Modern Environmental Science and Engineering (ISSN 2333-2581)
October 2019, Volume 5, No. 10, pp. 964-978
Doi: 10.15341/mese(2333-2581)/10.05.2019/010
Academic Star Publishing Company, 2019
www.academicstar.us

Modeling of Scenarios and Indicator of the Ecological Footprint for the Projection of the Production and Consumption of Beef in Brazil in 2040

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Abstract: Brazil, through decades of investment in technology that has raised not only productivity but also the quality of Brazilian beef, is among the most important beef producing countries in the world, becoming competitive with its product exported to over 150 countries. Beef production is accompanied by an increase in the consumption of natural resources on the planet, which among its impacts can be mentioned an atmosphere that is heated by greenhouse gas emissions. With this, Brazilian agriculture faces a choice: on the one hand the need for continuous production of beef, and on the other, the need to conserve limited natural resources for future human generations. In view of this, the search for technological efficiency in the use of resources becomes a target, but still treated in a secondary way by the segment. To meet the need to identify the limit of the planet's natural resources different ecological indicators have been developed and one of them is the Ecological Footprint. With all these reasoning presented, we create the panorama that grounded this research: the prediction of a future for the production and consumption of Brazilian beef, identifying its impacts and possible alternatives to mitigate the environmental impacts. To elucidate this scenario, this research was 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

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. [1, 2]. During the 8,500 years that followed, agriculture has evolved slowly through trial and error for food and fiber production. 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

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agriculture forward: machinery (replacing traditional equipment), use of fertilizers, pesticides, and improved seeds [3].

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 [1]. 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 [4]..

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 [5].. 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 [3].

According to FAO data (2014a) [6] 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 [7, 8].

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 [9], 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 [10].

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 [6]. A second concern is with the environment. According to FAO (2013) [9], 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.

In the current global scenario, sustainable beef production can result in generous and positive fruits to mitigate the 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 [3].

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 [11, 12]. In order to identify the limit of the natural resources of the planet, the indicator Ecological Footprint [13, 14], was used, but an indicator of sustainable food production and consumption (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 key question of this research is created: Why is integrating the indicators of the ecological footprint into the production and consumption of global beef beneficial for the future?

2. Background

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 [15, 16]. 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) [5] and the economy (GDP) increased about 50 times [17]. 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) [18], 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 [18].

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 [19].

According to Fao et al. (2014) [6], in 2014, out of a total of 1.4 billion head, 44% of its concentration is divided between Brazil (14%) India (13%), China (8%) and the United States (6%). Among the three main commercial herds (Brazil, the United States and China), the Brazilian presented the highest growth rate in the period 1993 to 2014 and out of a total of 63 million tons of meat produced, 48% of its concentration is divided among 4 of the 5 largest cattle producers: United States (18%), Brazil (15%), China (10%) and Argentina (4%).

As Brazil is present both in the ranking of the largest cattle producers and in the largest beef producers, it will be considered a reference for the analysis of this study, in terms of production and livestock productivity. Considering the total of the Brazilian bovine herd, about 90% is made up of cattle, whose production system is destined to the production of meat. For the purposes of this research, Brazilian production data were selected as parameters, since the country has the second largest cattle herd in the world and the first largest commercial herd. The country is also the third largest exporter of meat in tonnes and in billing..

The system of production of beef cattle has as a characteristic the application of a set of technologies and management practices, as well as the type of animal, the purpose of the breeding, the breed or genetic grouping and the ecoregion in which the activity is developed. It is possible to say that Brazil maintains the world leadership in export, both in quantity and in financial volume. Several factors have contributed to the increase in Brazilian exports in recent years, including sanitary aspects, improvement in the quality and precocity of the Brazilian herd, higher demand for food by emerging markets and lower production costs of the national product in relation to its largest competitors [6].

The herd, meat production, domestic consumption and exports have increased in recent years, although per capita consumption has stabilized with a slight decline in the year 2013. There is a prospect of increasing world consumption by 1.5% per year and may reach up to 76 million tonnes in 2022. In turn, domestic consumption accompanies the growth of per capita beef (currently 36 kg, reaching 59 kg in 2030), which will directly reflect the growth of the meat market [6].

