DOI: 10.22620/agrisci.2022.32.010

SUSTAINABILITY PERFORMANCE ASSESSMENT OF THE PARTICIPATORY GUARANTEE SYSTEMS (PGS): A CASE STUDY IN BEIJING FARMERS MARKET

Nadir Nadirli[1], Vugar Babayev[2]*

1 College of Economics and Management, China Agricultural University, Beijing 100083, PR China
2 Ganja Agribusiness Association, 19 Javadkhan Street, Ganja AZ 2000, Azerbaijan
E-mail: v.babayev@gaba.az

Abstract

Among the range of incentives that might motivate farmers to adopt more sustainable practices, focus is given on the role that institutional innovations such as PGS could play in the transition to sustainable agriculture. PGS are established by producers, consumers, local authorities and other interested stakeholders who collectively ensure that agreed sustainable agricultural practices are adopted. Despite the growing popularity, there is no an experimental assessment of sustainability performance (SP) of PGS in order to better understand the role of PGS in sustainable agriculture.

The objective of this study is to (a) assess a sustainability performance of PGS comprehensively, (b) perform a systematic assessment of synergies and trade-offs between sustainability dimensions and themes and (c) quantify the real influence of the selected sustainability themes on the least evolved theme.

The Sustainability Assessments of Food and Agriculture Systems (SAFA) Guidelines published by the Food and Agriculture Organization (FAO) provides a transparent and aggregated framework to encompass all aspects of sustainability as well as to understand how strength, weakness and progress could be tackled in the farming systems. This study used the indicator-based SAFA consistent SAFA Tool to assess sustainability performance (SP) of the Beijing Farmers Market (BFM) PGS in China. Based on the respective sustainability scores, the synergies and trade-offs between sustainability dimensions and themes were analyzed using the non-parametric Spearman correlation test, and a linear regression analysis was applied to identify the influence that selected sustainability themes have on a poorly rated theme.

The results displayed trade-offs between economic dimension and other three sustainability dimensions, due to vulnerability theme which is a most challenging and poorly-rated theme. Whereas the holistic management, biodiversity and water themes had a significant effect *($P<0.05$)* with the capacity to decrease vulnerability level by 43.4%, 41.4% and 37.3%, respectively. Through its positive influence, social dimension enhanced the achievement of sustainability goals on other dimensions. The study further argues that with a committed and supportive consumer base PGS could become a reservoir of social capital to build a fair and sustainable community.

This study presents a new perspective leading to a guideline for other PGS initiatives those early in the sustainability journey.

Keywords: PGS, SAFA, SP assessment, synergies, trade-offs

INTRODUCTION

Institutional innovations are considered as a new regulations and ways of re-organizing the relationships between producers and organizations (actors) in the food system (Hargrave and Van De Ven, 2006) by pushing the boundaries of the traditional roles of market and institutional intermediaries (Vorley, 2013). One of the examples of the institutional innovations is the participatory guarantee systems (PGS), which are defined as *"a locally* *focused quality assurance systems. They certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange"* (IFOAM, 2008).

PGS offer producers a wide range of benefits such as market access, farmer empowerment, improved social bonds, regular sales, cost-saving practices, a better management of natural resources and enhanced food security. Hence, PGS play a vital in to reduce food insecurity and poverty problems among rural farmers, thereby fostering more sustainable livelihood (Bouagnimbeck, 2014). Moreover, PGS can be used as a tool to improve organic agriculture and alternative certification system (Cifuentes et al., 2018); intensify knowledge sharing and disseminate good agricultural practices among farmers (Kirchner, 2014); facilitate peer-to-peer process, enhance food sovereignty for local markets (Kaufmann and Vogl, 2018). PGS have the potential to enable transformation towards sustainability (Anderson et al., 2019) but convincing evidence is needed on how PGS promote the transition to more sustainable food system (FAO/INRA, 2016). Although previous studies scientifically covered individual aspects of PGS (Bouagnimbeck, 2014; Cifuentes et al., 2018; Hirata et al., 2019; Källander, 2004; Kaufmann and Vogl, 2018; Kirchner, 2014; May, C., 2008; Nelson et al., 2010, 2016; Sacchi, 2019), a deep analysis that covers key aspects of sustainability and quantitative analysis of interactions between sustainability objectives lack to date.

Many different frameworks have been developed (Belcher et al., 2004; Binder et al., 2010; Singh et al., 2009), but most of them are unclear in getting agreement on how to asses sustainability (Giannetti et al., 2010; Lien et al., 2007). This perhaps partly due to lack of an agreed-upon definition of sustainability (Parris and Kates, 2003) and incompatible approaches to performance analysis in the field of sustainable development (Giampietro et al., 2006). For instance, Life Cycle Assessment (LCA) tools quantitatively evaluate environmental impact of a product considering the use of resources and emission of pollutants (Ran et al., 2015) but ignore the economic and social dimensions (Finkbeiner et al., 2010). Furthermore, the MESMIS framework has been applied to more than 20 case studies across Europe and Latin America in order to evaluate agricultural sustainability (López-Ridaura et al., 2005a, 2005b; Speelman et al., 2007). The operative structure of the MESMIS framework is based on a six steps. The first three steps are related to a system characterization, the identification of key aspects and the selection of indicators with respect to the three sustainability dimensions (environmental, economic and social). Whereas in the last three steps, sustainability of the resource management systems is assessed through mixed (qualitative and quantitative) techniques and multi-criteria analysis based on the information obtained from the indicators (López-Ridaura et al., 2002). However, the MESMIS framework excludes key indicators (e.g., stakeholder participation) from being included in the assessment (Astier et al., 2011). The system-oriented sustainability assessment approaches, such as Response-Inducing Sustainability Evaluation (RISE; Grenz et al., 2012; Häni et al., 2003), evaluate sustainability of farm management with respect to the three sustainability dimensions like MESMIS but with limited number of indicators. Schader et al. (2014) comprehensively compared the precision and scope of more than 30 different approaches identified in literature, concluded that none of them capture all aspects of sustainability assessment. The divergence between the proposed sustainability assessment tools and their components to measure "what matters to whom and how" reinforces the point that assessment frameworks remain fragmented. This means that they need to be holistic and harmonized, and integrate all essential components of sustainability establishing a "common language" for sustainability assessment that is relevant to governments, policy-makers and agricultural holdings whether they are big companies or small-scale producers. To close this gap, Food and Agriculture Organization of the United Nations (FAO) developed the Sustainability Assessments of Food and Agriculture Systems (SAFA) Guidelines, by providing a globally applicable aggregated framework for sustainability assessment (FAO, 2014). SAFA Guidelines is comprised of 4 dimensions, 21 themes and 58 sub-themes with specific sustainability objectives (Table S1). Based on the SAFA Guidelines, FAO created the SAFA Tool, which is an indicator-based tool in order to conduct sustainability assessment by supporting trade-off and synergy analysis.

This study aims to (a) apply the SAFA-consistent SAFA Tool to assess a sustainability performance of the Beijing Farmers Market (BFM) PGS comprehensively, (b) perform a systematic assessment of synergies and trade-offs between sustainability dimensions and themes using Spearman correlation test, (c) and quantify the real influence of the selected sustainability themes on the least evolved theme using linear regression analysis.

The sustainability performance assessment of the BFM PGS and identifying interactions between sustainability goals provide a roadmap leading to an evidence-based and action-oriented cyclic process conducive to the sustainable development of other PGS initiatives worldwide.

