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Methodological Proposal of the Holistic Environmental Metric Use at Sustainability Assessment on Agriculture Field

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ABSTRACT

Agriculture is essential for human life, as is a source of food, cosmetics, medicines, biostimulants, biopesticides, and other products of great interest. But sustainability refers to guaranteeing resources for future generations. Regarding the potential environmental impacts of agricultural practices, there must be adequate decisions in seeking better environmental sustainability. In this context, sustainability assessment is desired for the identification of sustainable practices, including agricultural activities. There are several tools for sustainability assessment described in the literature, mainly green chemistry metrics. But due to excessive simplifications of some green chemistry metrics and/or the possibility of incorrect adoption of a set of green metrics that leads to questionable interpretations, in a previous article, a new green metric for assessing the environmental sustainability of procedures in chemistry was developed, the holistic environmental metric named Green Graph Metric. Although aimed at chemistry science, the metric can be used in any field of knowledge, including Good Agriculture Practices. This article describes a methodological proposal by which agricultural farmers can use the green graph metric for the sustainability assessment of the use of fertilizers and soil additives, Water, Chemicals, Soil and substrate handling, Harvesting, and the environmental impacts of Waste management, Energy efficiency of agricultural activities on Wildlife protection, Air, and Human health.

Keywords: Agriculture; Green Chemistry; Green Metric; Holistic Environmental Metric; Green Graph

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1. Introduction

Agriculture is essential for feeding human and animal life. Besides, agriculture is a source of various commercial products. In addition to food, this sector provides cosmetics, medicines, biostimulants, biopesticides, and other products of great interest ^[1]. Moreover, agricultural waste can reach some applications, as it can be used for producing polylactic acid ^[2], energy ^[3,4], adsorbents ^[5], and green solvents ^[6]. Due to its potential, the production and trade market of agriculture are very resilient, even in periods of pandemics like COVID-19 ^[7]. In this scenario, the farm production plays an important role in the economy.

When the necessary conditions are met, agricultural growth takes place, and, in this way, can cause economic growth and a decline in the rate of poverty ^[8]. “End poverty”—as well as “end hunger”, which can be achieved by equality in food distribution—are goals established in Agenda 2030 for Sustainable Development ^[9]. Sustainability is an important theme: Smith et al. ^[10] describe sustainability as “the achievement of a balance between social, economic, and environmental needs that will sustain the planet and its population for the foreseeable future”. By applying sustainability concepts, we can guarantee future life on the planet.

Sustainability can be implemented in farming activities in several ways. Previous studies show that the modernization of agriculture, e.g., the use of treadmills and the Internet of Things, can lead farmers to achieve some aspects of sustainable production ^[11,12]. Sustainable aspects and principles can take place in various forms of agriculture, namely: organic agriculture, community-supported agriculture, sustainable urban agriculture, vertical agriculture, conservation agriculture, permaculture, agroecology and food forests, climate smart agriculture, organic farming, biodynamic agriculture, sustainable intensification and regenerative agriculture, integrated farming system and precision agriculture, as discussed by Smith et al. and Muhie ^[10,13]. This sector proved to be versatile in applying sustainability, as even conventional agriculture can present sustainable aspects ^[14].

1.1. Good Agricultural Practices (GAP)

Good Agricultural Practices (GAP) is the main tool

for implementing sustainability on farms. According to FAO, “the concept of Good Agricultural Practices is the application of available knowledge to the utilization of the natural resources based in a sustainable way for the production of safe, healthy food and non-food agricultural products, in a humane manner, while achieving economic viability and social stability” ^[15]. FAO establishes a standard for GAP, in which requirements to be obeyed are related to food safety, environmental management, produce quality, worker health, safety, and welfare, and general requirements ^[16].

According to experts’ view, the adopted GAP concept should include, when possible:

- three pillars of sustainability: the practices should be economically viable, environmentally sustainable, and socially acceptable;
- the focus on primary production;
- existing voluntary and/or mandatory codes of practice and guidelines in agriculture ^[15].

