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# Participatory Sustainability Assessment for Sugarcane Expansion in Goiás, Brazil

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**Abstract:** The sugarcane expansion in Brazil from 1990 to 2015 increased crop area by 135.1%, which represents more than 10 million hectares. Brazilian ethanol production hit a record high in 2015, reaching 30 billion liters, up 6% compared to 2014. In 2009, the Sugarcane Agroecology—ZAE-CANA—was launched to be a guideline to sustainable sugarcane production in Brazil. However, although it aims at sustainable production, it only considered natural aspects of the country, such as soil and climate. It is still necessary to develop instruments for studies on sustainability in all pillars. The aim of this study is to present the results regarding the application of the FoPIA (Framework for Participatory Impact Assessment) methodology in the Southwestern Goiás Planning Region (SGPR). FoPIA is a participatory methodology designed to assess the impacts of land use policies in regional sustainability, and the results showed the capacity of FoPIA to assess the impacts of land use change of the sugarcane expansion in that area. The major advantage of FoPIA is its participatory method feature, as it is possible to join stakeholders to debate and define sustainability guidelines.

**Keywords:** sugar cane expansion; sustainability assessment; FoPIA methodology

## 1. Introduction

Bio-ethanol from Brazil is an attractive type of biofuel because of its low price and relatively large greenhouse gas emissions reduction potential [1,2].

In the late 1970s, Brazil's National Bioethanol Program (PROALCOOL) ordered the mixture of anhydrous bioethanol (BE) in gasoline (blends up to 25%) and encouraged automakers to produce engines running on pure hydrated ethanol (100%) [3]. The Brazilian adoption of mandatory regulations to determine the amount of BE to be mixed with gasoline was essential to the success of the program [4]. The goal was to reduce oil imports which consumed one half of the total hard currency from exports. Although it was a decision made by the federal government during a military regime, it was well accepted by civil society, the agricultural sector, and car manufacturers [5].

Taking advantage of all the learning and experience of that period, the Brazilian government undertook some responsibilities against the international scenario related to climate change. In Brazil's Nationally Determined Contribution (NDC), submitted during COP21 in December 2015 and ratified in September 2016, the country agreed to reduce greenhouse gas (GHG) emissions by 37% by 2025 and 43% by 2030, with the 2005 emissions as a reference. To do so, the government agreed to increase biofuel (biodiesel and ethanol) participation by 18% in the energy matrix by 2030 [6]. Other commitments

were related to actions to reduce GHG emissions by some 37% by 2020 [7]. The sugarcane expansion in Brazil increased 135.1% in crop area from 1990 to 2015, which represents more than 10 million hectares [8].

In 2009, with Decree 6961 [9], the Sugarcane Agroecology Zoning—ZAE-CANA [10] was created to guide the sustainable sugarcane expansion in Brazil. ZAE-CANA's main goals are to provide technical subsidies to policy makers to direct sugarcane expansion into legally recommended areas and sustainable production in Brazil. To achieve these goals, the study followed the guidelines that will allow the expansion of production: indication of areas with agricultural potential for sugarcane harvesting without environmental restrictions; exclusion of areas with original vegetation and indication of areas currently under anthropic use; exclusion of areas for cultivation in the Amazon, Pantanal biomes and the Upper Paraguay basin; reduction of direct competition with food production areas; indication of areas with agricultural potential (soil and climate) for the cultivation it means with slopes below 12%, by mechanical harvesting.

However, although it aims at sustainable production, the zoning only considered natural aspects of the country, such as soil, climate and relief. Also, the governance continues through contracts, to guarantee the productive supply and effectiveness of the productive chain, thus enhancing uncertainty regarding the sustainability of the Brazilian biodiesel production program [11].

Since the 1990s, environmental studies identified a wide range of reflections on sustainability and agricultural production systems. These reflections converged to the idea that economic growth, environmental preservation and social equity should be considered together to achieve a satisfactory development level [12–15].

Also at that time, the concept of sustainable development (SD), also in the agro-energy sector, was widespread, despite shortcomings in making SD operational. Therefore, policymakers are increasingly demanding comprehensive and reliable analyses of policy impacts on the economic, social and environmental dimensions of SD [16,17].

The use of criteria on sustainability allowed the assessment of the impacts caused by development processes, both in urban and rural areas. This process has contributed to regional assessments such as the implementation of public policies aimed at developing measures to mitigate social and environmental liabilities [18,19]. For instance, the European Union and some of its countries have specific directives to access the sustainability of biofuels such as the Renewable Energy Directive 2009/28/EC [20] and the Fuel Quality Directive 2009/30/EC [21], which established sustainability criteria to meet EU targets and to be eligible for financial support.

