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An Interpretive Framework for Assessing and Monitoring the Sustainability of School Gardens

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Abstract: School gardens are, increasingly, an integral part of projects aiming to promote nutritional education and environmental sustainability in many countries throughout the world. In the late 1950s, FAO (Food and Agriculture Organization) and UNICEF (United Nations Children's Fund) had already developed projects to improve the dietary intake and behavior through school and community gardens. However, notwithstanding decades of experience, real proof of how these programs contribute to improving sustainability has not been well-documented, and reported findings have mostly been anecdotal. Therefore, it is important to begin a process of collecting and monitoring data to quantify the results and possibly improve their efficiency. This study's primary goal is to propose an interpretive structure—the "Sustainable Agri-Food Evaluation Methodology-Garden" (SAEMETH-G), that is able to quantifiably guide the sustainability evaluation of various school garden organizational forms. As a case study, the methodology was applied to 15 school gardens located in three regions of Kenya, Africa. This application of SAEMETH-G as an assessment tool based on user-friendly indicators demonstrates that it is possible to carry out sustainability evaluations of school gardens through a participatory and interdisciplinary approach. Thus, the hypothesis that the original SAEMETH operative framework could be tested in gardens has also been confirmed. SAEMETH-G is a promising tool that has the potential to help us understand school gardens' sustainability better and to use that knowledge in their further development all over the world.

Keywords: school garden; sustainability assessment; indicators; SAEMETH-G

1. Introduction

School gardens are increasingly part of projects related to the promotion of environmental and nutritional education in many countries throughout the world. In school garden projects, fruits and vegetables are grown in areas around or near the school, sometimes providing a small-scale staple food source, as well as other complementary activities. However, this is not a new approach; already in the 1950s, FAO (Food and Agriculture Organization) and UNICEF (United Nations Children's Fund) had begun the "Applied Nutrition Projects" meant to improve nutrition through school and community gardens. Numerous other interventions by government and non-government organizations followed, aiming to spread the development of a "garden culture". In what are commonly considered the developed countries, a "garden-based learning" (GBL) approach has prevailed, where gardens are laboratories for learning science, environmental studies, as well as topics such as art and literature.

In the report, "Revisiting garden-based-learning in basic education", published by FAO and UNESCO in 2004 [1], the authors document how there was already a strong movement in the 1800s tied to scholastic gardens, both in Europe (especially in Austria), as well as in North America. At the beginning of the 20th century, the great American horticulturalist, Liberty Hyde Bailey wrote:

> *"... to open the child's mind to his natural existence, develop his sense of responsibility and of self dependence, train him to respect the resources of the earth, teach him the obligations of citizenship, interest him sympathetically in the occupations of men, touch his relation to human life in general, and touch his imagination with the spiritual forces of the world"* [2]

emphasizing how experiential learning, ecological literacy, and environmental awareness, as well as technical agricultural subjects, could all be integrated within a garden. It is interesting to note how some of the key principles of sustainable development, such as inter- and intra-generational equity and the interrelation between multifaceted aspects, have already been mentioned in relation to a school curriculum almost 80 years before in the 1987 Brundtland report (known as "Our Common Future") [3].

In the southern hemisphere, the tableau is more variable: the origins of school gardens are less documented and quite often not institutionalized in official school curricula. In these cases, their design focused on the principal aim, which was not always achieved [3], of supplying food for school meals and improving the children's nutrition and health. Similarly to what happened previously in developed countries [4], youths who live in urban areas (but not only) have less and less experience with natural ecosystem complexity and are becoming strangers to the source of the food that they consume, with evident nutritional imbalances that cause important health problems, such as obesity [5–7].

By putting together these considerations, we can see how the perception of school gardens is still evolving and represents a response to the increasingly pressing needs for greater food security, environmental protection, more secure livelihoods, and better nutrition [8]. A school garden is both a sustainable action by itself, as well as a generator of other sustainable actions [9].

