# 4DGAP: New tool for multidimensional impact assessment and guide to certification programs for Good Agricultural and Environmental Practices

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# 4DGAP: New tool for multidimensional impact assessment and guide to certification programs for Good Agricultural and Environmental Practices

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***Keywords*— Sustainability, Environmental planning, Food security, Certification of agricultural quality.**

***Abstract*— Food markets are increasingly demanding the implementation of good agricultural practices programs (GAP) in the public or private sectors as a way to guarantee the sustainable and responsible production of safe food. Due to the large number of GAP programs being implemented, producers are often required to participate in several of them to comply with the demands coming from diverse buyers in different target markets; as a result, even though the majority of certificate requirements share factors in common, the costs of implementation and evaluation increase. In this context, a tool was created to analyze and manage multidimensional risks in agriculture (4DGAP tool) (evaluation of the GAP in four dimensions), developed through an alliance between Embrapa and IICA proposing methodological bases that would support the preparation and updating of indicators linked to the GAP programs, facilitate interplay between the different certification programs and likewise between programs and the producers, agribusinesses and governmental agencies that use them. In addition, its objective is to contribute to the reorganization of all kinds of rural farms, based on a concept of property planning in keeping with the technical and environmental parameters needed to comply with the principles of sustainable development.*

## I. INTRODUCTION

Since the end of the 90's, GAP programs have become common and even mandatory in the food production process, especially in relation to food destined for fresh consumption (Amekawa 2009, Mattos et al. 2009). Over time, it has become necessary to understand the reasons for the success and failure of these programs so their effectiveness can be improved. (Srisopaporn et al. 2015).

A lack of specific tools to evaluate and monitor GAP programs motivate the need to find options that serve as a basis for their development. In some cases, simple monetization of the systems' results has been used (Mandarino et al. 2019); however, the programs contain numerous variables that hinder a complete financial assessment.

With few exceptions, GAP programs are based on the triad of food safety, worker safety (or sustainability of the activity) and environmental protection, which has gradually evolved to resemble the makings of a system to assess the impact and environmental management of rural farms (da Cruz et al. 2006, Sabbag 2008, Blasi et al. 2016).

Although in the majority of cases the use of indicators to evaluate sustainability generates an incomplete description of a very specific problem, when applied to highly subjective matters, such as certification of agricultural quality, it can become a valuable tool to reduce the realm of speculation (Binder et al. 2010, Coteur et al. 2016). Mendoza and Prabhu (2003) recommend using these indicators, since they make it possible for the different variables to interact in a holistic manner, including economic, environmental, biological and physical factors, hence allowing the condition of the agroecosystem to be evaluated and described.

Notwithstanding the above, the difficulty of implementing a system depends on the selection of a certain number of socioeconomic, biotic and abiotic parameters that will serve as points of verification: having too few elements can result in a certification program that is too weak for the interested target audience, while an excessive number of elements can decrease the number of producers who are willing to participate in the program (Girardin et al. 2000, de Figueirêdo et al. 2010). Currently, there are several formulas to define the indicators, but even today the premise is that the indicator must be representative, and where possible, multidimensional (Bertocchi et al. 2016, de Olde et al. 2017).

While a system of GAP and good environmental practices is made up of a series of indicators of varying dimensions with different levels of importance where necessary, (Walter and Stützel 2009), generally speaking evaluating compliance with good practices is carried out at a global level, without regard for the size of each dimension or the interrelationships between them, which makes way for its implementation across all components of the chain, from the supplier of inputs to the consumer at the point of sale (Amekawa 2009). Compilation and data management of all the components are crucial, since they form the base for tracking the system and ensuring the chain of production/manufacture and stewardship of the products and inputs.

According to Rodrigues et al. (2003), Hayo et al. (2007) and Van Passel & Meul (2012), the typical restrictions associated with the use of indicators in environmental (or sustainability) analyses result from the lack of detailed information about choices made during the planning process, which is when methods of selection, compilation and data grouping are defined that will form the basis for the subsequent use of indicators.