The development of instruments for studies on sustainability criteria and indicators, as well as those on the impacts on land use, is quite recent and shows gaps that are still under analysis. However, they are important instruments to understand changes that take place in social, environmental or economic phenomena. They can drive a particular need or even resources indicating trends that are undetectable in the processes. Therefore, it is necessary to develop instruments to help land managers to assess the social, economic and environmental impacts caused by land use-related public and corporate policies. These instruments may be quantitative, based on indicators' response models and functions built according to scientific knowledge and census databases; as well, they may be qualitative instruments based on technical knowledge integrated to that of the local stakeholders.

Particularly, the FoPIA (Framework for Participatory Impact Assessment) methodology has been useful to prepare for the participatory assessment of significant changes in land use and in the possibility of sustainability. The FoPIA is designed to enable assessments of policy impacts that are sensitive to national, regional and local sustainability priorities by harnessing the knowledge and expertise of national, regional and local stakeholders who play a central role in the analytical process. The analysis of specific sustainability problems gives rise to realistic national and regional policy and land use change scenarios [17].

The FoPIA was originally developed for application in the European Union to conduct stakeholder-based impact assessments of alternative land use policies, for example, to assess the

policy options for biodiversity conservation in Malta [17]. This approach has been adapted for the assessment of land use policies in developing countries, with experiences in Indonesia, Tunisia and China [22–24].

Considering the assessment of impacts on the sustainability of sugarcane expansion policies in the southwestern region of Goiás state, Brazil, a participatory consultation was held to promote a structured interdisciplinary discussion about the sugarcane expansion in the region, to select public policy instruments for the construction of sugarcane expansion scenarios, as well as to define land use functions and indicators to be used in FoPIA. Hence, the aim of this study is to present the results regarding the application of this methodology.

## 2. Material and Methods

### *2.1. Study Area*

The Southwestern Goiás Planning Region (SGPR) was chosen as the focus area because of its prominent expansion of sugar cane. In 2012, the sugarcane planted area in the SGPR was 286,512 ha and, in 2015, it was nearly twice that area (412,466 ha) [8]. The region spreads across an area of 61,498,463 km$^2$ and 26 municipalities (Figure 1).

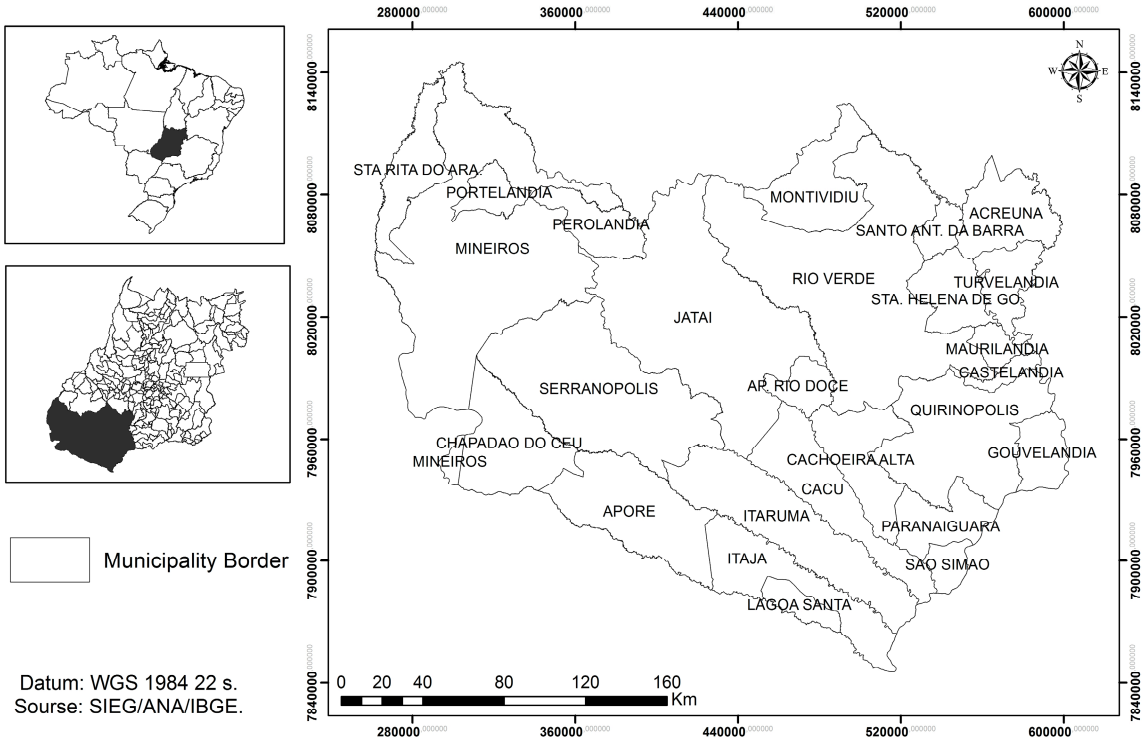


**Figure 1.** The Southwestern Goiás Planning Region and its municipalities. Source: SIEG—GO. Prepared by Trindade [25].

The sugarcane expansion in the large southern Goiás mesoregion is considered recent, as it started in 2004, mainly due to the advance of sugarcane agribusiness. The expansion of agribusiness in Goiás is characterized by high competition for land, favoring the leasing of large plots to harvest sugarcane for the sugar industry. This shows land concentration, mainly in parts of Southwestern Goiás involved in soybean and sugar cane production, and the exclusion of crops like rice, beans and, more recently, corn [26].

