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Possibilities for Sustainable Development in Corn Intensification Scenarios

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Summary. Agricultural activity is a trigger for economic development in Sinaloa, Mexico; corn is the most outstanding crop; however, production processes are far from sustainable development. Therefore, the objective is to analyse the aspects inherent to the intensification of corn cultivation from the perspective of sustainable development, examining the economic, social and environmental contexts of the corn cultivation process at a global, national and Sinaloa state level. This research was designed as a descriptive-explanatory study with a qualitative approach. The results indicate that there are several challenges that farmers face when moving agricultural processes towards sustainable development, such as lack of information, lack of innovation, risk aversion and resistance to change; in spite of this, the consequences of applying sustainable agricultural practices are positive, generating higher production and care for natural resources. Despite the effects that agriculture has had on the environment, changing the approach and restructuring corn production with a focus on sustainable development is the way forward to ensure that this activity can continue to develop over the years.

Keywords. Sustainable development, corn cultivation

1. Introduction

Corn is the most representative crop in Mexico due to its contribution to the economy and to society's food needs, as well as its social and cultural impacts. The state of Sinaloa stands out in the production of this grain, generating the largest volume at the national level [1]; even though the influence of this product on the agricultural sector is important, we cannot ignore the negative environmental externalities generated by corn cultivation, such as the depletion of water resources and pollution [2], factors that call into question the sustainability of its production processes.

Agricultural sustainability involves the management of a complex interaction between soil, water, plants, animals, climate and humans, with the aim of generating economically viable production that is appropriate to the environment and the development of the society in which it is carried out [3]. The pursuit of this sustainability brings with it the challenges of meeting ever-increasing demand, securing natural resources, building resilience to disasters, conflicts and crises, and making agricultural production systems more efficient and inclusive, capable of coping with emerging threats to agriculture and food systems [4].

In a study by Hopwood et al. [5] on agricultural sustainability, they propose an ecologically and equity-focused approach to the transformation of production processes, recognizing the growing environmental and social problems. They discuss the need for social transformation to avoid crisis and possible economic collapse, and consider social critique and stakeholders as necessary factors to overcome the environmental crisis. Table 1 shows some studies that have been located in the reformist approach to sustainable development, in which the statements of the Brundtland Report are taken up again with the focus on social change, where economists and market regulations for ecological sustainability are found, where they have also begun to focus on the proposal of Amartya Sen's theory of development as freedom and Sachs' theory of ecodevelopment.

Table 1. Trends in sustainable agriculture research

Source d	Year	Objective	Results
Theoretical approach to Sustainable Development: Ecologically focused transformation			
Foguesatto *et al.*	[6]	Review the factors influencing the adoption of sustainable practices in the world.	Factors influencing the adoption of sustainable practices are farmer characteristics, financial, exogenous and psychological.
Tiammee y Likasiri	[7]	Apply green management to corn production to reduce environmental impacts.	Corn residues can be used as feedstock to produce biomass fuel briquettes and fertilizers.
Li *et al.*	[8]	Propose a model for optimal irrigation water allocation in an efficient way and determine impacts on agricultural sustainability.	Water was considered as the decisive variable for economic profit and environmental pollution. A higher water allocation favored the sustainability of the system.
Ehiakpor *et al.*	[9]	To examine the drivers of sustainable agricultural practices, their interdependencies and the intensity of their adoption in corn in Ghana.	The drivers found are: use of improved seeds, rotation from corn to legumes, use of animal manure, retention of crop residues, zero tillage, integrated pest management and use of chemical fertilizers. Influencing factors are farmer age, experience and plot size.
Theoretical approach to Sustainable Development: Reformist			
Pang *et al.*	[10]	Achieve sustainable agricultural development and a rural economy based on a new system for assessing the quality of water and soil conservation.	Quality assessment contributes to the reduction of errors in quality control measures in accordance with water and soil conservation.

Laurett *et al.*	[11]	Understanding the antecedents, barriers and consequences of sustainable agricultural development, from the farmers' perspective.	Farmers perceive sustainable development to be focused on environment and resource conservation and financial solvency. Barriers to sustainable agricultural development are: lack of finance and support, lack of innovation, lack of leadership, resistance to change, lack of technical support, excessive legislation, risk aversion.
Theoretical approach to sustainable development: development as freedom			
Sarkar *et al.*	[12]	Ensure food security that safeguards natural resources for human well-being and to achieve the SDGs.	It is recommended to apply the LISA model of low-input agriculture to produce food indefinitely and profitably without damaging natural resources.
Theoretical Approach to Sustainable Development: Ecodevelopment			
Priyadarshini and Chirakkuzhyil	[13]	Identify the main social and environmental challenges affecting agriculture in India.	The adoption of agricultural practices throughout the production process together with value addition and rational distribution will influence the economy by boosting yields and restoring biodiversity and ecological stability, as well as reducing negative impacts, social and economic inequalities.

The above studies indicate a trend towards a link between agriculture and sustainable development, which will reduce the pressure that this activity exerts on natural resources, as well as contributing to guaranteeing food security [14], in such a way as to advance the economic and social development of the regions.

Thus, sustainable analysis of production is a necessity that must be present in the actors who can determine the direction of social and political activities, and which has an impact on the producer's work. In this sense, there is a need to define new ways of working, seeking development as an integrated process, with economic, social, political and environmental considerations, which is why the objective of this article is to analyze the aspects inherent to the intensification of corn cultivation from the perspective of sustainable development, examining the economic, social and environmental aspects of the corn cropping process at a global, national and Sinaloa state level.

2. Method

The present research was conducted under a qualitative approach with a descriptive-explanatory scope, which seeks to specify properties, characteristics and important aspects [15] of sustainable agriculture, as well as to explain how various factors of sustainability applied to agriculture are integrated into the triple bottom line: economic, social and environmental, in the global, national and state contexts. The literature review was adapted from the systematic review process proposed by Gupta et al. [16], which is divided into three sections with nine steps to follow (see Figure 1).