From the many analyses carried out on various projects [10–13], it has clearly emerged that for a school garden to be successful, some key "active ingredients" are always needed [14]. The school garden must be designed and carried out together with the local community and must correspond to the socio-cultural and environmental place, particularly for crop choices and garden management. Successful school garden projects do not just aim to involve the school's children, but also the school's directors, teachers, and parents, or rather school garden programs can and must have multiplying effects, encouraging the creation of private gardens in the case of school-age children, as described by Drescher [3]. Furthermore, regarding a successful program's objectives, gardens must build ties and synergies between learning, nutrition, health, agriculture, and sustainability [15].

One of the most interesting aspects of school gardens is their ease of realization; they can be developed both in rural and urban contests, with limited financial investments and manual labor needs. Furthermore, the potential use of domestic organic waste for compost provides the opportunity to institute an efficient use of limited resources and to close the nutrient cycle. This benefits the environment and forms a sustainable system [16–18]. Furthermore, another important contribution to sustainability comes from the large variety of crops, including those belonging to the local germoplasm [19], that can be found in school gardens and that create systems that are much more diversified in respect to the widespread agricultural models, even the small-scaled ones [20]. Finally, to reduce environmental risks, the crops are almost always cultivated in conditions that reduce the necessity for external inputs to a minimum (for example the creation of compost, use of legume species, and crop rotation) and that maximize quality yields. All of this shows how school gardens can be a new gymnasium for sustainable education [21]. Thus, they should be proposed as more than an educational objective, but as the very method where the message, as well as the structure, practices, and the entire educational system are all congruent [22]. In fact, in the last few years we have rediscovered an interest in education that includes nature activities (excursions in parks, observations of the wild flora and fauna, etc.), the impact of every-day life (education on waste, recycling, separated trash collection, home water-use, energy saving), and even agriculture and animal husbandry. The underlying theme is education on the relationships between humans and ecosystems, which was already delineated by Stapp in 1969 [23]. This widespread and growing attention towards environmental themes comes from a need to feel that one is making a contribution, and is fundamental because it is directed towards new generations, and to solving conflicts between the current model of development dominant in the population and the limits imposed by the finiteness of Earth's ecosystem [21].

In line with what has been sustained until now, it is possible to synthesize the objectives of the current school gardens as (1) reaching a better understanding of biological processes, sustainable agricultural practices, and environmental sensibility; (2) providing better information regarding healthy food choices, favoring the assumption of a varied diet, and guaranteeing irrigation water and sanitary services; and (3) reducing the cost of food and providing a safety net for the poor, giving them the possibility to cultivate their own food. Notwithstanding more than 50 years of experience regarding healthy food with school garden programs, the evidence that these gardens contribute in an integrated way to sustainability, with nutritional, educational, and economic results is not well documented and is largely anecdotal. Although many quantitative and qualitative studies have shown positive outcomes in the areas of food behavior (especially for vegetable intake) [4,24], and academic performance (especially for disruptive students) [25], there is the need to learn from these programs in a more structured way and to collect data to improve their efficiency and quantify the results obtained in terms of sustainability. The lack of an integrated evaluation of school gardens undermines the multifaceted contribution that they produce for society.

This work's objective is to evaluate the environmental, social, and economic sustainability of school gardens by applying an interpretive structure called the "Sustainable Agri-Food Evaluation Methodology-Garden" (SAEMETH-G), derived from an analogous model built for small scale agro-food systems [26]. SAEMETH-G situates itself within the studies that aim to translate the general principles of sustainability into practical and operational tasks for small agricultural systems by directly involving the users [27,28].

2. Materials and Methods

2.1. Geographical Location and Selected School Gardens

The study was carried out in Kenya in the counties of Embu, Muranga, and Nakuru (Figure 1). School gardens are widespread in these three counties, fulfilling educational, as well as community, needs in a regional context where agriculture is one of the principal sources of livelihood for the population. School gardens play a fundamental role in maintaining an awareness of how agriculture works; outside of school gardens, agriculture is almost completely absent from the school curriculum and the majority of young people who complete their primary and secondary education did not receive any training for an agricultural career.

School gardens initiatives are carried out by several different participants: they can come directly from government institutions or through agricultural extension officers, NGOs, foreign donors, or directly as a teachers' initiative. In this area, the local section of the Ministry of Agriculture is very active: numerous school, family, and community gardens have been formed thanks to the support and training provided by the Ministry (4K-Club), which is also working to promote the principles of organic farming.