MATERIALS AND METHODS

This section outlines the SAFA Tool used (Section 2.1), describes the selected PGS (Section 2.2), and explains the data collection and analysis process (Section 2.3),

2.1 The SAFA Tool Approach

The aim of the SAFA Tool approach (FAO, 2014b) is to provide a standardized metrics to guide assessments, which is detailed in terms of what “sustainability” means in a practical context. The SAFA Tool assesses the sustainability performance of the agricultural holdings with respect to the 21 themes and 58 sub-themes identified in the SAFA Guidelines (Figure 1).

For each theme and sub-theme, the SAFA Guidelines outline goals and objectives that are globally comparable in all contexts. For instance, for the theme Land the goal is “No land is lost due to surface sealing or mismanagement of arable lands and pastures, and soil fertility is preserved and enhanced”. Whereas for the sub-theme Generic Diversity the objective is “The diversity of populations of wild species, as well as the diversity of varieties, cultivars and breeds of domesticated species, is conserved and improved”. Each sub-theme contains a number of indicators that express sustainability performance on a scale from 0 to 100%. 0% represents an unacceptable state that do not meet the sustainability objectives, whereas 100% represents a situation where all implemented farming activities are related to the “best” achievable objective.

Unlike the SMART (Sustainability Monitoring and Assessment Routine) Farm Tool (Schader et al., 2016), the SAFA Tool sets the system but considers whether the assessed farm generates significant impact on sustainability in the surrounding community and ecosystem. The SAFA tool can also be used to cover the farming activities for one year, which provides a benchmark pointing out critical areas for further improvement. This is especially important for establishing a threshold values for the future sustainability assessment.

Science-based in nature, The SAFA Tool can be applied in a case studies. However, it is not a tool of rating which is appropriate for a product-specific sustainability such as LCS approach, and is focused on farms rather than the lifecycle of a product.

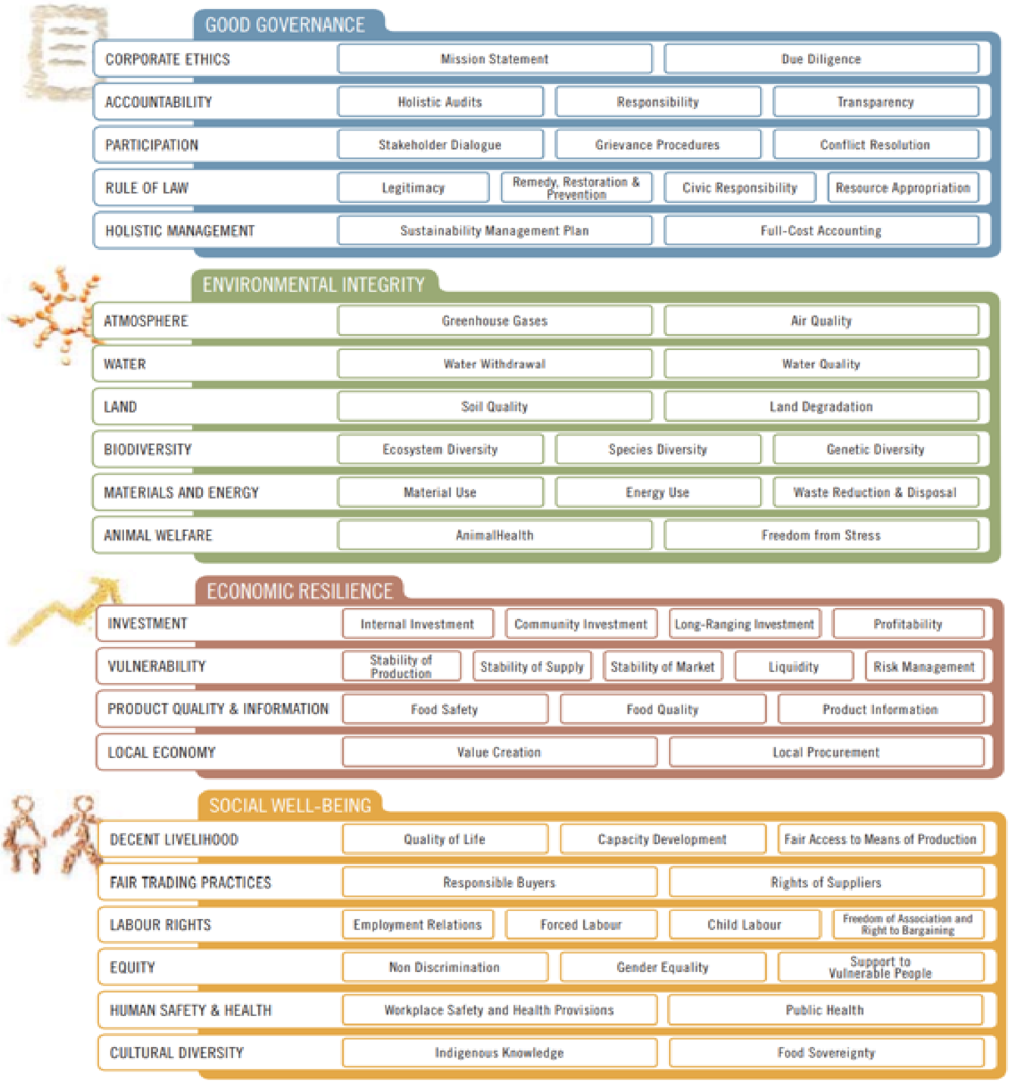

Figure 1. Overview of the SAFA dimensions and constituent components (themes and sub-themes). Source: Food and Agriculture Organization of the United Nations (FAO, 2014).

2.1.1 Determining the Sustainability Performance

The SAFA Tool approach (FAO, 2014b) starts with the mapping of the assessed entity and review of relevant sub-themes and indicators based on sustainability objectives and context, followed by determination of a performance score for each indicator, and finally, the visual representation of the sustainability report based on the performance scores.

The SAFA Tool (Version 2.2.40) contains a total of 116 performance indicators that facilitate measuring progress towards sustainability across the 21 themes and 58 sub-themes (*see Appendix 1, Table A1*). In this study, indicators used for the sustainability performance assessment have been selected according to the following criteria (Lebacq et al., 2013; Ssebunya et al., 2019)

- Parsimony: selection of minimal but manageable set of indicators,
- Consistency: the indicators are complementarity for an appropriate interpretation,

- Sufficiency: the indicators are comprehensive to integrate all sustainability goals

For each sub-theme, all indicators in the governance, economic and social dimensions are integrated into the calculation with the weight 1, and the weight is distributed evenly among indicators within each sub-theme (Table 1-A). No need for weighting if there is only one indicator in the sub-theme (e.g., Community Investment) whereas the sub-theme (e.g., Quality of Life, Stakeholder Dialogue) contains more than one indicator, the mean is taken out of the respective number of scores. If the mean is not possible, the lower score is given to the respective sub-theme.

Table 1. Overview of the different weights for the indicators in the governance, economic, social and environmental dimensions.

A. The number of indicators per sub-theme is:	Indicator weight in the governance, economic and social dimension
1	100 percent
2	50 percent
3	33 percent
4	25 percent
B. Combination of indicator types in the environmental dimension	Maximum potential indicator points[1] in the environmental dimension
T - R - P	1+2+3= 6 points
T- R - P - P	1+2+3+3 = 9 points
R - P - P - P	2+3+3+3 = 11 points
R - P - P - P - P	2+3+3+3+3 = 14 points
T - R - P - P - P	1+2+3+3+3 = 12 points

Source: (FAO, 2014)

On the other hand, the three types of indicators are differentiated in the environmental dimension, and the following weighting applies to the indicators in the environmental dimension:

- Target (T) indicators = 1 point
- Practice (P) indicators = 2 points
- Performance (P) indicators = 3 points

The combination of indicators in the environmental sub-themes are presented in Table 1 (B side). Performance indicators (e.g., Soil Quality) or those that are considered to be a direct measurement from an operation itself receive the most weight. Practice indicators (e.g., Soil-Improvement Practices) or those that are measured by reference for a certain level of good performance are given the second most weight. Target indicators (e.g., Water Conservation Target) are related to the existence of plan, monitoring, documentation and strategy with a particular sustainability target, and are given the lowest amount of weight. Examples of these three types of indicators are given in the Table 2.