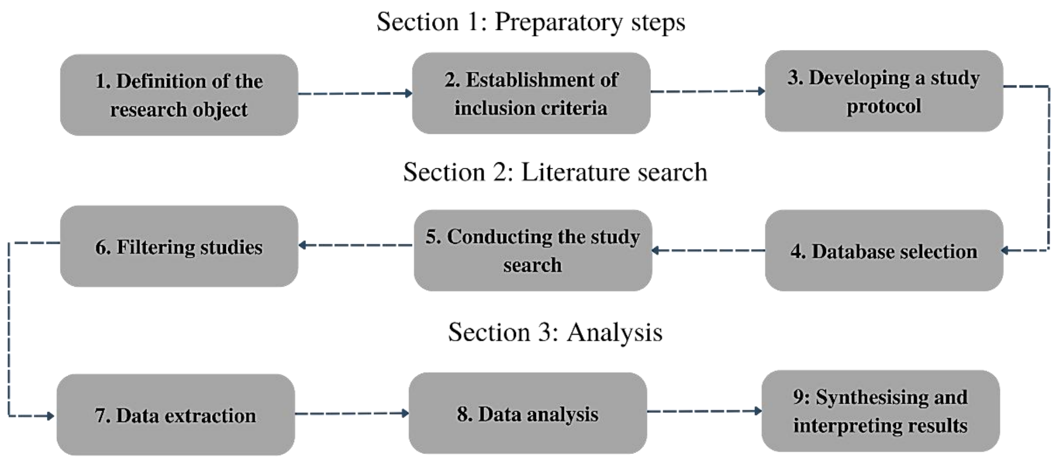

Figure 1. Steps for the systemic literature review.

The literature search is an extremely important part of the information gathering process, therefore, databases were selected, where different pages of publishing houses that compile scientific and academic publications were consulted, such as: JSTORE, Elsevier, Emerald, Science Direct, Oxford, Springer, Nature and Wiley. In the search for information, the following terms were used: sustainable development, intensification of corn cultivation, sustainable agriculture, challenges towards sustainable development. Data extraction used the categorization methodology, analyzing the articles under the approach of themes, methodologies, findings, prospective studies and socio-cultural contributions proposed by Velez and Calvo [17].

Data analysis was carried out using grounded theory [18]. Results are synthesized and interpreted through graphs and tables where the different publications are grouped according to the context in which maize cultivation is positioned.

3. Results

The results section is divided into four different points, the first of which focuses on agriculture within sustainable development; in the second part, corn cultivation is analyzed from the economic perspective of sustainable development at the three levels (global, national and state); the third point shows the analysis of the environmental component of maize cultivation, again considering the three levels mentioned above; and finally, point four details the social context of corn production in the world, Mexico and Sinaloa.

3.1. Agriculture in the Sustainable Development Paradigm

Sustainable development is defined in the Brundtland Report as "meeting the needs of the present without compromising the ability of future generations to meet their own needs", emphasizing that the three pillars of sustainable development - economic development, social development and environmental protection - should be in balance [18], with no one pillar dominating over the others. John Elkington's 1994 proposal on the Triple Bottom Line (TBL) outlines sustainable development by integrating social justice, economic prosperity and environmental quality, which would become the measurement criteria for organizations; this requires considering the benefits of these three aspects and also their effects [19].

Zarta Avila [20] defines sustainability as the integration of values in behavior, the understanding of the limitation of scarce resources and their relationship with the limits of economic growth; the need for a transformation in the economic system that guarantees industrial and agricultural production with clean energies by using renewable resources, as well as the satisfaction of present needs without compromising future generations, in order to reach the common good. Carpinetti et al. [21] add a dimension to the concepts of sustainability and define it as institutional and political, which focuses on building a governance structure, policies, norms and agreements for environmental management. The Food and Agriculture Organization of the United Nations (FAO) [22] defines sustainable agriculture as the management and conservation of the natural resource base, as well as the integration of technology, in a way that ensures the achievement of the satisfaction of human needs, as well as the conservation of land, water, soil, plant and animal genetic resources.

Within sustainable development, agriculture has objectives such as improving the health of producers and consumers, maintaining the stability of the environment, and ensuring long-term benefits for producers. It is a system that integrates production practices with the aim of feeding people, improving the quality of the environment, making efficient use of non-renewable resources and increasing the quality of life of society [23].

In the face of the challenges facing agriculture and in view of the transition of agriculture towards sustainability, the FAO [22] proposes five key principles to guide this strategic development:

- Sustainable agriculture requires optimizing efficiency in the use of natural resources.
- Sustainability requires direct actions for the conservation, protection and enhancement of natural resources.
- Agriculture that does not include improving rural livelihoods and contributing to social welfare is unsustainable.
- The resilience of people, communities and ecosystems, especially to climate change and market volatility, must be increased.
- Good governance is essential for the sustainability of natural and human systems.

3.2. Corn cultivation: a view from the economic axis of sustainable development

- *Global context*

Corn is one of the most widely cultivated grains around the world, ranking second only to wheat in world production, as well as being the cereal with the highest production per hectare; the importance of corn lies in its use as human food, for livestock consumption and as a raw material for various industrial processes [24].

According to data from the Foreign Agricultural Service (FAS) of the United States Department of Agriculture (USDA) [25], world corn yield (2019-2020 period) was around 1,116,000,000 tonnes and, in the 2021-2022 period, around 1,217,000,000 tonnes. In terms of harvested area, 193,000,000 hectares were used in the 2019-2020 period, while for the 2020-2021 period, the harvested area reached 196,000,000 hectares.