The SGPR has regional economic importance in the state, as well as consolidated logistics. However, it needs to be recovered and expanded to support the sugarcane expansion. At first

(2004–2008), much of the sugarcane expansion replaced soybean plantations, which, in turn, have shifted to pasture areas.

### 2.2. Methodology—FoPIA Background

The FoPIA methodology was developed as part of the EU-SENSOR project ("Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions") and applied to assess the impact of changing land use on different socioenvironmental situations of the European continent [17]. Subsequently, the FoPIA was adapted and used in the participatory impact assessment of different decision-making contexts and of environmental problems associated with land use and management in different Asian and African countries [22–24].

The FoPIA is a participatory methodology designed to assess the impacts of land use policies on regional sustainability. Its conceptual model, in which instrument users and public policy makers indicate policy scenarios to be assessed, considers variables such as driving forces, pressure, states, impacts, and responses (DPSIR). Each scenario generates different economic, fiscal or legislative conditions that, in turn, become driving forces of changes in land use. The pressures are changes in land use and management resulting from the implementation of policies. The pressures act on the states, as well as on the social, economic and environmental features of the regions subjected to changes, and they are represented by indicators. The impacts on sustainability are assessed through changes in the values of indicators as a response to the pressures, and through its relation with the sustainability limits or goals set to the region. Then, the decisions (responses) concerning the mitigation of or the adaptation to the impacts are then taken by the instrument users. However, due to limitations during the project, it was not possible to apply the entire methodology (Figure 2).

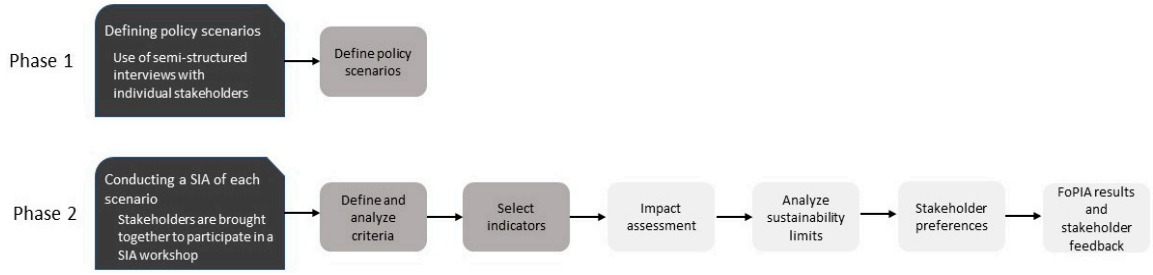


**Figure 2.** Framework for Participatory Impact Assessment (FoPIA) methodology steps [17]. Light gray boxes indicated what was not applied in this study.

In this study the FoPIA methodology comprises three stages: (1) The development of policy implementation scenarios and the consequent changes in land use, as well as the preliminary assessment of sustainability issues in the case study; (2) The definition of the Land Use Functions [27] suitable to the case study on a regional scale, by structuring the sustainability issue in the social, economic and environmental dimensions similarly balanced; (3) The definition of indicators for each Land Use Function, their responses to each scenario presented, followed by the integrated analysis of the results.

### 2.3. The Methodological Construction of FoPIA for Sugarcane Expansion in SGPR

In order to apply the FoPIA methodology to assess the impacts of land use change due to sugarcane expansion in the southwestern region of Goiás, a workshop for the participatory assessment of impacts on the sustainability of sugarcane expansion policies in Southwestern Goiás, was held at the Institute of Social and Environmental Studies (IESA—Instituto de Estudos Sócio-Ambientais) of the Federal University of Goiás (UFG), in Goiania, Goiás - Brazil, on 12 December 2012. The goals of this consultation were to promote a structured interdisciplinary discussion on the sugarcane expansion

in SGPR, to select public policy instruments for the construction of sugarcane occupation scenarios, and to define land use functions and indicators to be used in the FoPIA. It condensed phase 1 and two steps of phase 2 of the FoPIA methodology (Figure 2). These steps concern topics to be discussed by experts, who have experience and knowledge in the study subject, to promote the technical base for the furthers steps. The goal was the establishment of the sugarcane expansion drivers and their potential indicators. The further steps—unfortunately, not considered in this paper—would include other stakeholders' consultation, such as government representatives, farmers and practitioners.