Many local NGOs, including PICE (Progressive Initiatives for Community Empowerment), and NECOFA (Network for Ecofarming in Africa), in collaboration with foreign NGOs and associations, are operating in the three counties with the primary objective of educating the local community and sustainably using the existing human and natural resources to improve economic and social wellbeing. In Nakuru County alone, there are 90 vegetable gardens promoted by the Slow Food Foundation for Biodiversity through the project "10,000 gardens in Africa" [29].

Figure 1. Map of Kenya and the counties (underlined in red) where the school gardens included as case studies are located.

For the selection of the 15 case studies, we used a qualitative targeted sampling procedure [30], individuating the most representative school gardens of the various counties. In total, 15 gardens were selected with sizes that varied between 90 and 5000 m^2. The 15 gardens show different forms of interaction and participation among students, teachers, and the local community. Table 1 shows an overview of the selected school gardens.

Table 1. Overview of the selected school gardens.

County	Initiative	School	Locality	Size m^2	Participant	Start Date
Nakuru 1	Slow food	Primary School	Langa Langa town	3030	80	2012
Nakuru 2	ONG Necofa	Primary School	Village di Tayari	90	40	2012
Nakuru 3	Slow food	Primary School	Village di Kangawa	500	48	2011
Nakuru 4	ONG Ygep	Secondary school	Village di Temoyetta	3500	156	2010
Nakuru 5	ONG Necofa	Primary School	City of Elburgon	1000	52	2005
Muranga 1	Agricultural extension officer	Primary School	Village of Karega	1500	30	2010
Muranga 2	Agricultural extension officer	Primary School	Village of Nyako	2450	30	2010
Muranga 3	Agricultural extension officer	Primary School	Village of Ngungugu	375	30	2009
Muranga 4	Agricultural extension officer	Primary School	Village of Kiganjo	2450	30	2010
Muranga 5	Agricultural extension officer	Primary School	Village of Thika Greens	3000	40	2010
Embu 1	Local agriculture ministry	Primary School	City of Embu	1500	26	2010
Embu 2	School teachers	Primary School	City of Embu	5000	35	2004
Embu 3	Local agriculture ministry	Primary School	Village of Manyatta	4000	32	2003
Embu 4	School teachers	Secondary school	City of Runyenjes	4000	22	2012
Embu 5	Local agriculture ministry	Secondary school	City of Embu	2000	16	2011

2.2. SAEMETH-G Method: Dimensions, Components, and Indicators of Sustainability

The SAEMETH-G method has been developed as an attempt to make the concept of sustainability operative in school gardens, taking into consideration the triple bottom line of social, environmental, and economic sustainability. The sustainability assessment framework's construction was based on an interdisciplinary dialogue among a team of five Kenyan and 10 Italian experts, including the authors of the present work.

The 15 experts were both the heads of theoretical projects (professors, teachers, and researchers) but, most of all, of practical school garden projects (agronomists, managers of cooperative development projects, NGOs) addressing social, environmental, and economical themes. The team was composed to include different school garden stakeholders.

The construction of the framework moved across three levels of increasing complexity: first the selection of the sustainability dimensions; then, the individuation of the components; and, finally the choice of proper indicators as described in Table 2. Three focus groups were organized to support the exchange among research participants across the three levels of the framework elaboration. The socio-cultural, agro-environmental, and economic dimensions of sustainability, already selected for the SAEMETH framework for small agri-food system [26], were considered to also be well-suited for school gardens.

Table 2. Dimension numbers (Level 1), components (Level 2), and indicators (Level 3) of school garden sustainability.

Level 1: Dimension	Socio-Cultural	Agro-Environmental	Economic
Level 2: Component	Internal relationships External relationships	Biodiversity Culture/terroir Farming practices Productive process Energy	External input Selling
Level 3: Indicator (number of indicators)	19	22	9

Regarding the weight of the dimensions, the outcome of the exchange among the research stakeholders, reached during the first focus group, was to attribute an equal importance (equal weight = maximum 100 for each measurement) to each of the three dimensions in the total measure of sustainability.