FAO recommends guidelines for GAP geared toward the production of safe food, adequate utilization of natural resources, treatment of products and animals with good care, maximum protection for workers towards good health, and preservation of local ecology. These guidelines are based on 11 categories of activities and concerns on farm resources as follows:

1. Soil;
2. Water;
3. Crop Production;
4. Crop Protection;
5. Animal Production (when there are livestock activities);
6. Animal Health (when there are livestock activities);
7. Animal Welfare (when there are livestock activities);
8. Harvest and On-farm Processing and Storage;
9. Energy and Waste Management;
10. Human Welfare, Health, and Safety;
11. Wildlife and Landscape.

To implement GAP, farmer decisions based on risk analysis principles related to food safety, environmental, and social concerns are necessary ^[17]. In this context, the gains in sustainability of one field can deprecate the gains in another field. For example, an increase in safe food production (gain in economic sustainability) can occur

with an increase in persistent agrochemical use (decrease in environmental sustainability). So, the final overall decision about how GAP will be implemented must be in accordance with the higher degree of sustainability to be reached, and, in this way, the choice of the main sustainability issues to be solved is not always easy.

1.2. Environmental Sustainability

Among various aspects of farms' activities, the use of agrochemicals and scarce natural resources does not meet sustainability standards. For example, nitrous oxide emissions result from the application of fertilizers, manure handling, and other agricultural activities on soil, making agriculture the largest anthropogenic source of nitrous oxide emissions in 2022. Agriculture accounted for 74.6% of total nitrous oxide emissions in the U.S.A.^[18].

Regarding the potential environmental impacts of agricultural practices, there are 10 categories of concerns as follows:

1. Fertilizer and soil additives;
2. Wildlife protection;
3. Soil and substrates;
4. Water;
5. Chemicals (plant protection products, agrochemicals, non-agrochemicals);
6. Harvesting;
7. Waste management;
8. Energy efficiency;
9. Air;
10. Personal hygiene (associated with Personal Health)^[16].

For each category, there must be adequate decisions in seeking better environmental sustainability. To identify the best decisions, the use of sustainability metrics is helpful. In this context, performing an assessment with sustainability metrics is desired for the identification of the sustainability of practices in agricultural activities^[19].

2. Sustainability Metrics

There are several sustainability metrics described in the literature. In the agricultural field, the used sustainability metrics are based mainly on the model developed by the Organization for Economic Cooperation and Development^[20] or on the ISO 14000 model^[21,22], i.e., Life Cycle

Assessment^[23]. Also, FAO recommends the use of a risk assessment, which can be used as a sustainability metric^[15]. All these metrics take into account economic, social, and environmental aspects.

But the complexity of the former metrics requires carefulness in the assessment to avoid mistakes, and the higher simplicity of the latter metric can lead to misleading interpretations. So, a reliable metric must be used in a manner that farmers can perform an adequate sustainability assessment of farm activities. Besides, performing only the environmental assessment on sustainability requires a different metric.

In the field of Green Chemistry, the sustainability metrics problem is not different. The adoption of a set of metrics must be adequate to actually give a reliable green assessment, so that a chemical procedure carried out with methanol cannot simply be greener than the same procedure carried out with ethanol, for example. Also, simplistic green metrics cannot perform a more complete sustainable assessment as a Life Cycle Assessment (LCA), which, on the other hand, has some problematic issues regarding its use in some specific areas, such as Latin America.

Thus, to overcome these problems, Finazzi & Santos^[24] developed a new green metric for assessing the environmental sustainability of procedures in chemistry, the holistic environmental metric (HEM) named Green Graph Metric (GGM). Although aimed at chemistry science, this HEM can also be used by farmers for the assessment of sustainable practices implemented in agricultural activities, as all resources required in the GGM methodology can be identified in farm activities (e.g., all materials can be described in terms of chemicals) and can be quantified or estimated by scientific methods. Regarding this context, as described in the following sections, GGM can be easily applied in the agricultural field.

In this article, the use of the environmental sustainability assessment method developed by Finazzi & Santos to assess the sustainability in the agricultural field is discussed^[24].

3. The Green Graph Metric Assessment Applied to Agriculture Activities

The structure of the GGM obeys ISO 14000 guide-

lines ^[21,22]. In this model, the objectives and the boundaries of the activity must be specified, as the sustainability assessment can be different depending on the extension of the procedure. An activity can be assessed globally or only in terms of fertilizers or only in terms of air impacts, depending on the objective of the assessment.