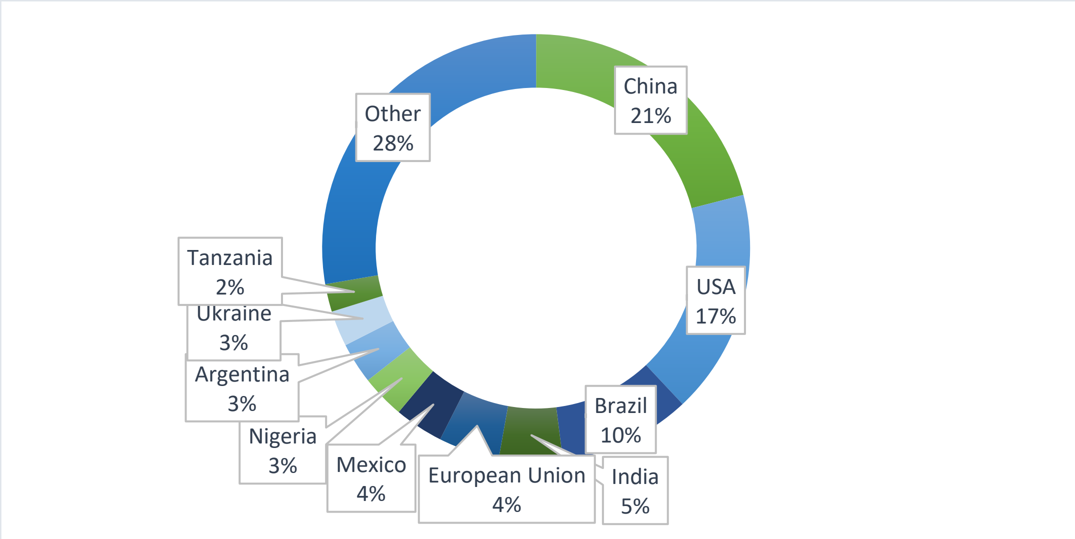

Figure 2. Percentage share of countries with the largest area under maize harvest.

In terms of harvested area, China has 21% of the world total, followed by the United States with an area representing 17% of the total, then Brazil, India, the European Union, Mexico, Nigeria, Argentina, Ukraine and Tanzania [26].

Global corn production contributes to supplying the international consumption of this grain, with the United States, China, the European Union, Brazil, Mexico, India, Egypt, Japan, Vietnam and Argentina among the countries that consume the most corn, the percentage of consumption by country is shown in Figure 3 [27].

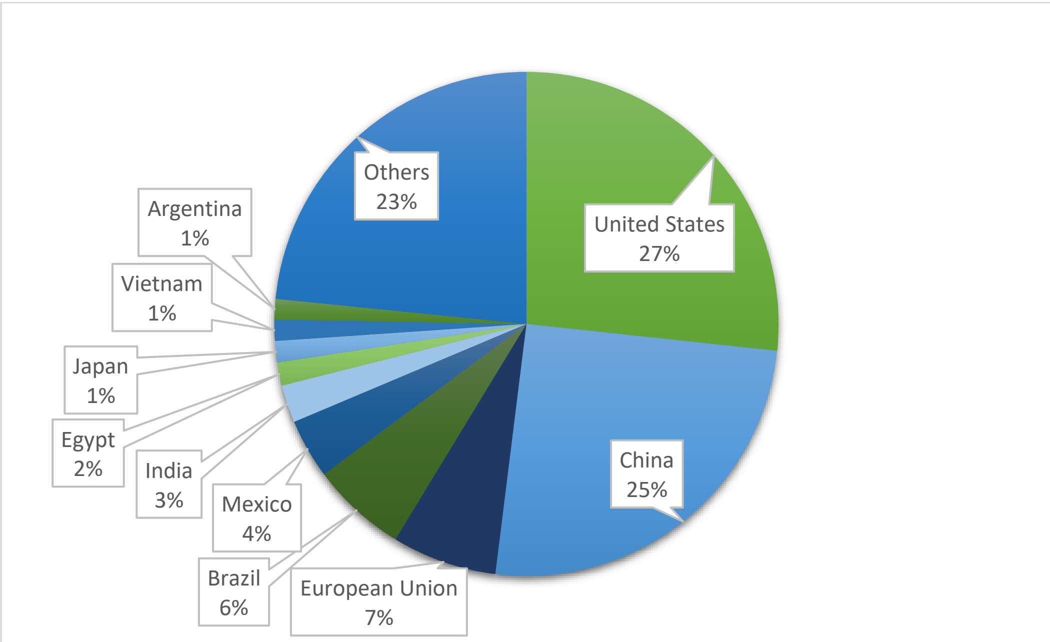

Figure 3. Corn consumption by country (measured as a global percentage).

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The main producers of corn are: United States, China, Brazil, the European Union, Argentina, Ukraine, India, Mexico, Russia and Canada, graph 3 shows the percentage share of world production by country highlighting the large share of the United States positioning itself as the leader with 32%, followed by China with 23% and Brazil with 10%, which together these three countries contribute more than half of the total, contributing 65% of world corn production [28].

One of the objectives of sustainable agriculture is to feed people [29]; however, as 50% of the world's food is concentrated in two countries, there is a risk of exerting hegemonic power over its fair distribution among the world's population.