All indicators in the SAFA Tool have a 5-scale rating (Table 3), and the rating increases gradually as the performance score goes up from unacceptable to best (Table 4).

Indicators which are considered irrelevant during the contextualization process can be omitted. For instance, indicator with the same name in the sub-theme Employment Relations may be irrelevant for small-scale organic producers since they mostly rely on the family work. But the omission of this indicator do not receive unacceptable score or a 0 percent, rather a potential maximum score of this indicator is subtracted from the total maximum potential score of the sub-theme to determine the overall rating for that sub-theme.

[1] These points are given only in case the best scores are achieved in individual indicators.

Table 2. Examples of different types of environmental indicators for assessing sustainability

Indicator type	Indicator example	Potential responses
Performance indicator	Does the enterprise's operation save seeds, or engage with breeding work to conserve traditional and/or rare breeds on farm?	Yes/no/partial Percentage
Practice indicator	What activities and practices have been implemented that have effectively increased the quality and fertility of soils?	Yes/no/partial List of practices
Target indicator	Has the enterprise set a target for reducing water consumption or water withdrawals?	Yes/no/partial

Table 3. Rating scales for the SAFA indicators

Rating scale	Description: The indicator is rated…
Best / 80 – 100%	…at the top level of sustainability performance
Good / 60 – 80 %	…at the good level of sustainability performance
Moderate / 40 – 60 %	…at the moderate level of sustainability performance
Limited / 20 – 40 %	…at the limited level of sustainability performance
Unacceptable / 0 – 20 %	…at the unacceptable level of sustainability performance

Source: (FAO, 2014)

On the other hand, if the indicator is deemed irrelevant without a justification, the final rating for the omitted indicator is 0 percent or unacceptable. This score then is averaged with other indicator scores to calculate the sub-theme rating. Thus, if a sub-theme (e.g., Internal Investment) contains only one indicator, and it is omitted without justification, the sub-theme rating is 0 percent, or unacceptable. If a sub-theme (e.g., Product Information) contains more than one indicator, and one of them is omitted without justification, a 0 percent or unacceptable score is averaged with the other indicator ratings to determine the overall sub-theme rating. To obtain a performance score at the theme level, an arithmetic mean of the sub-theme scores is calculated, or if not available the lowest score is given to the respective theme.

Table 4. Different rating scales for the indicators in the governance, economic, social dimensions (A), and environmental dimension (B, by type)

	Ratings (A)	Ratings (B)		
Rating scale	**Indicator points**	**Target indicator points**	**Practice indicator points**	**Performance indicator points**
Best / 80 – 100%	5	1	2	3
Good / 60 – 80 percent	4	0.75	1.5	2.25
Moderate / 40 – 60 percent	3	0.5	1	1.5
Limited / 20 – 40 percent	2	0.25	0.5	0.75
Unacceptable / 0 – 20 percent	1	0	0	0

Finally, all data set are integrated into a sustainability performance report, and this process is called data visualization. Data Visualization is a way of depicting the information in a polygonal form allowing to see the concepts and relationships.

2.2 Description of the Beijing Farmers Market (BFM) PGS

This study was carried out in the BFM PGS that is established in 2010. BFM PGS consists of 66 small-scale organic farms, and its dedicated team of 25 employees (including volunteers) run a weekly market and two community stores that their customers a wide range of organic produce throughout the year. Most of the farms are located around the city of Beijing, and a few of them are in Hebei Province. 46 actively-involved farms were selected, and 124 stakeholders (including the farmers, management body of the BFM, researchers, consumers and volunteers working at the community markets) were interviewed. Interviewed farmers were from Shunyi, Changping, Haidian, Fangshan, Huairou, Daxing districts of Beijing and Tangshan and Zhangjiakou districts of Hebei province (Figure 2). Selected farmers were mainly organic vegetable and fruit growers. Interviews and field observations were the primary source of information, and data collection process was carried out using two farm questionnaires.

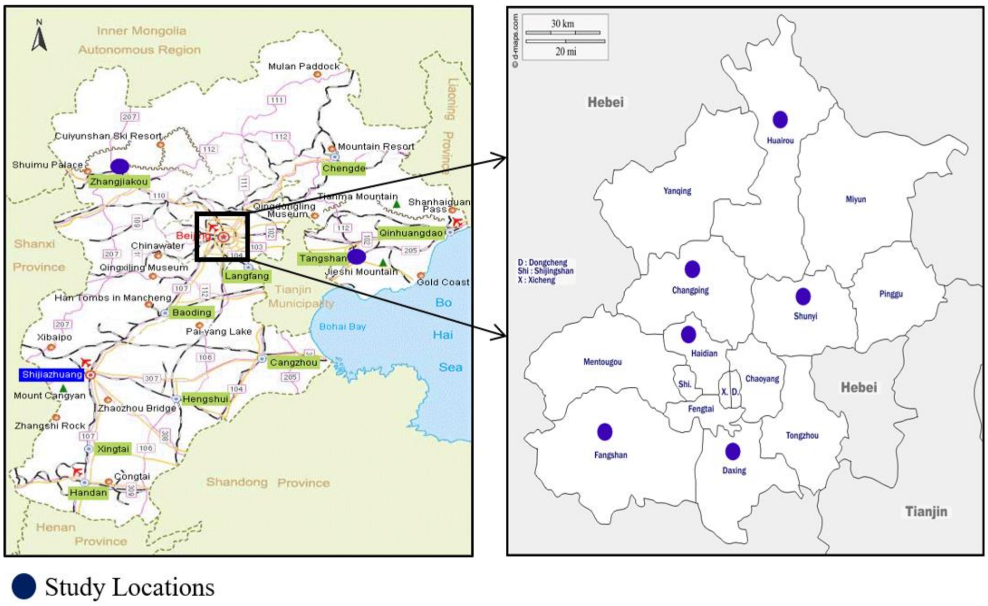

Figure 2. Map of the study locations

2.3 Data Collection and Analysis

Data collection was done between August 2020 and February 2021. Assessment process is illustrated in five steps (Figure 3). Step 1 started with literature and SAFA methodology reviews and preparation of the farm questionnaires. The preparation process was supplemented with the member farmers and key informants from the management body of the BFM PGS in order to understand the operating context of the BFM PGS. The SAFA Tool indicator set was contextualized to find relevant indicators for the study area. From a set of 116 indicators, 80 indicators (47 out of 58 sub-themes) were applied (*see Appendix 2*) to assess sustainability performance of the BFM PGS based on the "contextualization" described in Section 2.1.1.

Step 2 included an interview with the farmers and management body of the BFM PGS at the marketplace using a farm questionnaires. Interview process started with a question and answer session on the target indicators, followed by a farm visit especially for collecting the farm specific information on the practice-based and performance indicators.

In order to ensure that all of the relevant indicators were answered correctly, each of the farm questionnaires was checked with the farmers and management body of the BFM PGS for completeness in Step 3. Guidance notes were taken and identified gaps were communicated back the BFM PGS staff and the respective farm for appropriate editing. In the next step, the completed data sets were integrated into the SAFA Tool software to compute the sustainability performance scores for each theme.