GGM assessment with specific objectives is more useful in the agricultural field than performing with general objectives. For example, for tillage whose nutrient needs are low, or at a moment when the nutrient concentration is below the ideal, the excess of nutrients added next to harvesting can be useful for another tillage whose nutrient needs are high. In this case, the apparent excess of resources signifies sustainable activities. Among various reasons, this is one reason why specifying the farm needs and the boundaries of the activities to be assessed is crucial for performing an adequate assessment.

When the objectives and the boundaries are well defined, the GGM assessment is directly associated with the extension of the farm activities chosen for the evaluation. For an example of a corn tillage in which the boundaries of the related activities initiate with the soil weeding and finalize with the first harvesting crop, the assessment of the overall environmental sustainability of the activities can include the tillage area and its soil characteristics and/or the utilized fertilizers and/or water and energy consumption and/or waste generation and/or air (gaseous transfers by vegetables) and/or health hazards, depending on the adopted assessment chosen by the farmer. On the other hand, in the case of hydroponic cultures, the boundaries of the assessment do not include soil weeding, nor does the assessment include soil characteristics, but must include activities on the tillage over the period of interest, and depends on the objective of the assessment.

After defining the objectives and boundaries, an inventory of the activity to be assessed must be done. All resources used in the activity must be listed to perform the calculations of the GGM, i.e., the initial and the final resources, even intermediary resources, must be listed. For example, for the assessment of the extractivism of a medicinal plant in which 10 g of leaves are extracted, the initial resource is the entire vegetal body, when the objective of the assessment is to investigate if the vegetal life persists, but can be the ecosystem on an area of 10 km² if the

objective is to investigate the comprehensive ecosystem in this area. The final resource is the vegetal body after the extraction in the former case and the ecosystem in the latter case. If the plant does not survive, the final resource is converted to waste in the former case. Thus, the period considered for the assessment must be defined. In the same example, the initial resource can be 10 g of leaves if the chosen procedure utilizes this mass, and so on.

The utilization of GGM requires the transformation of material resources in terms of chemicals. In this way, estimates about the chemical composition of each resource can be made, as described in the following sections. Also, some difficulties associated with the measurement precision can be faced, so certain trends can be utilized for making the necessary estimates ^[20,24].

The next step involves the calculations. The GGM involves 16 calculations: 15 submetrics and the final value, as follows:

1. Problem of Prevention of Waste Generation;
2. Exposure to Toxic Compounds;
3. Accumulation of Toxic Compounds;
4. Human Carcinogens and Mutagens;
5. Procedure Safety;
6. Catalysis Efficiency;
7. Electric Energy Consumption;
8. Global Warming;
9. Ozone Layer Depletion Potential;
10. Smog Photochemical Formation;
11. Acidification Potential;
12. Eutrophication Potential;
13. Consumption and Disposal Thermic Potential of Water;
14. Human Health Damage caused by Ionizing Radiation;
15. Resource Consumption;
16. The final GGM value.

As can be seen in **Table 1**, the categories of concern in potential environmental impacts of agriculture practices can be associated to GGM submetrics in the following manner: Fertilizer and soil additives impacts can be assessed directly by submetric 1; impacts on wildlife protection by submetrics 2, 3, 11, 12, 13, 15; harvesting and soil and substrates impacts by submetrics 1 and 15; water

impacts (associated to thermal disposal) by submetric 13; chemicals impacts by submetrics 1, 2, 3, 4, 5, 8, 9, 10, 11, 12 and 14; waste management impacts by submetrics 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 13 and 14; energy efficiency impacts by submetric 7; impacts on air by submetrics 8, 9, 10; and personal health impacts by submetrics 2, 3, 4, 5 (including the use of proper protective equipment) ^[15]. All

chemical interactions must be considered, and catalyzed reactions are assessed directly by submetric 6. Chemical compounds produced by chemical reactions must be assessed in the same manner as chemicals utilized as resources. The final value of GGM accounts for the exposure time, whose value is utilized in the calculation of exposure to chemicals, which is associated with personal health.

Table 1. Association of GGM assessment with GAP requirements.