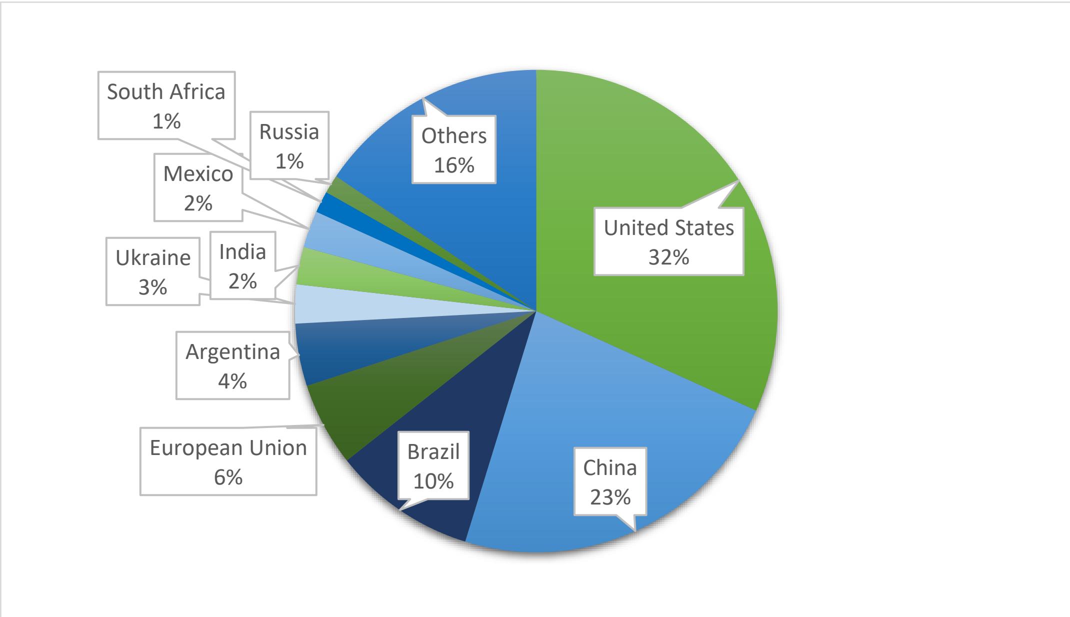

Figure 4. Share of global corn production by country

Corn production is one of the strong points of US agriculture; this crop represents one of the highly specialized components of the agricultural sector and is spatially concentrated in the so-called "corn belt" located in the Midwest [30], with Illinois, Indiana, Iowa, Missouri and Ohio being the states that make it up and produce a large part of the country's total production [31].

China, for its part, harvests 41 million hectares of maize, which keeps it in first place in terms of harvested area and in second place in corn production at the international level, with the provinces of Heilongjiang, Jilin, Nei Mongol, Shandong, Hebei, Henan, Liaoning, Shanxi, Sichuan and Yunnan standing out for their share of national corn production [32].

It is estimated that this country has an area of 17.2 million hectares, with an average production of 5.58 metric tons per hectare. The main producing states in the country are Mato

Grosso, which accounted for 40% of the national total, Paraná, with 21%, and Mato Grosso do Sul and Goiás with 15% and 12% of Brazilian production [33] [34].

The European Union contributed just over 66 million tonnes of corn in the 2019-2020 cycle, with a harvested area of 8 million hectares [27], with countries such as France, Romania, Italy, Serbia, Hungary, Germany, Spain, Poland, Greece and Austria contributing to the total corn production [35].

While Argentina, for the 2019-2020 season there was a harvested area of 6.2 million hectares, likewise, the production obtained was 8.06 tonnes per hectare, in this country, the main producing provinces of this grain are: Cordoba (31% of the national total), Buenos Aires (27%), Santa Fe (11%), Santiago del Estero (9%) and San Luis (4%) [31].

The above data show the general panorama, as well as the importance of maize cultivation in the economic aspect for countries in the world, given that production and consumption imply income from this crop, and, therefore, it triggers economic development of the sector and the regions where production takes place.

- Scenario for Mexico

Mexico ranks sixth in terms of harvested area at the international level among maize-producing countries, and from that year onwards it has maintained the pace of production and area devoted to the crop, except in 2011, a production cycle that was affected by climatic factors [36].

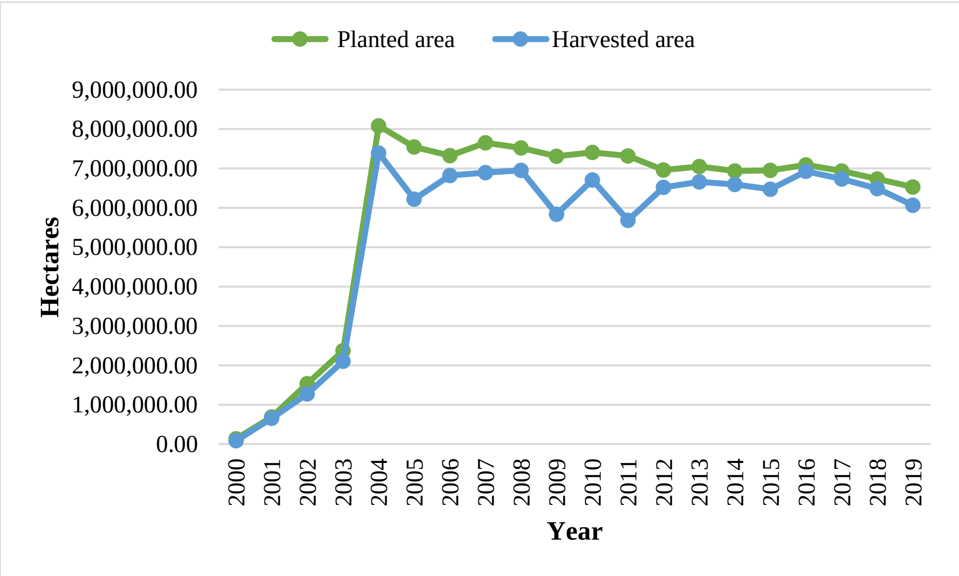

Figure 5. Area planted and harvested of white corn in Mexico.

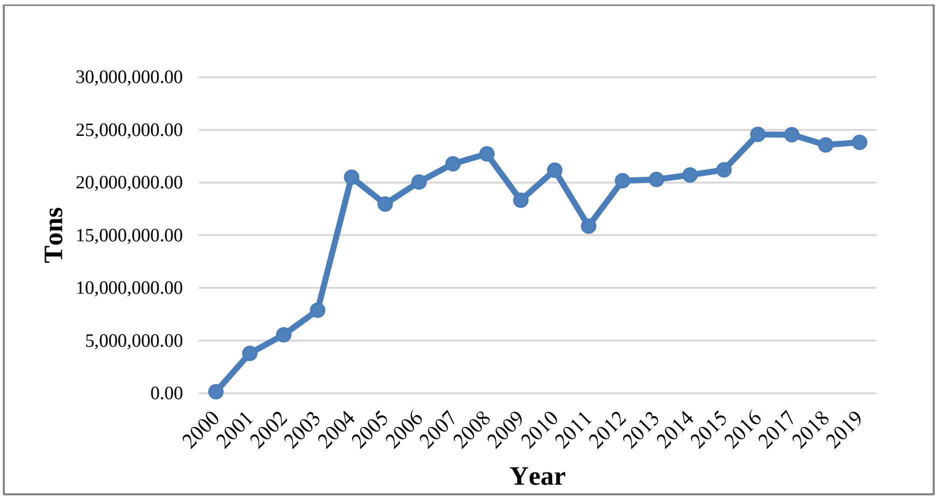

Figure 6. White corn production in Mexico

The average yield of corn production in Mexico (Figure 7) has maintained a trend of 3 to 4 tonnes per hectare.