The workshop was a consultation activity to regional experts to subsidize the construction of policy scenarios, as well as the selection of Land Use Functions and impact indicators, by taking into consideration the case study of the expansion of sugarcane in the SGPR.

The workshop for the participatory assessment of impacts on the sustainability of sugarcane expansion policies in Southwestern Goiás included 32 experts. The number of participants the research team considered ideal to the required dynamic activities of the FoPIA workshop. The criteria to define the experts was their performance in research projects at the SGPR or their experience in studies on the impacts generated by land use changes of sugarcane expansion in the region, favoring researchers, professors, Master's and PhD students experts in geography, agronomy, ecology, climatology, soil and rural sociology.

The workshop structure was based on guiding lectures, followed by group works and plenary discussions. The workshop was divided into three study sessions: (1) Public policy scenarios; (2) land use functions; and (3) impact indicators. These steps followed the FoPIA methodology [17] (Figure 2). A previous material contend technical information to support discussions during the workshop sessions was prepared and distributed to the participants. Thus, they could work on this material and upgrade it with their knowledge. The following sections describe each session and their outcome are described in the results.

#### 2.3.1. Session I: Public Policy Scenarios

Many factors are driving the increase in sugar cane production to meet the increase in ethanol demand in the national and international markets, such as government incentives (laws, decrees, public plans, programs, and policies) and foreign investment and market pressure (demand $\times$ supply). Based on past trends and on the experts' opinions it is possible to draw up reference scenarios. These scenarios represent developments without interference—in the absence of policy changes—they are the counterfactual, the background against which the impact of a policy can be evaluated. These scenarios are needed to know what the situation in the target year would be if policies did not change [28].

In the workshop one of the objectives was to identify the driving forces (key trends) that expand sugarcane in the SGPR, and select which would be considered in the baseline scenario. Also, the main public policies that promote sugarcane expansion sustainability were identified and selected to elaborate public policy scenarios.

Thus, six work groups were randomly formed for this session in order to discuss and summarize their findings around four guiding questions. These questions intended to exchange knowledge on sustainability concepts and how this knowledge applies to the case study and to the sugarcane expansion in the SGPR. These questions also aimed to point out the most appropriate public policies to the assessment, namely:

1. What are the main issues related to sugarcane expansion sustainability?
2. What are the main factors driving the sugarcane expansion in SGPR?
3. What are the main public policies promoting this process?
4. Consensually define which public policy would have greater influence on the sugarcane crop expansion and spatial distribution in the SGPR. Present two options for the implementation of this policy to build scenarios.

After the discussion, each group wrote down their answers in cards, which were presented at a plenary sitting and posted on a board. The session ended with a debate including all participants.

#### 2.3.2. Session II: Land Use Functions

The definition and use of Land Use Functions (LUFs) contribute to the aggregation and prioritization of indicators according to different social, economic and environmental functions performed by land use [29], that is, the LUFs summarize the relationship between the sustainability dimensions and the indicators to be built.

The SENSOR project considered nine LUFs, three for each sustainability dimension, namely: (a) the social dimension: Labor supply; human health and recreation; cultural (landscape identity, scenic beauty, cultural heritage); (b) the economic dimension: Industrial activities and construction; rural production and mining; transport; and (c) the environmental dimension: Supply and conservation of abiotic resources; support, provision and conservation of biotic resources; maintenance of ecosystem processes (Table 1). However, the LUFs are flexible and allow changes to better meet the goals of each case study. Therefore, the original LUFs were presented and discussed by the audience. It was reviewed in terms of relevance and suitability considering the investigated object of study—the sugarcane expansion in SGPR.

**Table 1.** Land Use Functions (LUF) defined by the SENSOR Project team based on the LUFs suggested to the European Union [26].

| Sustainability Dimension | LUF |
|---|---|
| SOCIAL | Labor supply<br>Quality of life<br>Human health and recreation |
| ECONOMIC | Industrial activities and construction<br>Rural production<br>Infrastructure |
| ENVIRONMENTAL | Conservation of abiotic resources<br>Conservation of biotic resources<br>Maintenance of ecosystem processes |

The working groups were reorganized into two groups for knowledge and experience representation in each sustainability dimension (social, economic and environmental). A panel was set up and the groups presented their results in plenary by posting cards containing land use functions defined by them, along with their supporting justifications.

#### 2.3.3. Session III: Impact Indicators

The experts participating in the workshop used the following criteria to select the sustainability indicators, built according to the recommendations of the Organization for Economic Cooperation and Development [30,31].

- Relevance to the formulation of policies
- Simplicity, conciseness, and ease of interpretation
- Analytical robustness
- Measurability
- Operability
- Availability (spatial and temporal).

The same work groups formed in the previous session applied the above-mentioned criteria to point out the most appropriate indicators to represent each LUF. Each group was asked to select

three indicators per LUF. The results of each group were presented in plenary and the indicators were grouped—eliminating redundancies—and systematized for further analysis.