GAP Requirements	The Impacts Are Directly Assessed by Submetric(s):														
	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fertilizer and soil additives	x														
Wildlife protection		x	x								x	x	x		x
Harvesting soil and substrates	x														x
Water													x		
Chemicals	x	x	x	x	x			x	x	x	x	x		x	
Waste management	x	x	x	x	x			x	x	x	x	x	x	x	
Energy efficiency							x								
Air								x	x	x					
Personal health		x	x	x	x										
Chemical interactions						x									

*Calculations of submetric 1 must be done with respect to the farm needs and to real environmental impacts for adequate assessment.

4. Specific Assessments

4.1. Soil and Substrates

Adequate management of soil and substrates minimizes losses and contaminations, as well as can improve the quality of soil biota, increasing crop yield ^[17,25,26]. So, the successful management must be identified by a sustainability assessment, which can be made with GGM. Although this metric is not designed to assess the physical structure of soil and substrates, the chemical composition of soil and substrates can be directly assessed, while biological activities can be indirectly assessed, as the chemical composition is associated with the biological activities and can be determined by chemical analysis.

The GGM method was designed with the need for the utilization of the actual chemical composition of used materials in a procedure, so that the soil chemical composition of the farm activity must be clearly defined. When chemical analyses for determining soil composition are not possible, the chemical composition of the soil must be estimated by the procedure operator. For example, the operator can estimate soil composition to be 45% mineral mat-

ter, 25% of air, 25% of water, and 5% of organic matter ^[27]. Mineral matter composition can be estimated by 46,70% Silica, 27,13% aluminum oxide, and 12,20% ferric oxide ^[28]. Air composition can be estimated as 78% nitrogen and 21% oxygen. Organic matter composition can be estimated in terms of carbon equivalent mass by

$$\text{carbon equivalent} = \frac{\text{number of carbon atoms}}{\text{in the molecule}} \times 12,011 \text{ (g)} \quad (1)$$

The molecule to be chosen in equation (1) must be in major proportion in the soil, and the soil composition can be determined based on local proximity to sites of previous studies ^[29].

To identify how some chemical compound concentrations are next to ideal, the following formula is useful for each chemical compound:

$$\text{chemical concentration} = \frac{\text{real concentration}}{\text{ideal concentration}} \times 100\% \quad (2)$$

When the result of equation 2 is less than 100%, some replacement of the chemical compound is needed; and when it is over 100%, there is an excess of the chemical compound at the site.

Performing soil GGM assessment can lead to detecting contamination that can impair soil quality and thus can affect plant growth^[30]. So, adequate sustainable management of soil is necessary. Soil quality indices can improve with soil management with wheat straw^[30]. Other methods of soil management can include crop rotation^[31].

4.2. Water

Sustainable use of water requires moderate consumption that attempts to achieve the best plant growth possible, leading to farm production without waste. This is an important matter in the field, as water scarcity is a major problem, and agriculture needs high water use for irrigation^[31–33].

Water is accounted for directly in GGM only with respect to thermal pollution; thus, the assessment must account for indirect measures. Although not accounted for directly in GGM when no temperature variation is verified, water use in agriculture can be assessed by accounting for soil moisture and/or leaching of chemicals (determined by chemical analysis of the water table), and/or accounting for water losses in chemical solution form, since potable water has dissolved mineral salts. The following formula can be utilized for performing a water use assessment on soil:

$$\text{moisture content} = \left(\frac{\text{wet mass}}{\text{dry mass}} \right) \times \frac{100\% - 100\%}{100\% - 100\%} \quad (3)$$

As water is used for irrigation, the pollutants, when carried out by the liquid, shall participate in the composition of the soil and/or the plant body and/or the substrate. Then, the water quality must be assessed as an initial resource in any assessment in agriculture, and wet materials/resources must be assessed as intermediate or final resources. When pollution is identified, some methods can be employed to acquire better water quality, e.g., adsorption of pollutants with agricultural products, as kiwi peels^[5].

4.3. Crop Production

The main resources associated with high crop production are fertilizers and soil additives. Plants survive with the nutrients carried from the air and soil. But harvesting routine leads to constant extraction of nutrients

from the soil, needing their replacement with fertilizers for maintaining productivity^[15,25]. Besides, during the crop period, there can be problems associated with the possible selection of the wrong nutrient source^[34] and/or limited absorption of nutrients by plants^[35]. So, fertilizer control can indicate the need for addition or for economization of the resource.

