with different implications. However, all scenarios had in common the quest for sustainability by mitigating the impacts caused by the use of the planet's natural resource biocapacity.

Although there is a subjectivity present in any research in the field of social sciences, it is possible to say, based on the considerations made in this research and literature investigated (related to natural resources and environmental impacts, sustainability indicators and scenarios) that investigations can be extrapolated to other sectors, making use of the model of production and sustainable consumption of beef, with the necessary adaptations. This becomes applicable because the research was structured through a scientific methodology, with defined steps and procedures.

For the selection of the experts interviewed, we sought researchers with training and adherence to the theme, in addition to some of them having professional experience in the researched area. Based on the model, the theory that based it and the other theories studied for the elaboration of this research, a structured questionnaire was developed for interviews. In the research and especially in the interviews, we sought to identify the patterns observed for difficulties and differentials in Brazilian production compared to other large producers, technologies, application of sustainability, trends in global consumption of beef.

The research indicated 4 plausible scenarios of production and consumption, in which only 1 of them guarantees the balance and the global sustainability in the use of resources.The research, using the developed prospective model, indicated a horizon of consequences arising from the current production process and consumption of global beef, accompanied by social consumption trends, influencing economic variables and future technologies, and at the same time indicated measures and actions potential that can modify this coming horizon to a prosperous horizon in the natural sustainable sense of the planet.

Through the model and their respective scenarios, it was possible to analyze that although there are different levels of global production and consumption, it is possible to effectively seek global sustainability through a change of efficiency in the use of natural resources, technological advances and the implementation of public production policies. Through the research it was also possible to perceive that the application of techniques of prospective scenarios are of paramount importance for academic advances and the decision making of managers. Future studies can be carried out to apply this model in different production and consumption chains, aiming at the preservation of the environment for future generations of humanity.

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