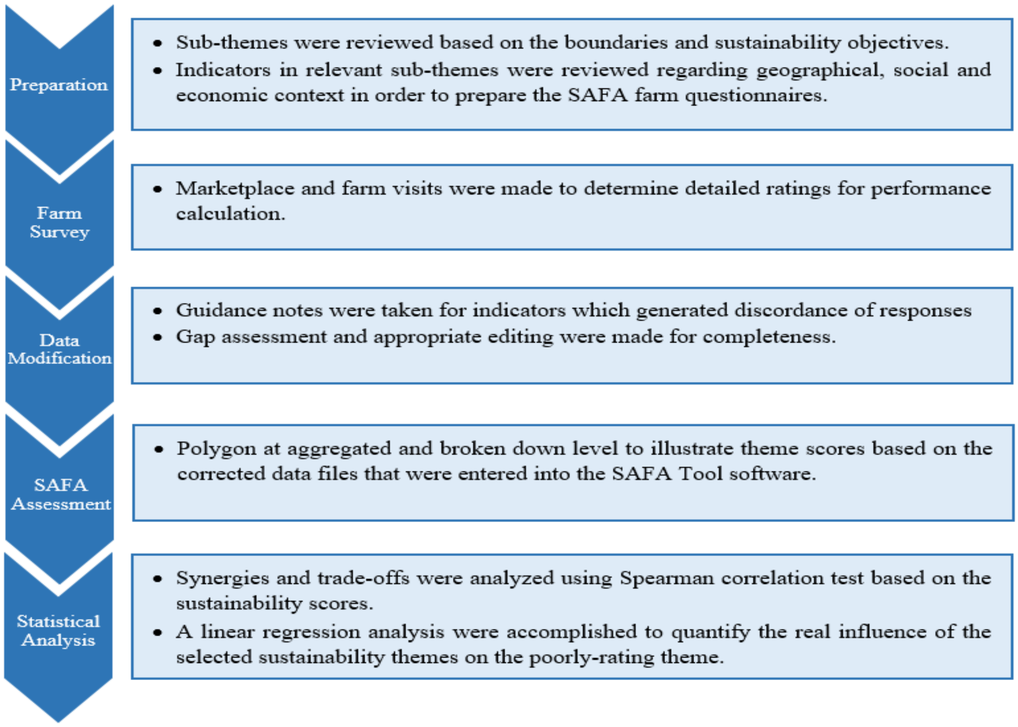

Figure 3. Illustration of data collection and analysis process

In the final step, based on the sustainability performance scores obtained in step 4 the synergies and trade-offs were analyzed using the non-parametric Spearman's rank-correlation test (Spearman, 1904). The coefficients ranged between $0<rs\leqslant+1$ represented synergies or positive correlations while the coefficients ranged between $0>rs\geqslant-1$ represented trade-offs or negative correlations. Additionally, a linear regression analysis was conducted to identify mathematical dependences between selected sustainability themes. All statistical analyses were made using IBM SPSS Statistics version 21 (IBM, 2012).

It must be noted that some performance indicators related to Water Quality and Soil Quality sub-themes in the environmental dimension were unavailable at the farm level since most of the small-scale farms were less able to test their soil and water quality due to a high analysis costs. However, considering that these two themes were vital in terms of evaluating the environmental sustainability and also in order for this study to provide a high quality assessment, water and soil samples were taken from the fields and analyzed.

The soil fertility status of organic vegetable fields was surveyed after the harvest of cool-season vegetables in November. The soil samples were taken at a depth of 0-20 cm using soil sampling probe. Furthermore, in order to test concentrations of water pollutants tube wells were pumped to remove stagnant water before fresh water samples were collected. A total of 30 (15 water and 15 soil) samples were analyzed for the water pH, electrical conductivity (EC), ammonium-nitrogen ($NH4^+$-N) and nitrate (NO_3^--N) levels, soil pH, soil organic matter (SOM), nitrogen (N) phosphorus (P) and potassium (K) contents at the Chinese Academy of Agricultural Sciences (CAAS) laboratory in the city of Beijing. The threshold values (Chen and Lu, 2002; CSBTS, 1993; Huang et al., 2015; MH, 2006; Wang and Xin, 1998; WHO, 1984; WHO, 2011; Wilcox, 1948), for the selected indicators were presented in Appendix 1, Table A2.

RESULTS

In this section, the results of sustainability performance of the BFM PGS as well as the correlation and regression analyses are assessed. First, sustainability performance is analyzed based on the performance achievement scores (Section 3.1). Subsequently, synergies and trade-offs among the dimensions and themes are discussed to outline the sustainability framework of the BFM PGS, as well as hot-spot points which the BFM PGS should be concerned about (Section 3.2). Finally, this study shows regression analysis in order to obtain the real influence of the selected sustainability themes on another (Section 3.3).

3.1 Sustainability Performance Assessment of the BFM PGS

Using the SAFA Tool (see Section 2), this study helped the BFM PGS to benchmark their farming activities against the sustainability objectives defined in the SAFA Guidelines.

The sustainability performance of the BFM PGS regarding the respective dimensions are presented below (Figure 4):

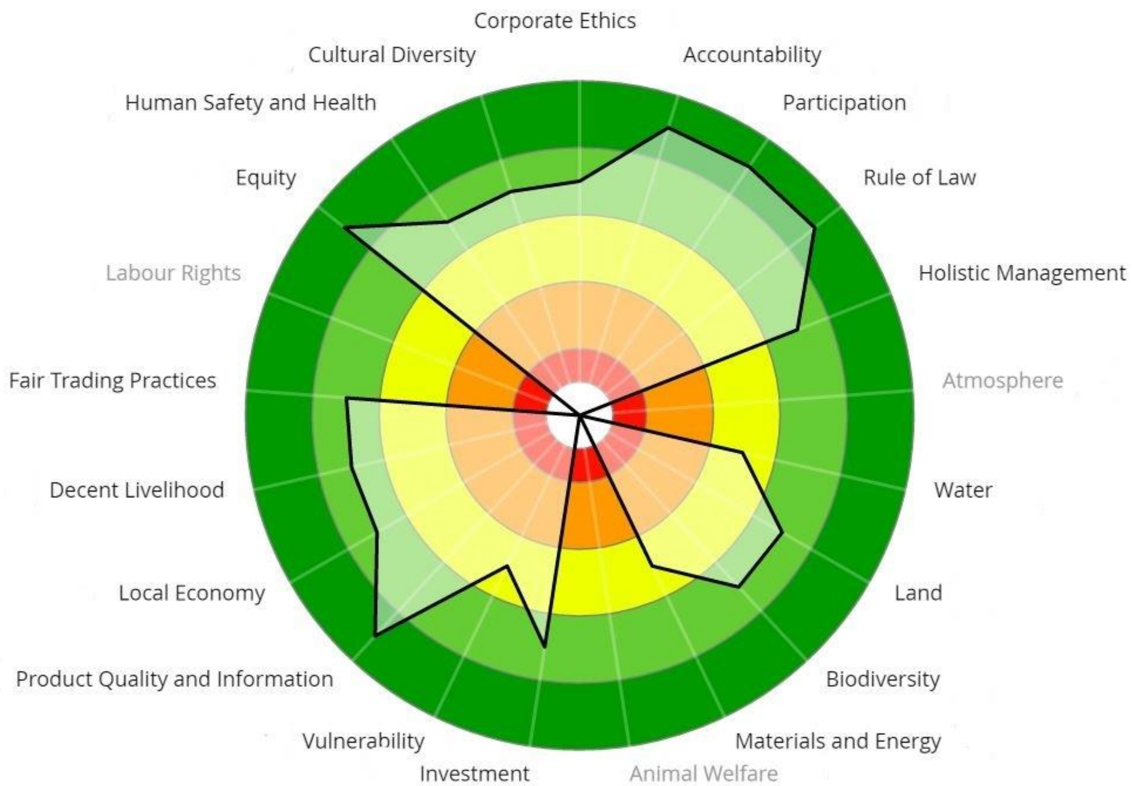

Figure 4. Sustainability Performance report of the BFM with respect to SAFA themes

Good Governance dimension: the result showed that all farms performed well with respect to the Corporate Ethics, Accountability, Participation, Rule of Law and Holistic Management themes. The main reason of this performance score is that the BFM PGS particularly emphasized collective action, transparency, democratic structure and independent governance in order to embrace social justice and community welfare which in turn, positively impacted its performance in the governance context.