The actual percent of fertilizer content in the soil or substrate can be determined by the following formula, similar to equation (2):

$$\text{fertilizer content} = \left(\frac{\text{real content}}{\text{ideal content}} \right) \times 100\% \quad (4)$$

So that seeking a manner for making fertilizer content equal to 100% in equation (4) by fertilizer control can avoid under- or over-application of fertilizers^[34]. In this context, equation (4) is more meaningful than the submetric 1 for determining the ideal crop production, and the submetric must be interpreted only in terms of the excess of fertilizer that causes real environmental impacts.

Although fertilizers provide vital nutrients to plants, direct exposure to them will cause health hazards in humans. Synthetic fertilizer can be toxic to humans in its raw form^[15]. As fertilizers also can cause eutrophication^[32], a sustainability assessment in this case is desired, since any chemical compound can exhibit environmental impacts, depending mainly on its concentration^[24], even alternative fertilizers that have been developed^[16], except only in cases of inert non-chemical fertilizers^[32], which clearly do not show any environmental impact.

To carry out the GGM assessment in this case, simply determining the chemical composition of these resources is necessary for the initial step. Determination of their contents on different substrates is necessary for the final step.

As storage of fertilizers must obey GAP^[15], this practice must be taken into account in the assessment too, since chemical interactions of fertilizers with other stored chemicals at the same place can occur.

4.4. Crop Protection

Crop protection has been made mainly by the use of agrochemicals, like fungicides^[15,36], pesticides^[32], insecticides^[37], and fumigants^[36]. Like fertilizers, the assessment

of these chemicals by GGM requires simply the determination of their content at the different steps of the metric process.

On the other hand, crop protection can be fully sustainable in terms of Chemistry when only non-chemical control methods are employed, like exploitation of organic control practices, allelopathy, biocontrol, and non-agrochemical use^[17,32,36,38]. But the benefits of these methods can be unclear with the choice of the GGM for the assessment when the methods are associated with agrochemical use, even when there are alterations in chemical compound contents in agrochemical formulations.

4.5. Harvest and On-farm Processing and Storage

Crop losses can occur during harvest and on-farm processing and storage. Applying GAP to prevent these losses is desired for better production. As GGM detects the total generated waste and the potential chemical interactions in the context of harvest and on-farm processing and storage^[15], crop losses are accounted for indirectly in the assessment.

For a direct account, the losses can be calculated by

$$\text{farm losses} = 100\% - \left(\frac{\text{good quality products}}{\text{total production}} \right) \times 100\% \quad (5)$$

4.6. Energy Management

Low energy consumption is economically sustainable and is desired, since energy consumption can be very expensive. Electric energy consumption is assessed directly in GGM by submetric 7, and must take into account the energy consumption of total electrical machinery, so that the result becomes reliable^[24].

As the submetric does not account for energy consumption produced by renewable sources, the sustainable energy generated by biomass, which is largely employed^[3-5], does not receive a low score in the assessment.

4.7. Waste Management

Determining the efficiency of waste management is crucial in a sustainability assessment. So, accounting for waste quantity is essential to verify how the sustainability

of activities can be improved.

In the GGM assessment, the waste amount is mainly accounted for by submetric 1. By this calculus, materials degradation, reuse, recycling, and correct disposal are also accounted for to better identify the sustainability of each activity.

Some aspects of waste assessment are important to highlight. First, specific substances assessment is possible: when necessary, each chemical compound can be assessed individually, simulating the activity only dependent on the chosen chemical. Then, natural processes like soil salinization can be predicted and/or avoided with analysis of GGM results.

Second, the GGM assessment of activities involving the reuse and recycling of waste can only present results of better sustainability when the overall activity, i.e., that comprehends the waste generation activity plus the reuse/recycling activity, is more sustainable when compared with the set of both individual activities. For example, the removal of ciprofloxacin with kiwi peels^[5] must be assessed from kiwi production and ciprofloxacin use, both in a single activity

1 — with and

2 — without reuse of kiwi peels, for comparison.

Another example is the removal of pesticides in water by activated carbon produced from biomass^[39], which must be assessed from the use of pesticides and the production of activated carbon, both in a single activity

1 — with and

2 — without reuse of activated carbon.

Third, total degradation of a chemical requires a period that can be larger than the period adopted for the assessment, so the degradation at the assessment moment must be calculated or estimated.