The definition of the components and the attribution of weights to the components (Level 2) of the various dimensions with the equal weights system led to the following outcome:

- for the social-cultural dimensions: two components were selected (internal and external relationships) with a weight equal to 50;
- for the agro-environmental dimensions: five components were selected (biodiversity, culture/terroir, farming practices, productive process, energy) with a weight equal to 20; and
- for the economic dimensions: two components were selected (external input, products sold) with a weight of 50.

This structure reflects the trade-offs made between the considered objectives and the priorities emphasized by the research team starting directly from the proposals of the different stakeholders [27]. By following the approach used for the formulation of SAEMETH [26], and already successfully applied by Van Calker et al. [31] and by Meul et al. [32], the research team tried to mediate the subjectivity of the school garden sustainability components in order to have a framework that allows data collection to be standardized and results to be comparable.

The selection, test, and refinement of the indicators were the most challenging part in terms of time and debate. Various indicators were tested for each component as well as various maximum and minimum values for these indicators. This pilot phase involved three school gardens (one for each county). Quantitative and qualitative data were considered for the indicator selection. For each of the chosen indicators, we have defined a minimum threshold (0 = for the worst situations) and a maximum (10 = the best situations); the reference values are, in some cases, derived through the best techniques available, in other cases through the results of an ad hoc questionnaire and through the proposals of experts. Finally, a set of indicators was agreed upon for the assessment of the 15 selected school gardens for the socio-cultural (Table 3), agro-environmental (Table 4), and economic (Table 5) dimension.

Table 3. Indicators and definition for Level 3 relative to the socio-cultural dimension.

Level 1 Dimension	Level 2 Component	Level 3 Indicator	Indicator Definition	Data Type *	Indicator Weight **
Socio-Cultural	Internal relationships	Decision-making structure	Transparency and clarity between the producers	b	5
		Organization of the group	Presence/absence of an organization of producers	b	5
		Involvement of younger generations	% of young people per the total product	a	5
		Role of younger generations	% of young people pursuing the strategy of garden management	b	5
		Involvement of women	% of women per total of product	a	5
		Role of women	% of women pursuing the strategy of garden management	b	5
		Use of the products	Rediscovery of historical recipes	a	5
		Contribution to the diversification of the diet	The garden allows you to diversify the diet	b	5
		Knowledge is transferred to the population in the garden	Sharing decisions and choices	a	5
		Participation of the producers	How often the group meets	a	5
	External relationships	Vertical transmission of knowledge	Recognition of the role of older generations	a	5.55
		Relationships with public and private institutions	Improvement of the relationships with public institutions and private entities and the possibility of influencing public policy	b	5.55
		Relationships with the local network	There has been an improvement in the local population	a	5.55
		Communication	Knowledge is transmitted to the population in the garden	b	5.55
		Communications systems	Social networks are used to promote the garden	b	5.55
		Events	Participation in events related to the Food Network	a	5.55
		Transmission of knowledge	The group transfers knowledge to children	b	5.55
		Relationship with suppliers	There is a direct relationship	b	5.55
		History and territory	The garden has strengthened the area's history	b	5.55

* a = quantitative data; b = questionnaire; ** the weights sum up to 100 for each Level 1 dimension.

Table 4. Indicators and definition for Level 3 relative to the agro-environmetal dimension.

Level 1 Dimension	Level 2 Component	Level 3 Indicator	Indicator Definition	Data Type *	Indicator Weight **
Agro-environmental	Biodiversity	Number of species	% diversification of products	a	6.66
		Number of local varieties/breeds	% of local varieties/breeds grown	a	6.66
		Varieties/Race	Number of varieties/breeds	a	6.66
	Culture/terroir	Systems	Traditional practices affecting orchard management	b	5
		Deforestation	Slash-and-burn	b	5
		Type of fences	Type of material used for the fences	b	5
		Traditional tools	Use of traditional tools for cultivation	b	5