Given the current low cost of compilation and data storage systems, these activities no longer pose an obstacle and have become key steps in conducting a thorough evaluation of certification programs and the structuring of management systems geared toward their improvement. Subjective bases for the data sets compiled over time have been abandoned, which allows the databases to be studied and analyzed, especially where it relates to rural farms. Therefore, as these databases grow, the systems of evaluation can also operate in a timely manner, assessing advances in the good practices program being implemented on the farm over time.

Another feature of the good practices programs which facilitates adoption of these evaluation and management processes is that compliance evaluations are carried out based on simplified verification lists which contain elements that are structured in keeping with a descending standard and scientifically based ceiling values that require integral completion in a binary form (yes or no); this avoids the occurrence of non-parametric subjectivity that is based on the evaluator's experience (Hayo and Van der Werf 2002, da Cruz et al. 2006). When techno-scientifically derived binary systems are used in evaluation processes involving verification, these binary systems are more restrictive compared to those that adopt partial compliance as an option, since by selecting the indicators and parameters that must be completed, the system will be satisfied only when it achieves full completion of the key points of the program, avoiding exchanges and interpretations that could affect the environment and go against the objectives proposed by the system creators.

Some GAP evaluation systems can use a combined standard that allows some elements of partial compliance to be included; in this case, the elements of mandatory compliance are clearly delineated in the binary evaluation and likewise the elements of partial compliance for purposes of their improvement (Amekawa 2009), including when they are evaluated with a certain degree of subjectivity depending on the evaluator (percentage, descriptive and qualitative, among others). However, what will define their approval in the evaluation will be the full presence of mandatory elements in the system, which emphasizes the importance of binary evaluation in the verification list process.

Due to the expansion of global trade, the difficulty of harmonizing several GAP certifications programs, international recognition of many private and public certification "seals" and the need to expand client base, producers end up contracting several certification programs so they can sell their products to various buyers in different countries. This situation drives up the cost of

GAP programs, as a result of the multiplication of compliance evaluation costs and the corresponding audits.

There is no interface between the certification programs, so rural producers and the certifying entities find it difficult to understand that several certifications share many requirements in common for which compliance is needed. Therefore, it was necessary to design an integrated evaluation tool, based on simplified indicators, that would analyze government and private certification programs and show the requirement dimensions in which the producer with. It is within this context that the 4DGAP tool arose, aimed at evaluating multidimensional impacts and steering the direction of GAP and good environmental practices certification programs.

The 4DGAP tool was developed through an alliance between Embrapa and IICA with the aim of establishing methodological bases to continue preparing and updating indicators that would facilitate the interface between different certification programs and producers, agribusinesses and government agencies. It not only facilitates assessing compliance with commercial demands for food safety, but also the progress made in reorganizing rural farms in each country in keeping with technical and environmental parameters required to meet the precepts of sustainable development.

## II. METHODOLOGY

The 4DGAP tool consists of a matrix of questions and binary responses (yes and no), created on a spreadsheet (MS Office Excel, Linux, Google, etc) that uses the same matrix mechanism. In order to build the questionnaire, information (metadata) is taken from the checklists of the main certification programs available on the market (GlobalGAP, Produção Integrada, TESCO Nature's Choice, BRC/GFSI, etc.), whose data originate from collections in the field; added to this is the interpretation of the origin of each verification element as needed, which transforms them into indicators (Amekawa 2009, Mattos et al. 2009).

Initially, the verification items in these programs were analyzed individually, point by point, selecting those that had the greatest capacity to represent the multidimensional character of the production context and the safety of the end consumer.

As a result, the 4DGAP tool was configured as a matrix with five columns (〖Axis Y〗_1^5): the first column contains the indicators in the form of questions, just as they would appear on the questionnaire sheet, and the rest of the columns correspond to each of the following dimensions: environmental care, worker/farmer safety, food safety and economics. The eleven groups of indicators were distributed along the length of the matrix (Axis X_1^n) as shown in Fig. 1.