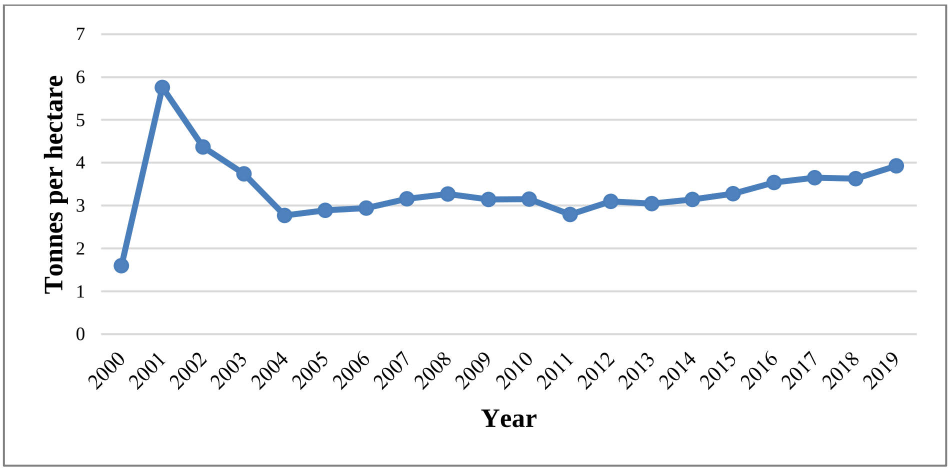

Figure 7. White corn yield in Mexico.

Total corn production in Mexico in 2019 was 23,817,000 tonnes, with a value of over 93 billion pesos (see figure 8). Of the national total, Sinaloa was the leading state in this crop, producing over 6 million 377,000 tonnes, representing 26.60% of the country's production, with a value of 23,284 million pesos (figure 8); similarly, Jalisco, Michoacán and the state of Mexico stand out for their important contributions to national maize production (see table 3) [37].

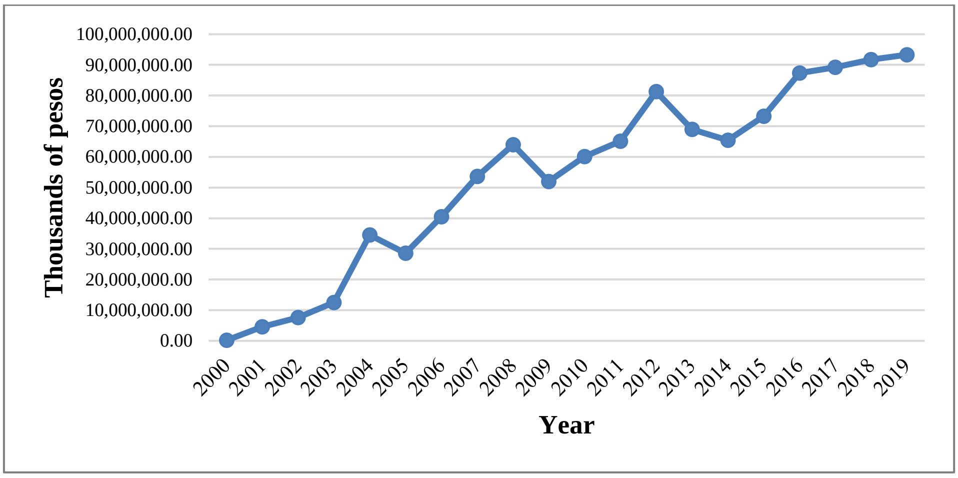

Figure 8. Value of production in thousands of pesos.

Table 3. Main white corn producing states in Mexico in 2019

State	Production (Thousands of tons)
1° Sinaloa	6.377
2° Jalisco	2.912
3° Michoacán	1.843
4° México	1.823
5° Guanajuato	1.671
6°Guerrero	1.286
7° Veracruz	1.113
8° Chiapas	1.111
9° Puebla	1.005
10° Sonora	0.692

- *Scenario for Sinaloa*

For Sinaloa, agriculture represents one of the main pillars of the economy, where 16.19% of the economically active population is engaged in agricultural activities [38], of which just over 165,000 people work in agriculture. In 2017, the entity contributed 11% to the state gross domestic product (GDP), which represents 7.3% of the national primary GDP. In terms of national agricultural production, it ranks fifth in the country, and in terms of national production value, it contributes 8.5%, placing it in third place among the states with the highest agricultural production value [37].

Figures 9 and 10 describe the behavior of the area used for corn cultivation and total production in the state of Sinaloa, from 2000 to 2019.

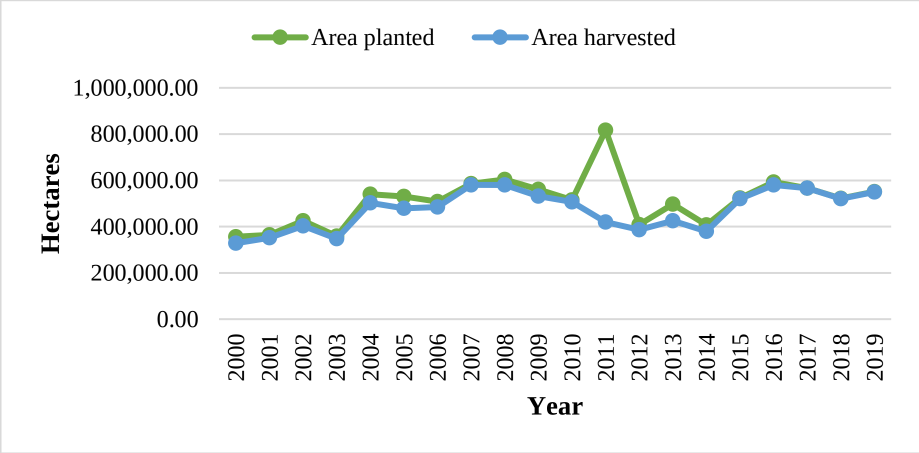

Figure 9. Area planted and harvest of white maize in Sinaloa.