Environmental Integrity dimension: Farms showed a good performance score with respect to the Biodiversity theme (72%) even though the overall performance score of the environmental dimension was lower than other dimensions. This low score was attributed to the Water and Material Use themes as the majority of the farms found themselves in a region (Beijing Plain) with high groundwater withdrawals due to intensive agricultural irrigation (Zhou et al., 2012). Moreover, a rapid urbanization and migration to the cities from an area where the farmers live negatively affected their material consumption patterns.

At the same time, water and soil test results (*see Appendix 1, Table A3-A4*) showed that Water Quality was the sub-theme where the all farms managed to perform well. Whereas for the Soil Quality sub-theme, the highest variability among farms in the performance scores was found as some farms have far exceeded the proposed threshold levels (e.g., soil pH, K and P content) (*see Appendix 1, Table A4-A5*).

Economic Resilience dimension**:** Farms performed well with respect to Product Quality and Information, Investment and Local Economy themes 85%, 80%, 80%, respectively. On the other hand, no single farm performed better than 58% for the Vulnerability theme. This indicates that for the Vulnerability theme sustainability objectives formulated in the SAFA Guidelines were relatively difficult to achieve for farms.

Social Well-Being dimension: High performance scores were achieved with respect to Decent Livelihood, Fair Trade Practices, Human Safety and Health and Cultural Diversity themes. At the same time, 100% of goal achievement was realized for Equity Theme. Even though farmers had access to information and knowledge through regular farm visits, sharing meetings and discussions with the consumers, scientists and researchers, the level of contact between the agricultural extension services (AES) and the farmers was too weak (*see Appendix 1, Table A6*). Only 25% of the farmers were visited by the AESs during 2019. The number of farmers visiting the extension services was 33% during the same period. But, a mutual exchange of information with the extension agencies can help some farmers to gain a clearer insight into balanced fertilization to improve their management and production skills, which in turn will positively affect their environmental sustainability performance. This is the synergetic effect of the social dimension on the governance and environmental dimension.

The key determinants that may affect sustainability performance of the BFM PGS are summarized in *Appendix 1, Table A7*.

3.2 Analysis of Interactions within Sustainability Dimensions and Themes

In the section 3.1, sustainability performance of the BFM PGS in terms of the dimensions and themes were analyzed. While the BFM PGS achieved high scores respect to a large number of themes, it did not perform well across all dimensions and themes. This justifies the importance of further assessment of synergies and trade-offs between dimensions and themes (Schader et al., 2016). When analyzing the dimensions individually, high performance scores were identified in the Social Well-Being (84%[2]), Good Governance (83%)

[2] The score for a particular dimension is determined as an average of the respective theme scores belonging to that particular dimension.

and Economic Resilience dimensions (75%), and low performance score in the Environmental Integrity (60%) dimension.

Based on the sustainability performance scores in Table 7, synergies and trade-offs were analyzed between dimensions and themes using Spearman correlation test. Synergies were found between governance and social dimensions (10%). To a lesser extent there were also synergies between environmental and social dimensions (1%) (Table 8).

Table 7. The SAFA Tool sustainability assessment scores for the respective themes

Sustainability themes		Beijing Farmers Market PGS (N = 46)	
		Mean	Std. Deviation
Corporate Ethics		81.553	1.267
Accountability		92.395	2.881
Participation		82.395	1.685
Rule of Law		84.526	2.826
Holistic Management		76.921	4.456
Water		52.763	2.454
Land		64.763	3.267
Biodiversity		72.027	3.192
Materials and Energy		51.579	4.221
Investment		80.842	1.853
Vulnerability		57.948	3.676
Product Quality & Information		85.421	3.301
Local Economy		80.711	2.205
Decent Livelihood		79.947	2.610
Fair Trading Practices		80.263	2.854
Equity		100.000	0.000
Human Safety & Health		81.421	2.201
Cultural Diversity		79.895	3.178

Table 8. Overview of synergies and trade-offs between sustainability dimensions. Green color and yellow medium color indicate synergies whereas red color indicates trade-offs

Dimensions	Good Governance	Environmental Integrity	Economic Resilience	Social Wellbeing
Good Governance	83%			
Environmental Integrity	-13%	60%		
Economic Resilience	-24%	-14%	75%	
Social Wellbeing	10%	1%	-8%	84%

In the theme level (Table 9), in the governance dimension, the highest degree of synergies were found between Corporate Ethics and Rule of Law, and between Holistic Management and Rule of Law followed by Corporate Ethics and Participation. While the synergies between Rule of Law and Participation, and between Holistic Management and Participation were low. In the environmental dimension, synergies between Biodiversity and Water themes were high. While Materials Use theme showed the lowest degree of synergies with the other environmental themes. In addition, environmental themes showed the significant synergies with economic and governance themes. In the economic dimension, synergies between Investment and Local Economy, and between Investment and Product Quality & Information themes were higher than the synergies between Local Economy and Product Quality & Information themes. Whereas Vulnerability showed the lowest degree of synergy with Product Quality & Information theme. In the social dimension, Fair Trading Practices had the highest synergies with other social themes, except Decent Livelihood theme.

It was also found that the economic dimension had the trade-offs with all sustainability dimensions (Table 8) due to Vulnerability theme. There were also trade-offs between the environmental and the governance dimensions. Furthermore, between the theme levels (Table 9), Vulnerability theme showed the significant trade-offs ($P<0.05$) with Accountability and Holistic Management themes in the governance dimension on the one hand, and with Water and Biodiversity themes in the environmental dimension on the other hand. In addition, Vulnerability theme also had the trade-offs with social themes such as Local Economy, Decent Livelihood. Trade-offs between the theme levels in all dimensions were even higher than the synergies. Whereas the trade-offs within the theme levels in all dimensions were lesser than the synergies.

3.3 Regression Analysis

A regression analysis was performed to generate a mathematical equation in order to demonstrate the statistical dependency between a selected sustainability themes. The Sustainability Performance Report *(Figure 4)* provided information regarding each theme individually, and the dependent variable was assigned to the Vulnerability theme which was a challenging and less evolved theme from the BFM PGS point of view. Furthermore, this theme seemed to be poorly correlated with other themes (Table 9).

The equation (1) captures the true relationship with the predictors, where the subscript X represents the associated themes.

$$Y_{vulnerability} = 160.737 - 0.434X_1 - 0.373X_2 - 0.414X_3 - 0.255X_4 \quad (1)$$

X_1 = Holistic Management theme,

X_2 = Water theme,

X_3 = Biodiversity theme,

X_4 = Material use theme,

From the Table 10, it can be seen that the predictor variables of Holistic Management, Water and Biodiversity are significant. Whereas the p-value for Material Use theme (0.059) shows that the relationship is not statistically significant. The coefficients indicate that for every additional increase in Holistic Management, Water and Biodiversity theme, it can be expected the negative tendency of the Vulnerability theme to decrease 43.4%, 37.3% and 41.4%, respectively.