The predominant cattle herding in Brazil, based on the use of forage plants adapted to the climate and soil conditions of the region and the limited use of inputs and present in the economic scenario for many years, has undergone a marked development in the last decades through expansion of the agricultural frontier, with the incorporation of new lands, mostly deprived of infrastructure and having wear of the soil by the intensive system of grain production [8]. However, it can be considered as a possible activity to be implemented and conducted with relative success, without the need for more careful preparation of the land, or more intensive use of inputs, technology and manpower. That is, in livestock production it is possible to produce, although with low efficiency and perhaps because of this, the country has suffered environmental and market pressures, to increase the availability of technology (technologies of recovery and management of pastures, launch of more productive cultivars of grasses, genetic improvement of the herd and etc.) with incentive the change of attitude for the productive sector of meat.

In order to make good pasture and grazing management, a work is done to increase the pasture area (supply) to provide more food to the same herd, meeting the necessary demand. This process can be characterized as the “primary phase” of expansion of livestock in areas of agricultural frontier, in which increased production is achieved, especially with the useful expansion of pasture areas.

In recent years a search for bovine production has been observed in a more professionalized and vertical way, with a movement of incorporation of technologies to the sector, supported by some investments in pasture formation, recovery or reform, but mainly in investments in quality of the herd and this is called by DIAS-FILHO (2011) of "secondary phase". In this context, it is possible to highlight the advanced use of genetic studies, which contributed to the identification of characteristics that produce greater weight gain and reduction in fattening time of the animal, and which at the same time made it possible to cross and later acclimatize to the country of breeds, in addition to the development of artificial insemination processes, resulting in higher productivity of livestock production.

The main processes in grazing food production systems are the use of light energy and the supply of nutrients for the growth of the forage plant. In animal production systems, two other stages are of great importance: (1) plants must be consumed by animals and (2) converted into animal products. Each of these stages has its own efficiency and can undergo management influence and contribute to the efficiency of the process as a whole, which has as its essence the effective balance between the deficiencies of the productive process: growth, utilization and conversion.

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 [20, 21].

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 international level are the "WWF — Living Planet Report 2014" [22] and the report "Living Forests Report 2011" [22]. Examples of nationally applied EF studies are: "Exergy based Ecological Footprint accounting for China" [23], "Accounting for demand and supply of the biosphere's regenerative capacity: The National Footprint Accounts' underlying methodology and framework" [24], "Ecological Footprint Time Series of Austria, the Philippines and South Korea for 1961-1999" [25]. Under the theme of food and/or agriculture, some EF-based models have been researched to analyze the future of food [26-33].

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 [34].

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 [24, 35].

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 EF [36].

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 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 [22]. 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?" [36, 37].

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 [37, 38].

The measure translated into EF is the productivity of the resources needed during the specified time period (e.g., one year), the product selected (eg crops, animal product and etc.) and the type of land bound (e.g., 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 [38].

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) [38]. Equivalence factors are derived from the Global Agro-Ecological Zones — GAEZ adequacy index, which consists of an Agriculturally Income Model.

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)?" [37]. 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. The Earth's BC increases with higher biological productivity and higher productivity per unit area [22, 38].

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, i.e., it is a biologically productive universal unit, which includes its waste absorption capacity [37, 38].

It should be noted that biocapacity depends not only on natural conditions but also on prevailing land-use practices (e.g., agriculture, forestry, etc.) [39]. 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 [40]. 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 [37, 38].

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, and Paré (2003) [41], 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, and Lakatos (2010) [42] 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, i.e., 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.

Since the researcher does 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.

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 [43], 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) [16, 44].

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 [45], which includes EF data of area, biocapacity, production, consumption, import and export converted into Global Hectare-Gha.

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 [46].

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) [47] for 2050 were used. The biocapacity data used in the simulations were obtained by through the Global Footprint Network [45] and was maintained in all simulations.

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 doctor level researchers 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. Analyses and Result

Considering as a premise that Biocapacity (Bi) refers to the Natural Resources available in the environment for livestock, the model of Production and Sustainable Consumption of Beef, developed in this research from the EF methodology. From the developed model, simulations were developed to identify the changes in Biocapacity and the measures to be taken to balance or achieve sustainability in global consumption and production of beef (see appendices).

Subsequently, prospective scenarios were developed for 2040, with a focus on Brazil and its role for world production, in order to forecast the future of global beef consumption and production. Each of the scenarios presents in its title the main feature of the scenario. As described in the methodology subtitle of this research, the scenarios were elaborated using the methodology developed by Wright and Spers (2006) [48], in which three possibilities of visions of the future are described: the extrapolative, exploratory and normative view, following the steps.