The number of hectares planted and harvested of corn and the significant volume of production that Sinaloa has been growing since the opening of the North American Free Trade Agreement (NAFTA) in 1994, now renamed T-MEC (Treaty between Mexico, the United States and Canada) to consolidate today as the national leader in production [2] [37].

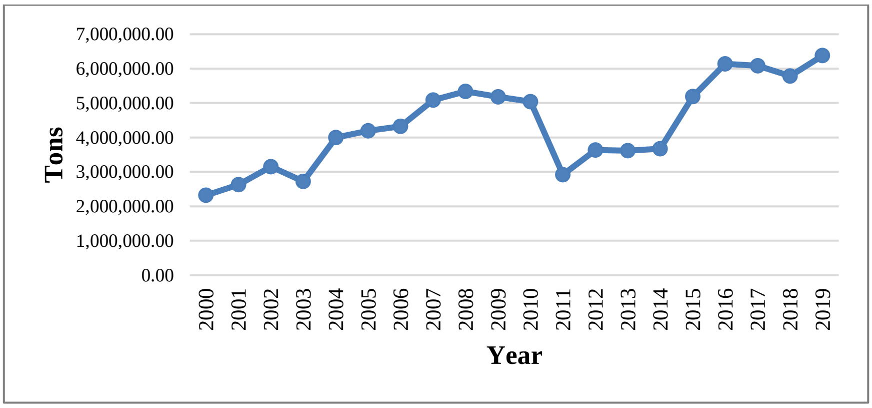

Figure 10. White corn production in Sinaloa.

The value of corn production in Sinaloa shows an increasing trend, reaching its highest point of the decade 2000-2010 in 2008, which was mainly due to the weakness of the US dollar at that time and the commercialization achieved from the volatility of agricultural commodity prices. In the second decade of the millennium, after the harmful effect of the 2011 frosts suffered in the entity in 2012, the value of corn began to take off due to the rise in commodity prices, and it was in 2015 and 2016 that gains in maize prices were observed as a result of the appreciation of the US dollar [39].

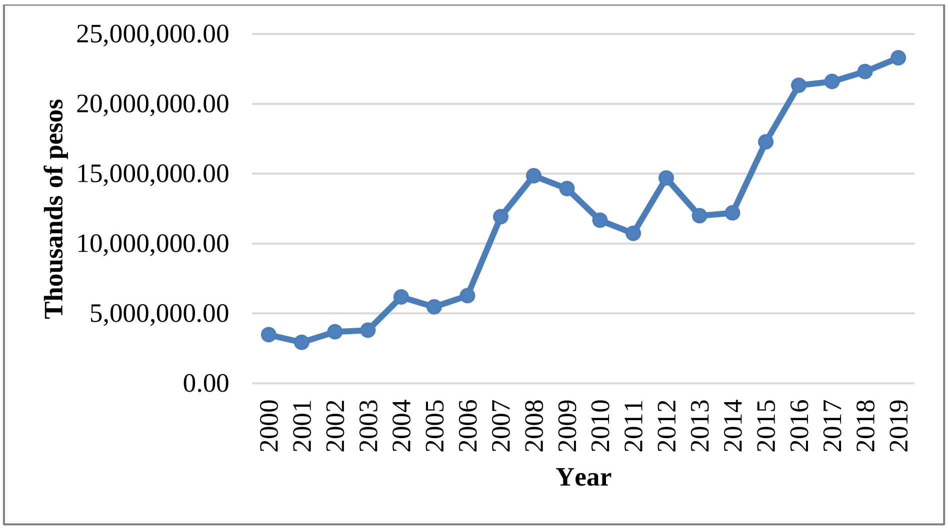

Figure 11. Value of maize production (thousands of pesos) in Sinaloa.

Comparing corn production and yield data, the situation that the state went through in the 2010-2011 period is notorious, where declines in production and yields were attributed to frost damage [40].

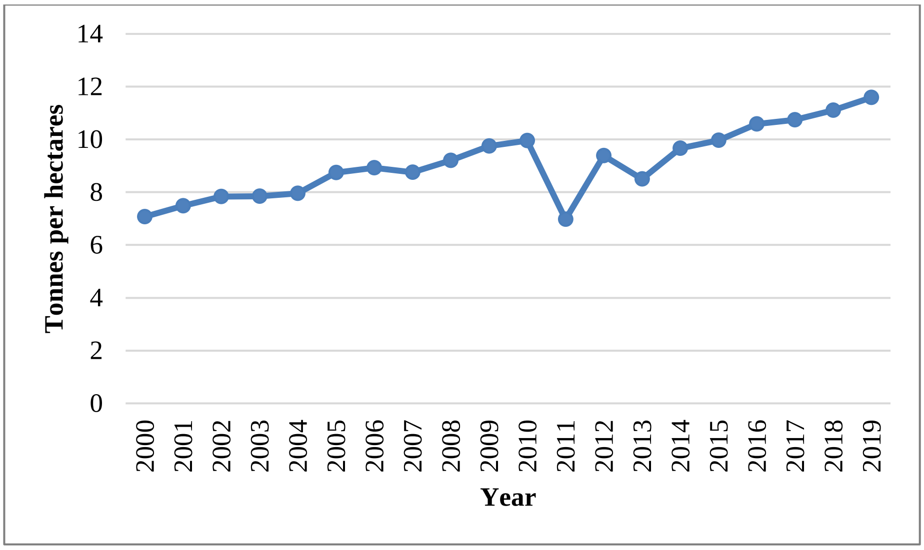

Figure 12. White maize yields in Sinaloa.

The state of Sinaloa is made up of 18 municipalities, 17 of which grow white corn, reaching a total production of 6,377,593.86 tonnes in the spring-summer and autumn-winter 2019 cycles in irrigated and rainfed modalities [37]. The distribution of production is headed by the municipality of Guasave, making it the most effective municipality in terms of corn cultivation and harvesting, with a yield of 12.60 tonnes per hectare, which was reflected in the value of production; thus, this municipality alone contributed one-fifth of the entity's value [41]. The corn production of the main municipalities of the state can be seen in the following table.