## 3. Results and Discussion

The activities carried out in the three sessions produced a summary of results obtained from the experts' work. Subsequently, a set of aspects that should compose the policy scenarios for participatory evaluation was presented by taking into consideration the feasibility of implementing the FoPIA methodology to assess social, environmental and economic impacts on the sugarcane expansion process in the SGPR.

### *3.1. Session I: Public Policy Scenarios*

To build reference scenarios, it was necessary to draw up guiding questions based on the local reality considering the development of the biofuel industry in the region. The responses given by the work groups were summarized for each question, as follows.

- What are the main issues related to the sustainability of sugarcane expansion?

There was strong transversality between the responses and comments of the work groups, and this shows the importance of the sustainability issues in their three dimensions (social, economic and environmental).

Regarding the social aspect, the factor "concentration of lands controlled by large companies (sugar and alcohol plants) and landowners for cattle breeding and soybean crops, at the expense of small/medium farmers and family farmers" was pointed out by nearly all groups. One group reported that the process started through land leases (for soybean, and later, sugarcane), as the price was attractive, especially for small producers. During the successive sugar plantation renewals, for example, the lease price fell due to the reduction in the sucrose content linked to the lease price. As the situation continued, the plants made a proposal to purchase the lands and thus consolidate the concentration of rural properties in the studied region. There was strong impact on the land ownership structure. It mainly affected small farmers, who lost their identity as rural producers and it significantly changed the local agricultural profile.

This reality has given rise to several issues related to the growth of the area cultivated with sugarcane monocultures in the SGPR: The transition from manual to mechanized harvesting systems without burning led to sugarcane cutters losing their jobs. These workers had no training and thus were not employed by the sugar and alcohol industry. These sugarcane cutters, and the small farmers who sold their lands, migrated to cities with insufficient infrastructure to absorb the new population. Another critical factor was the inadequate working conditions for the sugarcane cutters who remained in the non-mechanized plantations. As many of these workers are required to cut a very large amount of sugarcane per day, the physical strain often leads to exhaustion and occupational diseases [32]. There is also labor supply seasonality, a characteristic of the conventional sugarcane production system.

As for the economic aspect, the issue of increasing land prices was highlighted, since the sale of small properties caused strong impacts. Such impacts also occur in the urban real estate sector, as the demand for housing also increases due to the arrival of new workers trained to work in plants and the rural exodus of farmers who lease or sell their properties.

Tax evasion was reported as relevant to the local economy, as most of the income generated from the sugar and sugarcane production does not stay in the municipality. It is transferred to the plants' centers of origin installed in the SGPR, which are mostly located in the Brazilian southeastern and northeastern regions. Income concentration, characterized by the low equity in the distribution of the economic benefits generated by sugarcane production, was identified as an important sustainability issue, despite the large tax collection increase in the state and municipalities.

It was reported that the local food production has been strongly impacted by sugarcane expansion due to reduced family production or land use change of these families' lands for sugarcane production.

The study groups presented some environmental aspects. They highlighted soil compaction, worsened by the standardization of mechanized crop management techniques that replaced the extensive pastures and the annual crops of family farmers previously managed through manual techniques. Mechanical harvesting includes heavy machinery and its successive use in the fields, which leads to soil detachment contributing to its compaction. In addition to soil quality loss, water infiltration and retention capacity is reduced. This leads to increased rainwater runoff, as well as increased runoff of the water used in irrigation systems. The outcome is soil erosion and transportation of nutrients and pesticides to the beds of streams, creeks and rivers [33].

The change in sugarcane field drainage dynamics increases the risk of groundwater and aquifers contamination with pesticides and industrial wastes such as vinasse and heavy metals, dumped into the soil through fertirrigation. This is worse in soils presenting sandier texture, and the experts showed concern regarding this topic. The strong water footprint resulting from high evapotranspiration—typical of the sugarcane culture—is another relevant issue to the overall environmental impacts, since it threatens water availability to humans, fauna and flora [34].

In addition to these facts, the experts mentioned that burning-based sugarcane harvest systems are still used in the SGPR, and this leads to severe air quality issues.

The issue of biodiversity loss, which becomes more evident when livestock areas are converted into sugarcane fields, was also mentioned. Although these areas are already deforested, livestock coexists with small forest fragments and scattered trees, as they provide shade and shelter for farm animals, as well as landing to several bird species, especially in livestock systems with low technological input. These systems are quite evident in large areas that have not been converted into sugarcane crops or grain monocultures.

- What are the main factors driving the sugarcane expansion in Southwestern Goiás?

The agribusiness model in the SGPR and in the state of Goiás is similar to that used in the São Paulo countryside—the largest national sugarcane producer—facilitating crop expansion. The high domestic and international demand for energy sources as alternatives to fossil fuels was considered an important sugarcane expansion factor. This expansion was supported by public policies and international agreements that favored the transformation of ethanol into an agricultural commodity. The other expansion factors mentioned were the technological development of the sugarcane and bioethanol productive chain and land availability.