1) Scoping and Scenario Objectives: Scoping scenarios should permeate sustainable global beef production and consumption with the objective of identifying a sustainable pattern by combining the use of natural resources, economic variables, technological trends and global patterns of food consumption.
2) Identification of key variables, trends and events: Once the scope and objectives of the World Beef Production and Consumption scenarios were defined, and an analysis of the current scenario of the sector, it was possible to identify a list of the main variables of the scenarios: (1) GDP per capita; (2) Population Consumption and Food Standard; (3) Sustainability and use of natural resources; (4) Impacts caused by livestock to the environment; (5) Technology in cattle beef cattle.
3) Structuring the scenario variables: In this sense, it was possible to identify relevant invariant factors for World Beef Production and Consumption, such as population growth and GDP per capita, as well as the association of these variables with consumption. sector.

The division of variables was developed based on the technique of Analysis and Structuring of Models, developed by Wright (1991):

- Variables resulting: continuous reduction in biocapacity, deforestation.
- Intermediate variables: emission of polluting gases, deforestation, soil pollution.
- Causal variables: increase in GDP per capita, diversity of meat consumption, population growth.

4) Projection of future states of variables: The technique used in this step was the simulation, making use of qualitative and quantitative data. The simulations, explained in Appendices B-E, were carried out using the model developed in this research.
5) Identification of driving themes: Based on the simulations carried out in the previous stage, five driving themes were defined:

- Most likely scenario: Current Scenario
- Scenario 1: Scenario 2040 with Current Technology
- Scenario 2: Scenario 2040 with Moderate Technology
- Desired Scenario: 2040 Scenario with Technology in Search of Sustainability

6) Assembly of a morphological matrix of scenarios: An analysis was performed, together with the consistent combination of all the variables of the scenarios, generating a scenario matrix, which served as the basis for the writing of scenarios for the Production and Sustainable World Consumption of Bovine meat in 2040.

This scenario is based on the measurement of population data, per capita consumption, GDP per capita, EF, Production, Area for Livestock, Biocapacity and Biocapacity per ton of the year of 2011.

It is possible to notice that, in general, there is a reserve of biocapacity of 181 million Gha, attributed especially by Australia, Argentina, Brazil and South Africa. On the other hand, there are countries with a high biocapacity deficit, with special emphasis on China , Italy, Japan, which together provide a deficit of 66 million Gha.

One of the most important information in this scenario is the Biocapacity used per ton produced from meat, defined in the research model as Efficiency in the Use of Natural Resources. The countries that use the lowest levels of Biocapacity are Korea, Pakistan, Japan, Italy and Vietnam.

Although Brazil has a remarkable reserve of biocapacity, its Efficiency in the Use of Natural Resources is the 10th worst of the countries analyzed. This indicates that there is a possibility of technological improvement that will increase efficiency and, consequently, increase productivity.

Also noteworthy are Australia and Argentina, which have a high Biocapacity reserve, but with a situation similar to Brazil — low productive efficiency. Australia has great potential, but due to the drought suffered in the region, the soil was weakened, and this caused loss in the natural bank of pasture seeds, making it difficult to increase the cattle ranching and promoting a stagnation of the sector in the country.

In this way, it is understood that there is an opportunity to improve efficiency and increase productivity, which can contribute to the country's competitiveness and increase the position among global beef producers.

Scenario 2: Scenario 2040 with Current Technology

Projections indicate that there will be an increase in population and a reduction in the world poverty level, which may lead to increased food consumption in developing and underdeveloped countries. Highly populous Asian countries like China and India will lead to a substantial increase in the consumption of animal proteins, especially beef. However, at the same time that consumption is adjusted, ecosystems need to be preserved, that is, it is necessary to increase production without impacting the environment.

Recent research by Embrapa indicates that the increase in demand for Brazilian beef is linked to the preservation of natural resources [49]. Thus, tons of meat will be produced with high productivity so as not to negatively impact the environment in which the animal is inserted, using land and water rationally and integrating animal production into the existing ecosystem. The challenge of Brazilian and global cattle production is to increase productivity and herd without expanding the area available for production and for this technology plays an important role.

Pasture degradation is one of the main signs of the low sustainability of livestock farming in the different Brazilian and world regions. The inadequate management of the herd is considered as the main cause of this degradation and among the main problems of Brazilian livestock are the degradation of pastures and soils; inadequate animal management; the low replenishment of nutrients in the soil; the physical impediments of the soil; and low technological investments. These restrictions have the negative consequences: the low supply of fodder, low zootechnical indexes and low productivity of meat per hectare, in addition to reduced economic return and inefficiency of the system.