Table 4. Main white maize-producing municipalities in Sinaloa in 2019

Position	**Municipality**	**Production (Thousands of tons.)**
1	Guasave	1440
2	Culiacan	1162
3	Ahome	1100
4	Navolato	915
5	Angostura	537
6	Sinaloa de Leyva	508
7	El Fuerte	205
8	Elota	198
9	Mocorito	133
10	Salvador Alvarado	111

As can be seen, the cultivation of this grain in the world is one of the most important, especially for countries such as the United States, China and Brazil, which have high volumes of production and consumption of this crop. It is also worth highlighting the important economic benefits it brings with it in the world, in the case of Mexico and Sinaloa, which over the years has positioned itself in the first place in both production and high yields.

3.3. Analysis of the environmental component of sustainable development in maize cultivation.

- Environmental component of maize cultivation in the global scenario.

The environmental problems caused by corn farming began some time ago, the intensification of production based on monocultures, as well as the high quantities of inputs, have caused disturbances to biodiversity and ecosystem services, even threatening the sustainability of food production; Other damages include land degradation, salinization of irrigated areas, groundwater abstraction, increased pest resistance, greenhouse gas emissions and water pollution from agricultural inputs [42].

Table 2 shows different research on the environmental implications that have resulted from agricultural activities.

Table 2. Environmental implications of corn cultivation

Author/year	Environmental implications
Olanipekun *et al.* [43]	Agricultural activity is associated with environmental degradation.
Huang *et al.* [44]	Soil degradation is one aspect that threatens sustainable agricultural development.
Qi *et al.* [45]	Both agricultural practices and changes in land use can alter soil properties, including the physical, chemical and biological properties of soil.
Kunyu *et al.* [46]	Agriculture has controversial implications for climate change due to carbon emissions.
Zhao *et al.* [47]	Some environmental impacts of corn cultivation include reduced water availability, degradation of water quality, loss of soil nutrients, soil degradation, among others.
Kim *et al.* [48]	Corn production has environmental implications such as acidification and eutrophication.
Li *et al.* [49]	Agriculture is a major source of greenhouse gas emissions that contribute to climate change.
Lee *et al.* [50]	Corn cultivation generates considerable eutrophication effects as well as impacts on current and expected global warming in the period 2022 and 2100.
Pajewki *et al.* [51]	Agriculture is considered to be the main source of water pollution due to the use of nitrates, phosphates, pesticides, fertilizers and manure, generating pressure on biodiversity and reducing the life of flora and fauna.

Although agriculture is a major burden on water resources, it is a strategic activity to reduce pressure on water quantity and quality [52]. World agricultural production is responsible for 57% of the global water footprint being unsustainable because it goes beyond the available water resources, as it breaks the environmental flow criterion, so it must be reduced to alleviate water scarcity in the world [53], the water footprint measures the amount of water consumed in production processes in this case: agriculture, and it is thanks to this meter that the problem is identified in the rational use of water resources, which is presented with greater intensity due to water scarcity [54].

It is important to specify that in the environmental axis, the effects that agriculture has on the environment must be considered, but on the other hand, the negative effects that corn production may suffer as a result of environmental devastation and climate change must be taken into account. According to projections, corn yields are expected to be reduced in some regions by 2030 due to changes in rainfall and temperature variations [55]. Future scenarios for agricultural production include significant reductions in yields, further increases in maize prices, and a drop in meat and cereal consumption.

- *Environmental component of maize cultivation in the national scenario.*

In the environmental context, corn production in Mexico, the situation is not very different from what is happening in the global context, as it is the high concentration and use of pesticides that are causing the environment to deteriorate, causing profound damage to soils and ecosystems [56]. According to Martinez et al. [57], the country does not take the necessary steps to limit the use of hazardous pesticides that threaten the health of the population, a situation that contradicts the provisions of article 4 of the Political Constitution of the United Mexican States, which establishes the right of people to health protection; guaranteeing the correct application and coherence of legal frameworks and regulations, avoiding contradictions in this sense, represents an important challenge for the country.

- *Environmental component of maize cultivation in the state scenario.*

The use of fertilizers and pesticides in the production process of corn cultivation is important to consider due to the impacts generated on the environment. In this regard, Leyva et al. [58] point out that in Sinaloa agriculture there is a continuous use of pesticides, and there is also a problem regarding the disposal of containers that contain these chemicals, since, after being used, they are abandoned on the plots where they were applied, which generates more contamination.

Another important aspect that generates negative impacts on the environment is production based on monoculture, which has not incorporated highly technical systems to mitigate harmful effects on ecosystems [2]. Among the effects that have been manifested as a consequence of agricultural activities are the increase in temperatures, the frequency and intensity of storms, changes in rainfall patterns and sea level rise; future scenarios predict increases in temperatures and decreases in rainfall [59].

Based on the literature review, it can be seen that the adverse impacts of corn production are serious, causing losses of flora and fauna, as well as catastrophic effects on soil, air and water. It should also be noted that this activity not only contributes to climate change, but is also affected by it, impacting yields and production volumes due to the different hydro-meteorological phenomena. Therefore, it can be considered that both this component and the social component of sustainable development are the ones that receive the least attention when it comes to maize cultivation.

3.4. Social context of sustainable development in maize production.

- *Social context of corn production on the global stage.*

It is also important to note that agriculture employs around 1.3 billion workers worldwide, mainly benefiting smallholder families, especially in developing countries where agriculture still accounts for the majority of the labor force [60].

On the economic and social side, corn cultivation has contributed considerably as a source of income and employment, especially for rural areas, thus contributing to economic development. On the other hand, in the environmental dimension, there are problems that are palpable in the effects of climate change; consequently, the forecasts are not encouraging for the agricultural sector, since there are drastic impacts on natural resources; therefore, the vulnerability of this activity in the face of climate change is linked to the implementation of unsustainable levels of resource consumption [61].