| Detail of the checklist | | Measured dimensions | | | |
|---|---|---|---|---|---|
| 1. | Farm history and management | Environm | Worker | Food Safety | Economics |
| 1.1 | Management of physical space of the farm - Total | 0 | 0 | 0 | 0 |
| a) | Does the producer have the ability to read and interpret a map or sketch of the farm? | 0 | 0 | 0 | 0 |
| b) | The producer has at this time a map or sketch that allows viewing the farm; production areas, facilities, roads, water resources, forest, etc.? | 0 | 0 | 0 | 0 |
| c) | If necessary, does the owner have the conditions to design or help design a map or sketch for planning the property? | 0 | 0 | 0 | 0 |
| 1.2 | Production site management - total | 0 | 0 | 0 | 0 |
| a) | Does the farm have a risk map for chemical, physical and biological hazards for production and people? | 0 | 0 | 0 | 0 |
| 2. | Propagation material | | | | |
| 2.1 | Health and quality of propagation material - total | 0 | 0 | 0 | 0 |
| a) | Are the propagation materials certified for Health and Quality? | 0 | 0 | 0 | 0 |
| 3. | Soil and other substrates management | | | | |
| 3.1 | Soil maps - (Governmental indicator) - Total | 0 | 0 | 0 | 0 |
| a) | Is a soil map available for the region? | 0 | 0 | 0 | 0 |
| 3.2 | Soil analysis - Total | 0 | 0 | 0 | 0 |
| a) | Do you perform soil analysis on the farm? | 0 | 0 | 0 | 0 |
| b) | Does the producer know how to take the soil samples or does he have technical advice to do it? | 0 | 0 | 0 | 0 |
| c) | Does the producer know how to interpret the result of a analysis of his subjects, | 0 | 0 | 0 | 0 |

Introduction | Questionnaire | Program worksheet | Results displayed in graphics | Management matrix - government | Man ...

*Fig.1: Format of the 4DGAP matrix, where the indicators are placed on the horizontal lines and the evaluated dimensions in the columns. Source: Díaz et al. (2017)*

According to Díaz et al. (2017), the groups of indicators selected following the guidelines of Hayo and Van der Werf (2002) were derived from analyzing the checklists of GAP certification programs and the matrixes of the previously evaluated impact evaluation, resulting in the following elements: a) farm history and management; b) propagation material; c) soil and substrate management; d) fertilization; e) water management; f) crop protection; g) animal presence on the farm; h) hygiene and health; i) transportation; j) waste management and polluting agents; and k) training.

In each of these groups there should be at least one representative indicator occupying the matrix line (Axis X_1^n), without setting a maximum number as a limit, consistent with how it is represented in each dimension.

Subsequently, the 4DGAP tool was tested for its representativeness and the validity of the selected dimensions and indicators, with the support of, and analysis by government experts from several countries, field technicians, rural producers and users of safe food production and environmental assessment programs through meetings, interviews, and applications of the system on a phased experimental basis over a period of three years.

The data entry page of the questionnaire is found in the operative section of the 4DGAP matrix; it consists of a closed questionnaire where each line must be answered with a binary response: yes (1.0) o no (zero), according to the user's compliance with the questions presented in the checklist, which generated the indicators listed in Y_1, as shown in Fig. 2.

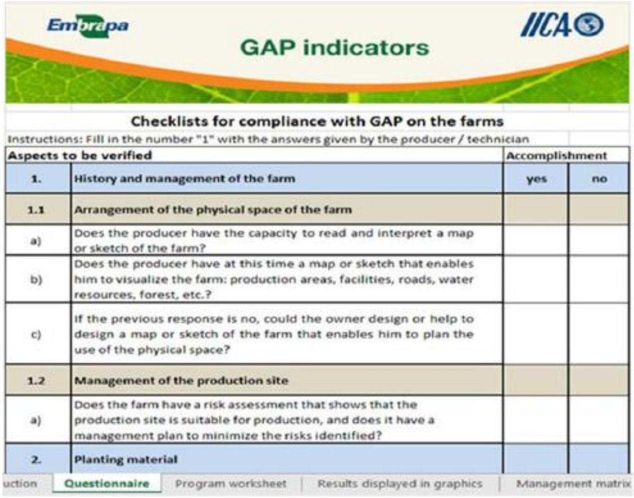



*Fig.2: Partial sample of the data entry questionnaire, with instructions on how to complete the columns on the right. Source: Díaz et al., 2017.*

Therefore, the indicator assumes a value of zero when the location being analyzed does not comply with the element of the checklist, or it complies partially, and a value of 1.0 when it complies fully. This eliminates the difficulty of assessing disparate indicators, since there is no comparison between them, just the verification of full compliance. It is fitting to emphasize that each indicator must show compatibility and the consequent score with at least one or more dimensions under analysis in the columns on the program worksheet. Therefore, the sum of the cells in each horizontal line should range in value between 1 and 4: the higher the value, the less specific and more representative it becomes.