Infrastructure and logistics such as agricultural flow paths and the ethanol pipeline installation plan, were considered the main sugarcane expansion factors in the SGPR. In addition, the agroecological suitability (soil, climate, topography) of most of the territory for sugarcane cultivation was considered average. This scenario qualified owners and entrepreneurs to receive government economic incentives for such purpose Manzatto et al. [10] (Figure 3).

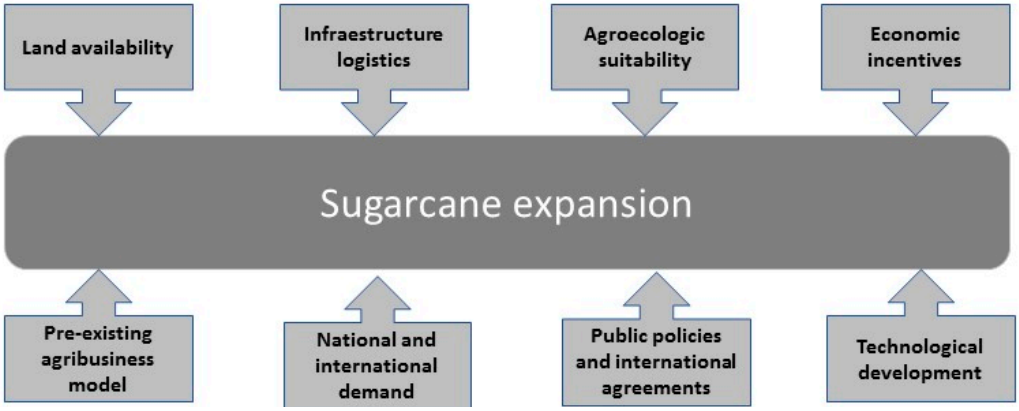


**Figure 3.** Sugarcane crop expansion drivers in the Southwestern Goiás Planning Region (SGPR).

- What are the main public policies promoting this process?

Some information on macro and micro state intervention policies were identified to reflect on intervention policies in the sugarcane industry and to simultaneously develop mechanisms to assess the industry impacts. The participants noticed that a set of policies should be highlighted in the SGPR: the Kyoto Protocol (at the global level); the National Agro-Energy Plan and the ZAE Cana (at the federal level); the Goiás Industrial Development Program ("Programa Produzir") and Grants and Taxes on services (ISS) at the state level.

The Kyoto Protocol (KP) is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC), which commits developed countries by setting internationally emission reduction targets. Brazil does not have a mandatory GHG emission reduction target; however, it has participated in the KP through the Clean Development Mechanism (CDM) projects. Clean energy generation projects, biofuels and other renewable sources could generate carbon credits to be traded on the carbon market. In this context, the National Plan for Climate Change (NPCC) aimed, among other things, "to foster the sustainable increase in the share of biofuels in the national transport matrix and work to structure an international market of sustainable biofuels".

One of the goals of the National Agro-Energy Plan [35] was to create conditions to internalize and regionalize the development based on agro-energy expansion and on the value added to the supply chain. The guidelines for this expansion were provided by the Agro-Ecological Sugarcane Zoning—ZAE-CANA [10].

Goiás state programs, such as *Programa Produzir* [36], which focuses on to the implementation and expansion of industries, also have a strong influence on the sugarcane expansion and reduce the due value-added tax (VAT) installments.

Finally, municipal policies were mentioned, including conveniences such as land grants and taxes on services (ISS) to implement new industries in Goiás. In addition, policies that have restricted sugarcane advancement, such as those found in the Rio Verde, one of the municipalities of the SGPR, which limited the sugarcane occupation to 10% of the municipal territory to protect areas planted with soybean, as well as the local food industry supply.

- Policy proposals that could be implemented.

The last item discussed in the sessions to create scenarios concerned proposals for public policy instruments to be implemented. These instruments would result in the effective transition of the production chains and allow the creation of sustainable logic-related actions.

Among public policy instruments, it was suggested that the ZAE-CANA should be further detailed to condition the government incentive contributions under the National Agro-Energy Plan, as this mechanism is considered critical to the process of sustainability. The agroecological zonings of the main crops in Goiás (scale 1:100,000) would enable a specific regulatory benchmark for Goiás and for the SGPR through the definition of sugarcane production priority areas. According to Manzatto et al. [10], many municipalities in the SGPR have large areas with medium/high suitability for sugarcane production, for example, Rio Verde (72%) and Quirinópolis (73%).

It was suggested that the environmental planning should be considered when formulating tax incentive policies.