Table 9. Spearman correlation values between sustainability themes

Dimensions	Good Governance					Environmental Integrity				Economic Resilience				Social Well-being			
Themes	Corporate Ethics	Account-ability	Participation	Rule of Law	Holistic Management	Water	Land	Bio-diversity	Material use	Investment	Vulnera-bility	Product Quality & Information	Local Economy	Decent Livelihood	Fair Trading Practices	Human Safety & Health	Cultural Diversity
Corporate Ethics	1																
Accountability	-0.004	1															
Participation	0.224	-0.12	1					-0.126				-0.237			+0.102		
Rule of Law	0.32	-0.032	0.134	1													
Holistic Management	-0.053	-0.019	0.089	0.226	1												
Water	-0.118	0.296	-0.077	-0.248	0.066	1											
Land	0.098	-0.021	0.028	-0.08	0.054	-0.066	1										
Biodiversity	-0.041	.709**	-0.129	-0.12	-0.205	0.159	-0.073	1				-0.135			+0.011		
Material use	0.039	-0.191	0.163	-0.091	-0.063	0.078	0.08	-0.162	1								
Investment	-0.069	-0.198	-0.046	-0.215	-0.012	-0.006	0.034	-0.084	-0.098	1							
Vulnerability	0.247	-.362*	0.127	0.057	-.329*	-.390*	0.049	-.356*	-0.129	-0.029	1						
Product Quality & Information	0.257	0.281	-0.095	-0.014	-0.272	0.217	-0.31	.355*	0.176	0.123	0.03	1			-0.075		
Local Economy	-0.086	0.29	0.106	-0.074	0.274	.336*	0.022	0.253	-0.119	0.193	-0.206	0.079	1				
Decent Livelihood	-0.21	0.096	0.072	-0.305	-0.147	0.165	0.192	0.013	0.068	0.136	-0.016	-0.156	0.22	1			
Fair Trading Practices	-0.04	-0.015	0.12	-0.001	.352*	0.14	0.203	-0.036	-0.169	-0.231	-0.005	-.336*	0.154	0.075	1		
Human Safety & Health	0.081	0.219	-0.218	0.274	0.224	-0.031	0.138	0.114	-0.139	-0.154	-0.018	-0.07	0.241	-0.059	0.172	1	
Cultural Diversity	-0.162	-0.095	-0.002	0.004	-0.033	-0.202	0.064	-0.125	-0.101	0.11	0.226	-0.148	-0.142	-0.091	0.19	0.107	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 10. Interactions between the sustainability themes

Variables	Coefficients [a]	Std. Error	p-values
Constant	160.737***	18.634	.000
Holistic Management	-0.434***	-3.361	.002
Water	-0.373***	-2.924	.006
Biodiversity	-0.414***	-3.068	.004
Material Use & Energy	-0.255	-1.956	.059

Note: ***Significant at the 1 percent level.
a. Dependent Variable: Vulnerability

DISCUSSION

The study aims at: (i) assessing the sustainability performance of the BFM PGS in the light of governance, environmental, economic and social dimensions, using a SAFA-Tool approach, (ii), analyzing the synergies and trade-offs between sustainability dimensions and sub-themes, using Spearman correlation based on the respective sustainability performance scores and (iii) performing a regression analysis to numerically show the effect of selected sustainability themes on a less evolved theme.

BFM PGS has high scores in a good governance, social well-being and economic resilience dimensions, and low score in the environmental integrity dimension. This is the characteristic of PGS where the effectiveness of the market regulation comes from the mutual supervision between market organizers and participants, and economic gains of the small-scale farmers are high because of getting direct access to a consumers. This finding is consistent with other studies, which reported a positive impacts of PGS as a mean for empowering small-scale farmers and local communities (Bouagnimbeck, 2014; Boza Martínez, 2013; Nelson et al., 2016) as well as facilitating access to markets and strengthening domestic food systems (Källander, 2004). This is also true for most PGS in the world – within the community stakeholders, especially producers and consumers act according to their common values and behavioral norms, and also have a strong identity and even emotional belonging to each other (Bouagnimbeck, 2014). These PGS have determined their own principles and ways of running the community in the original way in order to improve livelihoods of rural farmers.

Comparing the inter-linkages between a sustainability dimensions and themes, more trade-offs were found than synergies. Major trade-offs were seen between economic dimension and other three dimensions. In addition, the significant trade-offs were also observed between the economic themes and other themes (especially governance and environmental themes) due to Vulnerability theme, emphasizing that specific focus is needed to improve Vulnerability theme. It is further clear that the vulnerability level might disrupt the volume of a production, stability of supply as well as quality standards in the near future. In addition, there could be records of input supply shortages that revel that at least some farmers have unfavorable level of vulnerability to certain inputs which in turn could affect economic sustainability as a whole.

On the contrary, synergies were found between social dimension and other sustainability dimensions (except economic dimension). In addition to the synergies between the social dimension and the other dimensions, there were also significant synergies founded between the social theme Fair Trading Practices and governance theme Holistic Management, which emphasizes the importance of the social dimension through its positive influence in the other dimensions of sustainability.

After contrasting with a sustainability performance report (Figure 4) and Spearman's correlation coefficients (Table 9), Vulnerability theme was counted as the most challenging indicators, so a mathematical dependency equation was obtained. From the Table 10, it is obvious that Holistic Management theme was the most effective theme, with the capacity to decrease vulnerability level by 43.4%. The next effective themes in order of importance were Biodiversity and Water themes. Each of these explained vulnerability level decrease by 41.4% and 37.3%, respectively following a doubling of applied units. The results also showed that Material Use theme affects vulnerability but not significantly. A possible explanation could be that in the studied area, a decreasing number of local input suppliers, gradual loss of traditional farming varieties and knowledge, popularization of hybrid seed and manure from industrial farms negatively affect farms' material consumption patterns, and further improvement in the material consumption patterns could decrease vulnerability level.

The significant effect of Biodiversity and Water theme can be explained by the fact that the protection of biodiversity and water resources are necessary to sustain the functioning of ecosystems and human communities (FAO, 2014). Therefore, the efficient water management practices and the availability of buffers in a form of species and generic diversity can help to decrease a tendency of the vulnerability level.

4.1 Limitations of this study

Since interviewed farmers were mainly a small-scale organic vegetable growers, Animal Welfare (including Animal Health and Freedom from Stress sub-themes) theme were omitted because of out of scope. In the study area, farming activities did not produce potentially polluting gaseous emissions, and operations did not depend on external energy inputs of any kind. In addition, sub-themes such as Greenhouse Gases and Energy Use can be examined more quantitatively using the life cycle assessment method in order to obtain reasonable and credible results. Therefore, Atmosphere theme (including Greenhouse Gases, Air Quality themes) and Energy Use sub-themes were omitted. Besides, Full-Cost Accounting sub-theme was also omitted since this an emerging field as well as a complex and difficult subject without an international consensus on its standards.

In the Social Well-Being dimension many sub-themes refer to the handling of employees, and therefore have less relevance for farms in the study area. Member farms of the BFM PGS generally rely on family work in order to cope with the varying availability of labor, and participatory approach on a voluntary basis is encouraged as a labor-saving strategy among farmers living in the same area. That's why, Labor Rights theme (including Employment Relations, Forced Labor, Child Labor and Freedom of Association and Right to bargaining sub-themes) and Rights of Suppliers sub-theme were also omitted.