The final results are shown on the results and graphics worksheet, where a numerical table is generated to show the results of the different indicators, together with a radial graph to show the overall verification of the analysis and the final score, as seen in Fig. 3 and 4.

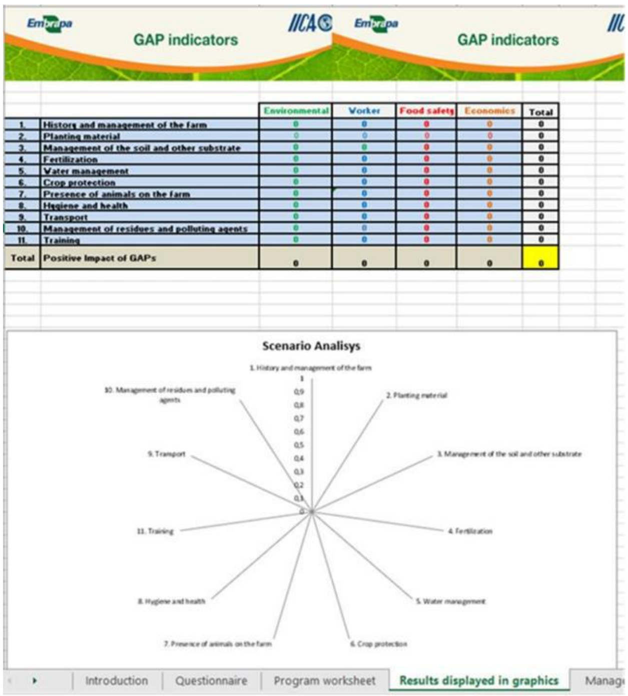



*Fig.3: Presentation of the output data in numerical and graphical form, with the corresponding quantitative axes for each group of indicators for the general overview. Source: Díaz et al., 2017.*

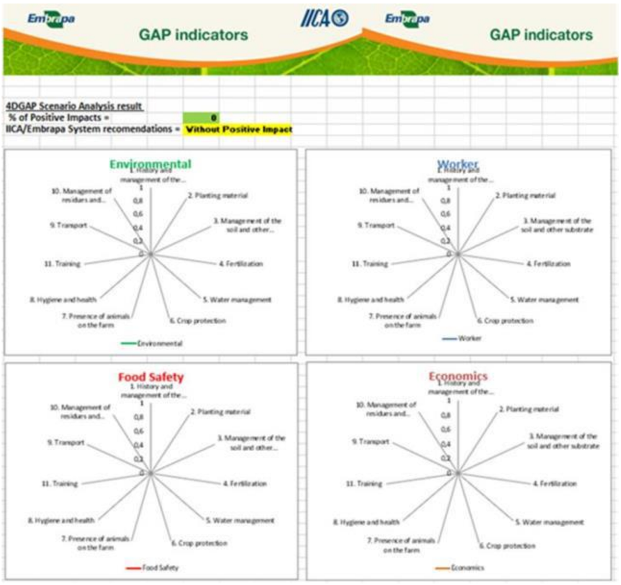



*Fig.4: Presentation of the scenario analysis result, and a general overview for each of the individually analyzed dimensions. Source: Díaz et al., 2017*

The scoring produced by the tool is organized in three stages:

1. The numerical standardization of the sum of the columns in the dimensions for each group of indicators, where the sum of the values in the dimension column is divided by the maximum number of group dimension

indicators (Idg) contemplated in that dimension (Equation 1), which allows for a normalized response to be generated between zero and 1.0.