Also, the development of an environmental education policy to encourage better understanding of the use and impacts related to soil, water resources and biodiversity was suggested. The ecological VAT could be used to reward municipalities that encourage land management changes. Accordingly, the development of a certification policy with economic incentives to certified systems was suggested. Figure 4 summarizes the main proposals built in public policies discussions.

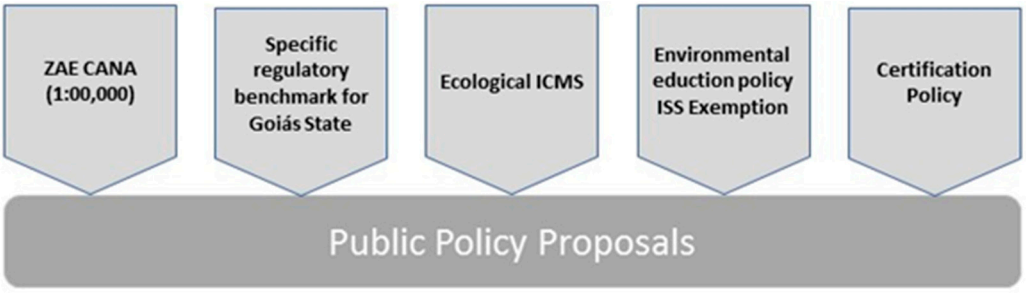


**Figure 4.** Strategies and public policy themes suggested for the sustainable development of sugarcane expansion in the SGPR.

### *3.2. Session II: Land Use Functions*

The work groups presented their views on LUFs initially adopted by Sensor project (Table 1) and suggested some modifications. A plenary consensus was obtained and a set of three LUFs was proposed for each sustainability dimension, as well as the potential indicators to achieve each LUF (Table 2).

Regarding the social dimension, the experts showed concern about the quality of the manual labor found in the SGPR agricultural production systems. These activities were often considered inhospitable, especially in the case of crops using sugarcane burning before the harvest. The proposal for the inclusion of the health and quality of life aspects in order to compose LUFs to assess this issue was accepted unanimously. The inclusion of the local socio-cultural development LUF was also suggested as LUFs hold recreational, educational, religious, scientific and cultural land use functions. The SGPR is notable for its natural beauty and its rich, exuberant landscape, mainly due to the heterogeneity of its elements.

Regarding the economic dimension, rural production along with the local consumption expansion issue were considered important to comprise another LUF as a way to reflect on the local impacts of the sugarcane expansion, and about the difficulty to produce and consume other food products. The income evasion was pointed out in Session I. If only the agricultural production is assessed, a positive result might hide a local negative impact, such as the reduced consumption of locally produced agricultural products. A similar situation can be found in the Mid-Goiás Planning Region, where sugarcane crops expanded much between 2000 and 2011, increasing from 23,000 to 123,000 hectares, which pushed up either the land value or the food supply in the region [37].

The region hosts one of the largest protected areas in the Cerrado biome, the Parque Nacional das Emas, whose integrity is threatened by the land use in its surroundings. Plateaus, cliffs and gorges, forest fragments, and water sources that drain their waters to three major watersheds (Paraguay, Araguaia and Paraná rivers), as well as cultural and archaeological sites, provide the local population and visitors with the scenic beauty and the cultural wealth of the region. Monocultures devoid of the tree element—which some cattle ranches still have in their pastures—are dominated by heavy machinery and, in some cases, use burning as an agricultural practice. Thus, they represent a high risk to the integrity of rural landscapes in the SGPR.

As for the environmental dimension, by taking into consideration the importance given to water resources in both productive activities and in the supply for human consumption, as well as the high water demand in the sugarcane culture, the insertion of the conservation of abiotic resources LUF was proposed. It was considered comprehensive and included issues such as water resources and erosion and loss of soil and nutrients.

**Table 2.** Indicators to assess sugarcane expansion sustainability in the SGPR.

| Sustainability | LUF | Indicators |
|---|---|---|
| SOCIAL (a) | Labor quality and supply | Hiring, firing and balance<br>Average income<br>Employment rate by sector<br>Use of local labor |
| | Health care and quality of life | Access to basic sanitation<br>Hospital facilities and beds/100,000 inhabitants<br>Student attendance per school year<br>Crime rate |
| | Local socio-cultural development | Number of public leisure facilities<br>GINI index<br>Cultural groups<br>Number of Municipal Councils<br>Number of high school graduates |
| ECONOMIC (b) | Industrial activities and construction | Urbanization rate<br>Industrial diversification<br>Industrial gross domestic product (GDP)<br>Availability of public transportation<br>Electricity consumption |
| | Rural production and local consumption | Agricultural GDP<br>Agricultural diversification<br>Area occupied by crops<br>Consumption of local agricultural products |
| | Infrastructure | Electrical power generation<br>Electric transmission network<br>Road network diversity<br>Electricity cogeneration |
| ENVIRONMENTAL (c) | Conservation of abiotic resources | Consumption of pesticides and fertilizers<br>Use/ Agroecology Zoning (ZAE) discrepancy<br>Percentage of preserved PPA<br>Total use/sugarcane expansion rate<br>Soil loss<br>Burned area/harvested area |
| | Conservation of biotic resources | Percentage of preserved permanent preservation area (PPA)<br>Total use/sugarcane expansion rate<br>Burned points/year<br>Deforestation rate—pasture clearing<br>Number of fragments (measures of associated landscape)<br>Pesticide consumption |
| | Maintenance of ecosystem processes | Percentage of preserved PPA<br>Carbon stock and sequestration<br>Water body sedimentation rate<br>Percentage of contiguous production area (landscape/permeability matrix)<br>Fragmentation level of the remaining forests |