5. Conclusion and policy implications

It is important to look at the factors (Table 6 – left side) that positively affect a sustainability performance of the BFM PGS and the future behavior of inputs and control mechanisms (Table 6 – right side) that are conceptually external to the farming system, when setting the right priorities and suggesting changes on farms or for policy implications. This highlights the importance of understanding a set of strategies to construct sustainability pathway.

Looking at the interactions between sustainability themes (Table 9), Vulnerability theme was the most challenging to optimize as major trade-offs exist with other themes, and the Holistic Management, Biodiversity and Water themes exhibited a strong influence on the Vulnerability theme (Table 10). Therefore, it can be concluded that a holistic view of sustainability with the long-term goal of improving resilience and adaptive capacity to potential shocks positively affects the negative tendency of the Vulnerability theme since they proved to be interlinked. In addition, given the synergetic effect of the social dimension, it can also be concluded that a specific attention on the social dimension will shed light on the performance of the other sustainability dimensions.

This study has some policy implications. BFM PGS has a committed and supportive consumer base which in turn consumers become increasingly receptive to the farmers' products. Consumers who have a deep understanding and recognition of community-supported agriculture constantly appear in the market. They do not often satisfy with the support through purchase, and are willing to provide support in the form of voluntary services. This means that with PGS a community could have a dedicated function to make this responsive consumer base become the labor, intelligence and communication medium of this quality assurance system. Without PGS, this format cannot go further as it advocates the idea of achieving quality assurance through communication and collaboration between producers and consumers. This is an important strength of the PGS as a socio-institutional function on building a truly sustainable community.

Consequently, this study encourages the policy-makers, non-government organizations, investors and people to be more receptive and responsible towards PGS and create positive conditions for sustaining PGS.

CONCLUSION

As a result of the analysis of the changes in the temperature regime it was revealed that it will be warming the plants vegetation period. The timing of sowing and germination will be shifted to an earlier date, which will allow using the moisture accumulated during the winter more efficiently. When implementing the climatic scenarios the changes in agro-climatic conditions will lead to the changes in oats crop photosynthetic activity: there will be an increase in the relative leaf area, the total plant mass, a crop photosynthetic potential during the growing season. It has been defined that the level of expected oats yields under the implementation of the RCP4.5 and RCP8.5 climatic scenarios and early sowing dates will be higher than those obtained under the average long-term conditions.

APPENDIXES AND HIGHLIGHTS

Appendix 1
Appendix 2
Graphical Abstract
Highlights

REFERENCES

Anderson, C.R., Bruil, J., Chappell, M.J., Kiss, C., & Pimbert, M.P. (2019). From transition to domains of transformation: Getting to sustainable and just food systems through agroecology. Sustain. 11. https://doi.org/10.3390/su11195272

Astier, M., Speelman, E.N., López-Ridaura, S., Masera, O.R., & Gonzalez-Esquivel, C.E. (2011). Sustainability indicators, alternative strategies and trade-offs in peasant agroecosystems: analysing 15 case studies from Latin America. Int. J. Agric. Sustain. 9, 409–422. https://doi.org/https://doi.org/10.1080/14735903.2011.583481

Belcher, K.W., Boehm, M.M., & Fulton, M.E. (2004). Agroecosystem sustainability: A system simulation model approach. Agric. Syst. 79, 225–241. https://doi.org/10.1016/S0308-521X(03)00072-6

Binder, C.R., Feola, G., & Steinbergerac, J.K. (2010). Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture. Environ. Impact Assess. Rev. 30, 71–81. https://doi.org/https://doi.org/10.1016/j.eiar.2009.06.002

Bouagnimbeck, H. (2014). Global Comparative Study on Interactions Between Social Processes and Participatory Guarantee Systems - A Best Practice Study For Learning And Development With Case

Studies From Africa, Asia, Europe And Latin America. IFOAM.
Boza Martínez, S. (2013). Los Sistemas Participativos de Garantía en el fomento de los mercados locales de productos orgánicos. Rev. Latinoam. 12, 15–29.
Chen, L.S., & Lu, J.L. (2002). The vegetable nutrition and fertilization technology. (In Chinese). Chine Agric. Press. Beijing.
Cifuentes, M.L., Vogl, C.R., & Padilla, M.C. (2018). Participatory guarantee systems in Spain: Motivations, achievements, challenges and opportunities for improvement based on three case studies. Sustain. 10. https://doi.org/10.3390/su10114081
CSBTS (China State Bureau of Technical Supervision) (1993). Quality standard for ground water (GB/T 14848-93). Available online: https://www.chinesestandard.net/PDF/English.aspx/GBT14848-1993 (accessed on 26 January 2021).
FAO/INRA (2016). Innovative markets for sustainable agriculture – How innovations in market institutions encourage sustainable agriculture in developing countries, Loconto, A., Poisot, A.S. & Santacoloma, P. (eds.) Rome, Italy.
FAO (2014a). Sustainability Assessment of Food and Agriculture Systems (SAFA), Version 3. Retrieved from http://www.fao.org/nr/sustainability/sustainability-assessments- safa/en/ Food and Agriculture Organization of the United Nation (FAO), Rome.
FAO (2014b). Sustainability Assessment of Food and Agriculture Systems (SAFA) Tool. USER MANUAL VERSION 2.2.40. Food and Agriculture Organization of the United Nation (FAO), Rome. FAO.
Finkbeiner, M., Schau, E.M., Lehmann, A., & Traverso, M. (2010). Towards life cycle sustainability assessment. Sustainability 2, 3309–3322. https://doi.org/10.3390/su2103309
Giampietro, M., Mayumi, K., & Mundac, G. (2006). Integrated assessment and energy analysis: Quality assurance in multi-criteria analysis of sustainability. Energy 31, 59–86. https://doi.org/https://doi.org/10.1016/j.energy.2005.03.005
Giannetti, B.F., Almeida, C.M.V.B., & Bonilla, S.H. (2010). Comparing emergy accounting with well-known sustainability metrics: The case of Southern Cone Common Market, Mercosur. Energy Policy 38, 3518–3526. https://doi.org/https://doi.org/10.1016/j.enpol.2010.02.027
Grenz, J., Thalmann, C., Schoch, M., Stalder, S., & Studer, C. (2012). RISE (Response-Inducing Sustainability Evaluation), version 2.0. Sch. Agric. For. Food Sci. HAFL. Bern 1–5.
Häni, F., Braga, F., Stämpfli, A., Keller, T., Fischer, M., & Porsche, H. (2003). RISE, a tool for holistic sustainability assessment at the farm level. Int. Food Agribus. Manag. Rev. 6.
Hargrave, T. J., & Van De Ven, A. H. (2006). A collective action model of institutional innovation. Acad. Manag. Rev. 31, 864–888. https://doi.org/10.5465/AMR.2006.22527458
Hirata, A.R., Rocha, L.C.D., Assis, T.R. de P., de Souza-Esquerdo, V.F., & Bergamasco, S.M.P.P. (2019). The contribution of the participatory guarantee system in the revival of agroecological principles in southern Minas Gerais, Brazil. Sustain. 11. https://doi.org/10.3390/su11174675
Huang, G., Fei, L., Yang, Y., Kong, X., Li, S., Zhang, Y., & Cao, D. (2015). Ammonium-nitrogen-contaminated groundwater remediation by a sequential three-zone permeable reactive barrier

(multibarrier) with oxygen-releasing compound (ORC)/clinoptilolite/spongy iron: column studies. Environ. Sci. Pollut. Res. 22, 3705–3714. https://doi.org/https://doi.org/10.1007/s11356-014-3602-4

IBM (2012). IBM SPSS Advanced Statistics 21. https://doi.org/http://www.sussex.ac.uk/its/pdfs/SPSS_%0AAdvanced_Statistics_21

IFOAM (2008). Participatory Guarantee Systems. Case studies from Brazil, India, New Zealand, USA and France, IFOAM.