Idg = (n marked indicators representative of the dimension / nT total indicators representative of the dimension in the group) ……….(1)

2. The summation of the indicators, first on the Y axis, in the form of dimensions in each group, where, in a situation of perfect compliance, the index reaches 1.0 and nears 0 where non-compliance with the demands on the interviewees' control lists is detected, and then on the X axis, where, if there is full compliance with the requirement of the indicator group, a score of 4.0 is obtained, which decreases when the elements in the control list under analysis are not fulfilled.

3. The summary phase forms the basis of the farm's planning and environmental management phase, where it indicates to the decision maker the areas that are weak and the extent of measures to be taken.

4. Once the final sum of the columns and rows is obtained, a single numerical value is generated so that the general matrix score varies between 0.0 (zero) and 44.0 (Equation 2). The tool is reset using this value, which is then divided by the total value (44) and multiplied by 100, which generates a positive impact value (PI%) in the form of a percentage where values closer to 100% represent environments with better socioeconomic and environmental conditions and a greater degree of compliance with the food safety requirements compared to scenarios with values closer to zero, where the positive impacts detected would be less.

PI (%) = (Σ Group indicators and dimension)/44*100 ………..(2)

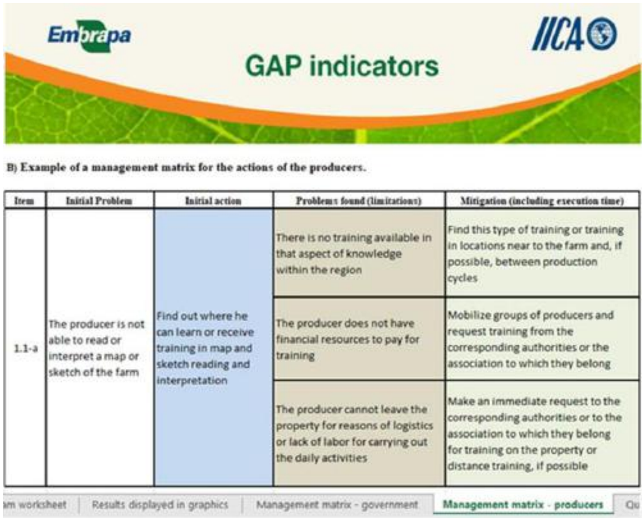
This simplified value facilitates the analysis of the overall evolution, and broken down by areas, of the same farm over time, as well as the comparison between the analyses of different farms, validating efforts to improve the production system and monitoring the individual, group and regional process. Therefore, the tool could appear in three different scenarios:

1. The maximum value of 100% would mean the "maximum positive impact" has been achieved and the sustainable development prerequisites have been fulfilled by applying all the suggested agricultural and environmental practices, hence it should stay productive

2. A value of 0% (zero) would signify the worst case, classified as "no positive impact"; because of this the system would register a high level of environmental degradation, which means no actions were identified in the unit being analyzed that could generate positive impacts and the grower will need to implement a recovery plan for the farm, a status which reflects in the system as "Apply environmental management".

3. Any intermediate value between the two values above would mean the grower must execute a recovery plan for the farm, classifying it with the status of "Apply environmental management".

The final item constitutes a guide to resolve the problems described in the analysis generated after the user completes the 4DGAP. It applies the principles of environmental management as it relates to the general surroundings of the farm, including the social, economic, productive and ecological dimensions present in the productive space. If the index generated by the 4DGAP is other than 100%, it means the analysis detects risks in at least one of the analyzed dimensions on the farm area being investigated, but they can be mitigated using measures based on the following problem-solving matrix: a) What was the initial problem? b) What initial measure can be taken? c) What are some of the problems that occur after taking the initial measure? d) What can be done to resolve the resulting problems and for how long? This process is shown in Fig. 5.