- *The social axis of corn production in Mexico.*

On the economic side, Mexico has a negative corn balance due to the high level of imports, but it is forced to import maize because domestic production is unable to meet demand. In terms of environmental protection, this crop has had a major impact on pollution, environmental deterioration and natural resources. On the other hand, it employs and sustains a large number of people, and is also one of the main producers at a global level, which contributes to supplying society, as it has become the main product in Mexicans' diets [2].

- *The social axis of maize production in Sinaloa.*

In 2019, corn production had a value of over 23 billion pesos (graph 10) in addition to being a source of employment; however, it represents adverse impacts on both the environment and health [57], the social component has been adversely impacted by corn production in the state, due to the use of chemical pesticides that contaminate the soil and water, thereby causing damage to health, Martínez-Valenzuela et al. [62] warns that if exposure to agrochemicals continues at the same rate as it has been developing, illnesses such as cancer may develop; in the state, cases of children with this illness related to exposure to this type of chemical have been studied without conclusive evidence as yet.

Although the cultivation of corn is an economic activity that generates employment, and in the particular case of Mexico and Sinaloa it is an essential part of culture and food, the social aspect of the production of this grain is an alarming point, since some of the studies mentioned above emphasize that the excessive use of inputs (chemicals, pesticides, manure, among others) is causing dangerous damage to the health of society.

4. Discussion

Cereal production and global food security are confronted with issues such as climate change, environmental degradation and declining yields, and the answer to these challenges may be a sustainable intensification of global agricultural production, supported by a restructuring of agricultural systems. Such restructuring must involve the development of conservation agriculture, water resource management, soil health, and for all this to work, the joint participation of the actors involved in production, such as farmers, government, organizations, society and the private sector, is necessary [42].

The agricultural sector needs to move towards an agriculture that is self-sufficient, economically viable, energy efficient, resource conserving and socially acceptable, all aspects must be considered when planning and creating models that contribute to the development of the countryside [29], for this, sustainable agricultural systems must make use of different technologies, promote research, scientific research and technological development, focusing on production systems and also on the underlying natural and socio-economic resources [22].

Similarly, it is important to adopt sustainable agricultural practices, which consist of five attributes: conservation of resources, non-degrading environment, technically appropriate, economically viable and socially acceptable, in turn, to ensure benefits at different regional, national and global levels; with the implementation of these practices, it favors increased production, soil and water conservation, among others [6].

Among the challenges facing agriculture as it moves towards sustainable development are: financial injection, since it is considered that adopting sustainable practices entails higher production costs; lack of government support for sustainable agriculture, lack of understanding of what consumers want and need, difficulty in innovating and introducing new ways of working, lack of successful examples of applying sustainable agriculture, lack of information on new, more efficient and sustainable methods, lack of specialized support or advice, resistance to change, difficulty in understanding what sustainable development is, aversion to change and many other aspects [6] [11].

Some aspects of sustainable development in agriculture are higher profitability in production, more efficient use and conservation of natural resources, less damage and pollution of water, soil and air [11]. In the 2019 National Agricultural Survey, conducted by INEGI [63], the main problems of corn cultivation in the state are detailed, which in turn, represent challenges to consolidate sustainable agriculture, of which the following stand out: high costs of inputs and services, lack of training and technical assistance, loss of soil fertility, insufficient infrastructure for production, middlemen, low prices, disorganization in production, access to credit, strict technical and phytosanitary requirements, difficulties in the transport of production and storage, among others; regarding losses in agricultural production in the state, the main causes have been: droughts, excess humidity, floods, frost, low temperatures, wind, hail, pests, disease and natural fires.

Similarly, the Government of the State of Sinaloa, Mexico (2020), takes up the importance of adopting sustainable agriculture, recognizing the need to promote environmentally friendly practices, the training of producers, as well as the dissemination of the benefits of the practice of sustainable agriculture with the use of specialized machinery and equipment.

As can be seen, some of the challenges faced by farmers in Sinaloa in the pursuit of sustainable agricultural development are similar to those faced globally. Ehiakpor et al. [9], Priyadarshini and Chirakkuzhyil [13] point to lack of training, access to agricultural credit, plot size, field demonstrations, scientific advice, as determinants for the adoption of sustainable agricultural practices.

5. Conclusions

Sustainable agricultural development entails, firstly, seeking a balance between economic, social and environmental benefits, following the triple bottom line, if benefits are to be achieved in these three aspects. Secondly, it implies a synergy for the creation of production chains focused on corn production, where all links in the chain benefit, so that this activity focuses on sustainable development.

The intensification of corn cultivation from the economic point of view has brought with it important contributions at the global, national and state level, as it generates income from the purchase and sale, as well as being an important source of employment, especially for those people who live in the rural areas where this activity is carried out. It is noteworthy that in the three contexts analyzed here (global, Mexico and Sinaloa), this (economic) axis of sustainable development is the one that receives the most attention, demonstrating that the social and environmental aspects have been neglected.

The social aspect of sustainable development has been neglected, although people in vulnerable situations are employed, the adverse effects outweigh the benefits, since this activity involves the use of inputs such as chemicals, pesticides, fertilizers, which cause damage to the health of the people living around where maize cultivation takes place. On the environmental side, unfortunately, there are several damages (soil, water and air pollution, erosion, desertification, eutrophication, among others) that have been generated on natural resources, ecosystems, biodiversity and, especially, on the health of living beings that inhabit the planet as a result of excessive actions with unethical approaches.

Therefore, from an international sustainable development perspective, corn cultivation in Mexico and Sinaloa cannot yet be considered sustainable agricultural production. It should be noted that, although agro-ecological measures have been implemented, ecosystem services are used within production systems, precision technologies are implemented, and organic inputs are integrated, there is still a long way to go. Sustainable agriculture can no longer be seen as an option, today it must be seen as an urgent necessity.

It is proposed to carry out more research on sustainable agriculture under Amartya Sen's approach, given that it is a scheme that integrates the perspectives of the triple bottom line under the approach of the common good, with social development as a premise, i.e. to contribute to advancing development as freedom to achieve social appropriation of the postulates of sustainable agriculture, especially for producers.

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