The most used current technology involves the application of integrated production systems (crop-livestock or livestock-forest or crop-livestock-forest), which diversify production and maximize land use, increasing the profitability of the area.

Within this scenario, due population growth was projected, GDP per capita and per capita consumption equated to GDP per capita, remaining static the Biocapacity available for livestock and maintaining the same Efficiency in the Use of Natural Resources, considering that there will be no progress 2040, but the same processes and production systems will be maintained today.

The result of technological stagnation is perceptible in this scenario through a serious imbalance in global biocapacity, resulting in a deficit of 413 million Gha, attributed especially to China (responsible for 330 million Gha), Brazil (with 36 million Gha) and Russia (with 22 million Gha).

In this way, it is possible to understand that through the projections carried out, the technological stagnation in cattle raising brings serious impacts to the environment and makes its production and consumption unsustainable ecologically.

Scenario 3: Scenario 2040 with Technological Advancement Moderate

In this scenario, the projected growth in population, per capita GDP and per capita consumption are projected to be equal to GDP per capita, with the availability of available biocapacity for livestock farming remaining static and adding 10% to the level of Efficiency in the use of natural resources in each of the countries.

Scholars argue that some of the techniques of moderate efficiency of pasture and planting management result in improved soil fertility and tend to produce yields of 30 to 40%, per animal and per area. Some of these technologies involve covering and restoring grass. And with this, the technique of crop-livestock-forest integration (iLPF) has been a good option in many countries for moderate technological advances in cattle raising.

Through this scenario, it is possible to identify that the overall negative balance of biocapacity shows a reduction of 67% (compared to Scenario 2), remaining at 277 million Gha. And of this negative balance, China is allocated 283 million Gha, that is, Australia still contributes a positive balance of biocapacity to around 69 million Gha.

In addition to China, Russia, Mexico, Brazil, and Venezuela present contributions to the deficit in global biocapacity, totalling 52 million Gha.

In this way, it is possible to understand that even with a moderate technological advance of 10% in Efficiency in the use of Natural resources of each one of the countries, there is no change to a level of production and consumption of sustainable beef.

Scenario 4: Scenario 2040 with technology for sustainability

Producing more with less, application of genetics to increase productivity and profitability of herds, pasture management with iLPF, strategies for bovine reproductive efficiency — are some of the advanced technologies available for bovine production.

In intensive systems, additive supplementation becomes a powerful weapon to exploit to the maximum the genetic potential of the animals, as well as the fodder and supplement offered. Among the additives available on the market, organic products are highlighted in the scenario of sustainable production, because they act effectively and do not impact the environment. Brazil has a predominantly tropical climate, which favours the production of high-quality fodder crops and high productivity in the rainy season. Ruminants are able to take advantage of fibrous food and live based on fodder diets and, in this way, beef can be produced in a sustainable manner and without direct competition with human food [49].

Supplementation has gained importance for all animal categories and in all periods of the year, and can vary according to the desired productive indexes —

from the most extensive, with slaughter of animals from 48 months to the most technical, with slaughter of animals of 24 months , which has greater capacity of stocking, doing the basics: takes care of the pasture, supplements correctly and offers quality water.

Some scholars assume that advanced technology, correct pasture management, available quality water and organic supplementation are the basis for the success of beef cattle production. In this way, the future of beef cattle production in Brazil is linked to the increase in productivity in a sustainable way, with adequate integration of the available technologies in the market to the existing management system in the property, producing quality meat in quantity and above preserving natural resources.

In addition, Brazil has a total available arable land estimated at 152.5 million hectares or 17.9% of the territory, of which 62.5 million hectares or 7.3% of the territory is made up of the arable land already used. Researchers indicate that there is a potential for expansion of agriculture and livestock, especially in the cerrado region, corresponding to 90 million hectares or 10.5% of the territory, corresponding to the arable areas available and not yet used. These data indicate that the advance of agriculture and livestock in Brazil need not occupy reforestation, nor deforest areas for planting soy or any other crop, but using degraded areas or intensifying cultivation in areas already available for agriculture would already be enough to significantly expand agriculture and livestock production in Brazil, increasing both the production and the level of employability, in addition to increasing the volume of exports.

This scenario provides for the application of advanced technology, which until then is mentioned and considered, but little applied effectively in beef cattle breeding in Brazil and the World to achieve sustainability. In the scenario it is identified that it would be necessary to add 30% to the level of Efficiency in the Use of Natural Resources of each one of the countries to search for sustainability.