GAP indicators

B) Example of a management matrix for the actions of the producers.

| Item | Initial Problem | Initial action | Problems found (limitations) | Mitigation (including execution time) |
|---|---|---|---|---|
| 1.1-a | The producer is not able to read or interpret a map or sketch of the farm | Find out where he can learn or receive training in map and sketch reading and interpretation | There is no training available in that aspect of knowledge within the region | Find this type of training or training in locations near to the farm and, if possible, between production cycles |
| | | | The producer does not have financial resources to pay for training | Mobilize groups of producers and request training from the corresponding authorities or the association to which they belong |
| | | | The producer cannot leave the property for reasons of logistics or lack of labor for carrying out the daily activities | Make an immediate request to the corresponding authorities or to the association to which they belong for training on the property or distance training, if possible |



*Fig.5: Example of an analysis performed in the risk management matrix of the 4DGAP system performed on a situation found in an analyzed rural property. Source: Díaz et al., 2017.*

This matrix, which is based on similar risk analysis systems found in administrative and environmental processes applied to agriculture (Campos and Melo 2008, Garza-Reyes et al. 2018, Huber et al. 2018), is filled out freely, since this is the way in which users present the problem, realize it exists, dedicate time to study a solution and think of ways to resolve it while taking into account their technical and economic limitations and seasonal constraints.

Given that the problem-solving matrix is a practical exercise that is under development, it can change over time as problems are solved, as they are replaced by others and as more complex solutions arise than what were initially proposed.

## III. APLICATION AND CONSIDERATIONS

After its final structuring, the 4DGAP was evaluated in the field between 2016 and 2018 through its application among a group of producers participating in different private or public certification programs involving different crops in Brazil (Brasilia Qualidade no Campo, Programa de Alimentos Seguros y Produção Integrada/Brasil certificado) and Costa Rica (GlobalGAP and BPA-MAG), with subsequent interview, using a questionnaire with open answers, as a way to test whether rural producers understood it, gauge its acceptance among them, and verify both the ease with which technicians trained in its use could implement it and the tool's robustness in relation to different production and certification systems (see Table 1).

*Table 1. Application of the 4DGAP tool by country, the certified quality program, the number of producers and type of product.*

| Country | GAP Program/ certification seal | Number of producers analyzed | Type of product certified |
|---|---|---|---|
| Brazil | Brasília Qualidade no Campo[1] | 1 | Vegetables |
| | Produção Integrada/Brasil Certificado[2] | 2 | Fruits/ viticulture |
| | Programa Alimentos Seguros (PAS)[3] | 20 | Fruits/ viticulture |
| Costa Rica | GlobalGAP[4]/BPA-MAG[5] | 1 | Fruits |
| | BPA-MAG[5] | 3 | Vegetables |
| | BPA-MAG[5] | 1 | Strawberries, mulberries |

[1] Brasília Qualidade no Campo is an official program of the Government of the Federal District of Brazil.

[2] Produção Integrada and the Brasil Certificado seal constitute the Brazil government's official GAP certification system; it is administered by the Ministry of Agriculture and is recognized internationally.

[3] The "Programa Alimentos Seguros" and the PAS seal constitute a private certification program used by producers in Brazil; it is recognized by multinational companies that purchase their products.

[4] GlobalGAP is a private certification program used by producers worldwide and it is recognized by multinational companies that purchase their products.

[5] Program BPA-MAG is the Government of Costa Rica's official GAP certification system; it is administered by the Ministry of Agriculture and Livestock (MAG).

As the field surveyors were applied, the refinement of the 4DGAP was also made, which started to be considered adjusted from the lack of new demands on the part of technicians and producers. When applied by different people under different circumstances, the robustness of these evaluation systems proves interesting for decision-makers (Shackelford et al. 2019) whether it is the decision-maker is the rural producer who needs monitoring and direction to manage the particular circumstances of his farm; the certification program managers, who would have a clearer vision of the program's evolution; or the public agencies that would obtain feedback both on their projects with the aim of supporting these programs or the environment, and on the management of resources and efforts in this regard.

According to Mauchline et al (2012) and Coteur et al. (2016), in order to guarantee the robustness of the system after its launch, interviews to generate farm analyses were conducted among different people and different agencies, ranging from the producer who is directly involved in production and the company's technical assistant, to the company that receives and processes the product. Therefore, besides the 4DGAP team that created the tool, other technical advisors and extension officers were trained to apply the method and evaluate impressions concerning the advantages and challenges of implementing the tool, the interpretation of results and the guidance given to producers.

The first impression of the effectiveness of the 4DGAP tool came from the group of developers who applied the tool to different certification programs: whether the programs were complex or simple, they did not encounter any problems in terms of adaptability. Since the indicators' core principles were represented across the different programs and given that there were no unclear questions that would be subject to interpretation and therefore put the evaluation system at risk, the questions were answered in an efficient manner.