Fourth, waste generated by biological or biochemical processes, like those present in biomass systems, can be complex to determine, so estimates must be made^[24]. For example, estimates on nutrients in a biomass reactor can be made regarding the amounts of carbohydrates and proteins. Another example is biochar that can be produced by carbonization of biowaste of biomass reactors^[40] and has shown innumerable benefits, e.g., in soil fertility, pollution remediation, mitigation of greenhouse gas emissions, abiotic stress, and disease management^[41]. Biochar can be

considered as being totally carbon by estimation.

4.8. Life Protection

Life protection comprises animal health, human health, and wildlife protection. Life protection involves good quality of soil, water, and air. But pollution can take place when heavy metals are present in soil^[30], in water^[33] and nitrous oxide in air^[19]. Water can suffer acidification^[32], e.g., by biological activities. Agriculture production enhances global warming due to 19–29% of total global greenhouse gases (GHGs) emissions, like methane, nitrous oxide, and carbon dioxide^[32,42]. Water and air can carry pollutants on a worldwide scale, so that the adequate mitigation of pollution is ultimately important.

All efforts made to mitigate water and air pollution are favorable to agricultural sustainability. “The mitigation potential of agriculture relies on sustainable agricultural practices which include organic farming, agro biodiversity, better land and water management practices, composting, vermicomposting, integrated pest management, cover cropping, mulching, use of biofuel/bio energy, reduction of fertilizer use, crop rotations, and soil conserving tillage which reduce soil erosion”^[42]. Then, the use of adsorbents for pollutants removal from water^[5,39] and techniques like agroforestry and reduced tillage for climate resilience are promising to achieve better sustainability, as a global meta-analysis found that agroforestry systems can store up to 9.5 Mg C/ha/year^[43,44].

Life protection can be considered the main assessment of GGM. By performing the overall calculation, life protection is assessed across the entire metric process, except for only the submetrics 6 and 7.

Regarding some sustainable benefits that can be noticed towards global warming—like carbon sequestration—the calculus of submetric 8 can be adjusted, making CO₂ equivalent mass negative or altering the calculus to the following:

$$GW = ((\text{total mass utilized at the procedure}) + \sum \text{CO}_2 \text{ equivalent mass}) / (\text{total mass utilized at the procedure}) \times 100\% \quad (6)$$

The numerical result will exceed 100%, since carbon sequestration decreases the carbon dioxide content in the air.

$$\text{gain} = (GW - 100\%) \quad (7)$$

Then, the value corresponds to the real gain in sustainability.

For example, the utilization of equation 6 for the calculus of the carbon sequestration in the Asia Pacific in the period 2000–2010^[44] can be made by making the numerator = total biomass at 2010 and denominator = total biomass at 2000:

$$GW = (2.28 / 1.82) \times 100\% \quad (8)$$

The numerical result will exceed 100%, as expected, since carbon sequestration promotes better sustainability. Replacing the values in equation (7) makes the real gain in sustainability equal to 25,3%.

5. Final Remarks

Several activities can be assessed by GGM directly or indirectly. For example, direct benefits of reforestation can be assessed by submetric 15, as planted biomass is a renewable resource. If deforestation is replaced by reforestation of the same vegetation species and there is no other resource consumption, the submetric value equals 100%. Also, the gain in sustainability by the use of vegetable scraps as fertilizers can be directly assessed by submetric 1, since they can be considered material appropriately disposed or degradable material.

Some farm activities can lead to the generation of recyclable or reusable materials. In those cases, the activities that employ recycling or reutilizing materials must be assessed together as a set. Although the gain in sustainability cannot be assessed directly by GGM, performing the overall assessment of activities with and without the use of recycling or reutilizing materials can reveal the difference between considering recycling and reuse or not.

The interpretation of the results of GGM assessment is more adequately done when all values are considered individually and globally due to the need for coherence of discussions in sustainability with Green Chemistry Principles. For example, sometimes the use of a natural compound is not more sustainable than a similar manufactured chemical compound from the point of view of waste generation and/or chemical reaction yield^[45].

In the overall context, GGM proves to be an adequate tool for sustainability assessment in the agricultural field. The metric has the potential for indicating the gains in sustainability with GAP adoption, even when individual chemical compounds are assessed. Gains in sustainability can also be measured with estimates and evaluations of the mitigation of pollution, such as global warming.

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