Amidst a global sustainable scenario, China still has a severe biocapacity deficit of 186 million Gha, which is balanced by reserves from Australia, Brazil, USA, Uruguay, New Zealand, Colombia and South Africa, which could be prone to exporters to meet the projected demand of China.

With the inclusion of the technological advance of 30% of the scenario, there is the result of Sustainable Efficiency in the Use of Natural Resources of each one of the countries. It is possible to compare the level of Efficiency in the Use of Natural Resources with moderate and advanced technology and to conclude that among the big producers and consumers, the USA is the country with the lowest rate for achieving sustainable efficiency with advanced technology.

With this scenario, it is possible to conclude that the overall sustainable level of beef production and consumption is feasible, provided that significant technological advances occur.

5. Conclusion

In the scenarios developed, a considerable increase in the demand for beef is forecast, and production will continue to be led by the US, followed by China, Brazil and Argentina. According to Rural Center (2012), some factors will be responsible for boosting beef productivity in the future:

• World population growth (forecast of about 9 billion people in the coming decades);

• 70% of the population is concentrated in the urban area and thus has easy access to consumption;

• Increase in the per capita income of the world population;

• Westernization of consumption, that is, more people consuming different types of meat, especially beef.

Based on the expected increase in demand, some countries have greater potential to increase their beef productivity. Brazil and a part of the African continent have availability of area, incidence of rains, temperature, luminosity and water resources favourable to the increase of production. In Brazil alone there are approximately 333 million hectares that can be used in cattle production, without the need for deforestation.

Brazil will continue to be the largest exporter of beef in volume and at low cost. Thus, despite their low cost, Brazilian cattle ranchers have one of the lowest rates of return on livestock investment among the largest exporting countries (the front only of South Africa, Colombia and Australia). This will lead to increased production for higher return on investment in volume produced and traded, especially in export, while maintaining the same level of technology used in 2011.

In the United States, the drought of the past forced the slaughter of the herd of females and the removal of part of the herd from the South to the North for lack of water. Consequently, confiners and industries have lost investment and the consumer population is disbursing high value for the consumption of American meat. This has led countries importing American beef to reflect on it and turn to other major exporting countries, such as Brazil.

In China, the total cost of livestock production varies because different types of fattening systems are used. And because of this, the return on investment of the products also suffers variation. Consequently, the country continues to be a major exporter of beef.

Thus, the scenarios foresee an optimistic future especially for Brazil, in economic issues related to its position as a world producer of beef. Considering sustainable optics, the scenario provides for reduced reserves of biocapacity in some producing countries, and a continuous increase in the deficit in its majority, and especially in Brazil, if it develops a strategy to become the largest producer and seize the opportunities that arise for export in countries with productive difficulties, there will be a significant increase in the deficit and, consequently, a high level of unsustainable production. On the other hand, if it adds significant technological advances in its production, it becomes one of the most sustainable global productions with biocapacity reserves.

Among the main difficulties of beef cattle production in Brazil and in the world are the unfavourable financial scenario for the use of technology to promote productivity, but in view of this, some corrective actions involving public and private policies could be implemented to the correction of bottlenecks and reduction of environmental pressure by sustainable production conditions. In addition, the low adoption and diffusion of basic technologies make productivity low and, in some ways, inefficient.

On the other hand, Brazil has differentiated itself from other large beef producers due to its potential to increase Brazilian productivity, low production costs and climate and abundant water resources, allowing the Brazilian productive chain to offer the market a product that is difference in flavour and production model. However, once this productive superiority exists, it can be maintained if the most advanced technologies are adopted and deployed in order to improve current production techniques.

When referring to technology, this is not always associated with sustainability, which is often applied in an abstract way or is related only to preservation areas, when in fact it could be applied in all aspects of the production and consumption chain of cattle beef cattle, allowing the broad sense of the term (economic, social and environmental pillars) to be fully applied.

According to experts responding to scenario validation, the trend is for an expansion in beef demand, especially in emerging countries such as China, Brazil and India, and that per capita consumption will progress according to the historical patterns of GDP per capita, while technological advances will advance according to the demand for beef.

With respect to the scenarios developed, opinions are not unanimous. For the most part, Scenario 2 was considered as extrapolating. This happens because the opinion of experts indicates a promising future to technological advances in beef cattle. However, most identify that Scenarios 3 and 4 are between the exploratory and normative, with capacity to be realized, if there are deep foundations. Thus, it is in the interest of both agriculture and the economy of the countries involved to predict scenarios, whether they are optimistic or pessimistic about such a socially and economically important activity.

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