With regard to the programs that had the largest number of respondents, we made sure to send the interviews to trained technicians in order to obtained external input. According to the responses gleaned by these teams, it was verified that although users initially thought the questionnaire was long, once it was being applied it was possible to discuss and find solutions to many of the problems that were detected; later on, this would facilitate the work of technicians as they supported producers, turning it into a positive factor.

The tool was considered useful for revealing problems that often were not considered or were not obvious to farmers, which allowed targeted work to be done after the planning phase.

Another positive factor was the numerical visualization based on the final classification that resulted from the farm's evaluation and the partial values that ensued from the analysis, which shows the exact areas in which the producer could attain maximum results and investment options to reach the goal. This opened up the opportunity to assess the need for significant financial investment to reduce the wait time or select and fulfill critical high impact factors with less resources and time. As a result, the producer was able to face head on the difficulties that came with environmental management in his area of production, since he had a better understanding and a better basis for making decisions.

One advantage of the tool that was mentioned was the fact of having a group of producers who were using the same certification program, since this fostered an environment of internal competition to attain the qualifications endowed by the tool, making it possible to compare producers and generate the sense that improving is a requirement.

Finally, something that caught the attention of the technicians who applied the questionnaires and who worked directly with the group of producers is that the model allowed them to have a temporal view of the process, as they started to follow the evolution of sustainability standards and environmental impact, as the producer met the demands generated in the check list and then organized in the management matrix generated by the producer. These developments were previously restricted to eventual descriptive reports, when required by the certification programs, otherwise information would be lost to the process.

In addition, since 4DGAP tool facilitates continuous transformation, increasing or decreasing ratings both globally and at the level of indicators, it was easy for farmers to implement planning and impact verification to the extent they were re-evaluated.

## IV. SAFETY FOOD AND PUBLIC POLICY IMPLICATIONS

For local governments, the intrusion of foreign certification systems, private or not, usually focused on the export of local agricultural products, affects the organization of the official food security system in the country.

The existence of a tool that allows assessing and juxtaposing the requirements of the different certification systems operating in a country or administrative region, allows the opening of discussions regarding a policy of equivalence between the different "quality seals", whenever they depart the common basis of assessment through BPAs.

Likewise, if this tool has an advisory system for organizing the productive environment in the form of a matrix of risk analysis and management of the productive environment, it also facilitates the planning of agricultural policy for the region or by culture, since the bottlenecks for the implementation of good practice systems, generally required for products focused on exports, they can be planned based on real demands, avoiding unnecessary expenses with under or over dimensioning efforts, resources and manpower.

Therefore, the 4DGAP system offers an organizational advantage to support policies to support the agricultural sector of a specific country, region or productive sector, whenever they need to discuss the possibility of adjusting the official and unofficial certification systems in force for the local situation, facilitating the work of the production chain, product buyers or governments.

## V. CONCLUSION

The 4DGAP tool was designed to conduct an integrated evaluation of the various certification programs (official or private) available on the market. In the sample analyzed, neither developers nor technicians who were subsequently trained to implement it encountered any difficulties in understanding or applying it to the various programs.

The model provides the ability to monitor the improvement in the sustainability of the certified production system over time, maintaining the record of actions performed in the past and the planning of those that will still be necessary to achieve the optimization of the process, minimizing the impacts environmental, economic and social aspects of the analyzed production system.

After the initial impact that the evaluation, and as interviews were being held, a positive, collaborative attitude ensued among them during the analysis and discussion for solutions.

The annotation and graphics system helped the producers in visualizing the existing problems in the evaluated areas, as well as in the application of the environmental management matrix to solve the problems, with the support of technical advisors and extension staff, which can also be useful in a process of agricultural government planning in determining the bottlenecks of agricultural policy for the region or the productive chain analyzed.

The 4DGAP tool can be useful for analyzing the effectiveness of GAP programs, specifying which aspects or indicators reveal strengths or weaknesses and, at the same time, can also be used to assess the efficiency of different programs, whether private or official, allowing the harmonization among them, as a form of agricultural policy, if necessary.

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