### *3.3. Session III: Impact Indicators*

The work groups in the Session III were the same as session II and, according to criteria such as relevance, simplicity, robustness, measurability, operability and spatial and temporal availability, they chose the indicators that would be most appropriate to represent each LUF defined in the previous session. Each work group proposed three indicators for each LUF, according to the sustainability dimension they represented (Table 2).

Fifty-three indicators were pointed out by the six work groups. The analysis and removal of redundancies and inconsistencies resulted in 43 proposed indicators: 13 social, 13 economic and 17 environmental indicators (Table 2). The experts understood that the indicators must reflect the impacts of land use changes on the municipality or region, based on a broader scale than that observed exclusively in production areas such as plants or rural properties.

Regarding the social dimension, most experts agreed to include indicators capable to evaluate the quality of issues such as job opportunities, education, public security and leisure for the people.

Similarly, not only did the suggested economic indicators measure the industrial and agricultural production values, but they also assessed the diversification of these products. They measured power generation and assessed its distribution. They also measured the availability of public transportation, as well as the capacity of the road network to meet the demand for transport. Thus, the experts selected variables to identify the relationship between social and economic factors in order to expand the potential to improve the local population's quality of life.

The environmental issue is reflected in the indicators representing the relevant impacts to sugarcane monocultures, namely the contamination of soils and water resources by pesticides and excessive nutrients (especially nitrogen) [38]; the biodiversity loss due to the sugarcane monoculture and the way it is managed by agricultural companies and landowners [39,40]; the air quality, which is strongly compromised by the smoke from post-harvest burning [41]; and the soil compaction and its subsequent incapacity to retain sediments, nutrients and water [42].

## 4. Conclusions

The sugarcane expansion scenarios in the SGPR indicate the dynamics of the expansion and point out some weaknesses and potentialities of ethanol production in this region. This information can be analyzed in the light of the influence of the driving forces that operate in the local industrial and agro-industrial sectors, which may favor or restrict the cultivation of sugarcane in the region. The study collected information that allows us to conclude that the edaphoclimatic conditions, the availability of areas for cultivation, and governmental policies at the federal and state levels are among the main attraction factors for the implantation, expansion and revitalization of the sugar and alcohol industry in the SGPR.

The ZAE-CANA was the main instrument of public policies selected for the construction of sugarcane expansion scenarios in SGPR. Other public policies and drivers should be considered in scenarios for the expansion of sugarcane. However, due to the socio-environmental diversity of the region, the same set of public policy instruments can result in very different social, economic and environmental impacts. The participatory methodological approach provided the basis for evaluating the sustainability impacts caused by the expansion process of sugarcane cultivation and the implementation of ethanol agribusiness in the SGPR.

Based on technical knowledge integrated with the stakeholders of the local society, it was possible to indicate the LUF and the indicators that should be considered in the FoPIA in the SGPR sugarcane expansion scenarios. The LUF defined in this study were similar to those originally proposed, demonstrating that the LUF set by the experts address the main sustainability issues of the sugarcane expansion in SGPR. Participants, however, placed a special emphasis on the health care issue of quality of life as a new LUF proposal. They also stressed the local socio-cultural development, which would include recreational, educational, religious, scientific and cultural land use as the region shelters landscapes with remarkable scenic beauty. The prioritization stage of the indicators was not carried out due to the low availability of time during the workshop so that the participating experts could have access to more information and reflect on the issue. However, they showed a clear need to select a minimum set of indicators in a participatory way associated with each LUF to evaluate and monitor the sustainability of scenarios for expansion of sugarcane cultivation geared to the industrial production of sugar and ethanol in SGPR.

Finally, the results indicate the potential of the FoPIA methodology as a tool to assess sustainability in a participatory way, bringing together stakeholders to discuss and promote guidelines to achieve sustainability. However, as the methodology was not fully applied, it was not possible to access stakeholders' preferences and feedback.

FoPIA has proven to be a powerful tool—although it is complex and demands a great amount of energy input. We highly recommend this tool; however, we must stress that studies that use it must require thorough previous planning, especially concerning the workshops and stakeholders mobilization.

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