Källander, I. (2004). Participatory Guarantee Systems – PGS. Swedish Society for Nature Conservation.

Kaufmann, S., & Vogl, C.R. (2018). Participatory Guarantee Systems (PGS) in Mexico: a theoretic ideal or everyday practice? Agric. Human Values 35, 457–472. https://doi.org/10.1007/s10460-017-9844-2

Kirchner, C. (2014). Participatory Guarantee Systems (PGS) Practitioners' Track, IFOAM Organic World Congress 2014, "Building Organic Bridges", 13 - 15 Oct., Istanbul, Turkey. https://orgprints.org/23255/7/23255.pdf., in: Participatory Guarantee Systems (PGS): IFOAM Organics World Congress.

Lebacq, T., Baret, P. V., & Stilmant, D. (2013). Sustainability indicators for livestock farming. A review. Agron. Sustain. Dev. 33, 311–327. https://doi.org/10.1007/s13593-012-0121-x

Lien, G., J.Brian, H., & Ola, F. (2007). Risk and economic sustainability of crop farming systems. Agric. Syst. 94, 541–552. https://doi.org/https://doi.org/10.1016/j.agsy.2007.01.006

López-Ridaura, S., Keulen, H.V., Ittersum, M.K. van., & Leffelaar, P.A. (2005a). Multiscale Methodological Framework to Derive Criteria and Indicators for Sustainability Evaluation of Peasant Natural Resource Management Systems. Environ. Dev. Sustain. 7, 51–69. https://doi.org/https://doi.org/10.1007/s10668-003-6976-x

López-Ridaura, S., Keulen, H. van, Ittersum, M.K. van, & Leffelaar, P.A. (2005b). Multi-scale sustainability evaluation of natural resource management systems: Quantifying indicators for different scales of analysis and their trade-offs using linear programming. Int. J. Sustain. Dev. World Ecol. 12, 81–97. https://doi.org/ttps://doi.org/10.1080/13504500509469621

López-Ridaura, S., Masera, O., & M Astier (2002). Evaluating the sustainability of complex socio-environmental systems. the MESMIS framework. Ecol. Indic. 2, 135–148. https://doi.org/https://doi.org/10.1016/S1470-160X(02)00043-2

May, C. (2008, n.d.). PGS Guidelines—How Participatory Guarantee Systems can develop and function. Bonn, Germany: International Federation of Organic Agriculture Movements (IFOAM). http://www.ifoam.org/sites/default/files/page/files/pgs_guidelines_en_web.pdf. IFOAM.

MH (Ministry of Health of China) (2006). Standards for Drinking Water Quality. (GB 5749-2006). Available online: http://tradechina.dairyaustralia.com.au/wp-content/uploads/2018/08/GB-5749-2006-Standards-for_Drinking-Water-Quality.pdf (accessed on 26 January 2019).

Nelson, E., Tovar, L.G., Gueguen, E., Humphries, S., Landman, K., & Rindermann, R.S. (2016). Participatory guarantee systems and the re-imagining of Mexico's organic sector. Agric. Human Values 33, 373–388. https://doi.org/10.1007/s10460-015-

9615-x

Nelson, E., Tovar, L.G., Rindermann, R.S., & Cruz, M.Á.G. (2010). Participatory organic certification in Mexico: An alternative approach to maintaining the integrity of the organic label. Agric. Human Values 27, 227–237. https://doi.org/10.1007/s10460-009-9205-x

Parris, T.M., & Kates, R.W. (2003). Characterizing and measuring sustainable development. Annu. Rev. Environ. Resour. 28, 559–586. https://doi.org/10.1146/annurev.energy.28.050302.105551

Ramos, C. de M., & Laurenti, R. (2020). Towards the agenda 2030: A quantitative analysis of synergies and trade-offs between the sdgs of spain during 2000–2019. Sustain. 12, 1–14. https://doi.org/10.3390/su122410506

Ran, Y., Lannerstad, M., Barron, J., Fraval, S., Paul, B.K., Notenbaert, A., Mugatha, S., & Herrero, M. (2015). A review of environmental impact assessment frameworks for livestock production systems.

Sacchi, G. (2019). Social Innovation Matters: The adoption of participatory guarantee systems within Italian alternative agri-food networks. Strateg. Chang. 28, 241–248. https://doi.org/https://doi.org/10.1002/jsc.2265

Schader, C., Baumgart, L., Landert, J., Muller, A., Ssebunya, B., Blockeel, J., Weisshaidinger, R., Petrasek, R., Mészáros, D., Padel, S., Gerrard, C., Smith, L., Lindenthal, T., Niggli, U., & Stolze, M. (2016). Using the Sustainability Monitoring and Assessment Routine (SMART) for the systematic analysis of trade-offs and synergies between sustainability dimensions and themes at farm level. Sustain. 8. https://doi.org/10.3390/su8030274

Schader, C., Grenz, J., Meier, M.S., & Stolze, M. (2014). Scope and precision of sustainability assessment approaches to food systems. Ecol. Soc. 19. https://doi.org/10.5751/ES-06866-190342

Singh, R.K., Murty, H.R., Gupta, S.K., & Dikshit, A.K. (2009). An overview of sustainability assessment methodologies. Ecol. Indic. 9. https://doi.org/https://doi.org/10.1016/j.ecolind.2008.05.011

Spearman, C. (1904). The Proof and Measurement of Association between Two Things. Am. J. Psychol. 15, 72–101. https://doi.org/https://doi.org/10.2307/1412159

Speelman, E.N., López-Ridaura, S., Colomer, N.A., Astier, M., & Masera, O.R. (2007). Ten years of sustainability evaluation using the MESMIS framework: Lessons learned from its application in 28 Latin American case studies. Int. J. Sustain. Dev. World Ecol. 14, 345–361. https://doi.org/https://doi.org/10.1080/13504500709469735

Ssebunya, B.R., Schader, C., Baumgart, L., Landert, J., Altenbuchner, C., Schmid, E., & Stolze, M. (2019). Sustainability Performance of Certified and Non-certified Smallholder Coffee Farms in Uganda. Ecol. Econ. 156, 35–47. https://doi.org/10.1016/j.ecolecon.2018.09.004

Vorley, B. (2013). Meeting small-scale farmers in their markets: understanding and improving the institutions and governance of informal agrifood trade, IIED/HIVOS/Mainumby, London/The Hague/La Paz.

Wang, J.F., & Xin, S.Z. (1998). Negative effects of fertilization and countermeasures. (In Chinese). J. Conserv. Agric. Environ. 17, 40–43.

WHO (World Health Organization) (2011). Guidelines for Drinking-Water Quality, 4rd ed.; World Health Organization: Geneva, Switzerland.

WHO (World Health Organization) (1984). Paraquat and disquat: environmental health criteria 39. World Health Organization: Geneva, Switzerland.

Wilcox (1948). The Quality of Water for Irrigation Use, US Department of Agriculture. Tech. Bull. No.962, 40.

Zhou, Y., Wang, L., Liu, J., Li, W., & Zheng, Y. (2012). Options of sustainable groundwater development in Beijing Plain, China. Phys. Chem. Earth 47–48, 99–113. https://doi.org/10.1016/j.pce.2011.09.001