Table 4. *Cont.*

Level 1 Dimension	Level 2 Component	Level 3 Indicator	Indicator Definition	Data Type *	Indicator Weight **
Agro-environmental	Farming practices	Seeds	% in-house production of propagation material	a	1.81
		Forest and woody plants	% in-house production of propagation material	a	1.81
		Rotations	% crop rotations	a	1.81
		Intercropping	% intercropping with other plant species	a	1.81
		Green manure	Using green manuring	a	1.81
		Composter	Compost is created	b	1.81
		Organic fertilization	% use of natural fertilizers	a	1.81
		Fertilization	% use of synthetic chemical fertilizers	a	1.81
		Defense products	% use of synthetic chemical pesticides	a	1.81
		Natural defense products	% use of natural pesticides	a	1.81
		Irrigation	Water conservation and an efficient use of resources	b	1.81
	Productive process	Transformation	Rediscovery or experimentation with transformed products	a	10
		Conservation	Improvement of conservation quality	a	10
	Energy	Water source	Type of water used for irrigation	b	10
		Renewable energy	Use of renewable energy sources	a	10

* a = quantitative data; b = questionnaire; ** the weights sum up to 100 for each Level 1 dimension.

Table 5. Indicators and definition for Level 3 relative to the economic dimension.

Level 1 Dimension	Level 2 Component	Level 3 Indicator	Indicator Definition	Data Type *	Indicator Weight **
Economic	External input	Buying seeds-seedlings-saplings	% products bought	a	7.14
		Buying forest plants	% products bought for forest plants	a	7.14
		Buying compost	% compost bought	a	7.14
		Buying chemical fertilizers	% products bought for the chemical fertilizer	a	7.14
		Buying chemical herbicides/pesticides	% products bought for the chemical defense	a	7.14
		Buying natural pesticides/herbicides	% products bought for the natural defense	a	7.14
		Land	Type of contract that regulates the possession of the garden	b	7.14
	Selling	Selling products	% of products sold on total	a	25
		Type of sales	Commercial network used	b	25

* a = quantitative data; b = questionnaire; ** the weights sum up to 100 for each Level 1 dimension.

2.3. Collection and Statistical Elaboration of the Data

The data were collected for each garden during two visits, lasting about three hours each, (interviews were conducted with at least 30% of the people involved) including a meeting with the project manager in loco conducted by an expert trained in our method. The training program of the expert, carried out in Italy, included a theoretical part with lessons on how to obtain the information on a specific indicator as well as training in the field developed in gardens located in the cities of Turin and Palermo (Italy). At the end of the training period, the expert was well versed in asking for and verifying responses in a standardized way. English was used as the reference language. The interviewer was always accompanied by a translator, who translated the question into Swahili or, where necessary, into the local dialect.

Once the data had been collected, they were first elaborated and viewed graphically, similarly to SAEMETH [26], by putting dimensions, components, and indicators together so that they could be analyzed both singularly and as a whole, considering different scales of analysis (the 15 school gardens, a single school garden, a single dimension, a single component). For the information regarding Level 1 (dimension), the data have been visibly grouped together in a bar graph. For Level 2, a radar chart shows all of the components of total sustainability together, independently of their size. This operation is made possible by the equal-weights approach regarding the size pertaining to each one. This tool supports school gardens coordinator to conceive of their achievements in a holistic way. The indicator values of the analyzed systems are positioned along the axes of a radial diagram scaled from 0 to 100, from the worst (0) to the best (100); therefore, the external ring of the diagram represents the optimal values measured for each component. Furthermore, for Level 2, a principal components analysis (PCA) was performed in order to show the behavior of the components in the school garden's sustainability assessment. Kaiser-Meyer-Olkin and Barlett's sphericity tests were used to test and analyze the appropriateness of the PCA. For an easier interpretation of the PCA results, varimax rotation was applied. For Level 3, a cluster analysis was used in order to show the trend of the 50 indicators in relation to the 15 school gardens. Ward's method of hierarchical clustering with squared Euclidean distance was applied to explore the sample grouping. All of these statistical analyses have been performed with SPSS software 13.0 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Application of SAEMETH-G: Level 1—Dimensions

The bar graph (Figure 2) shows the total sustainability of value each school garden. Only the Iruguini Garden (Muranga 1) exceeds the threshold of 200, showing positive values (the minimum sustainability threshold was equal to 50 for each single dimension—defined by the research team) for all of the three dimensions. All of the other school gardens registered a total sustainability value comprised between 150 and 190. In the case of the gardens of Embu (1, 2, and 4) and Nakuru (2 and 4), the agro-environmental dimension is less than 40, indicating problems relative to the cultivation techniques adopted.

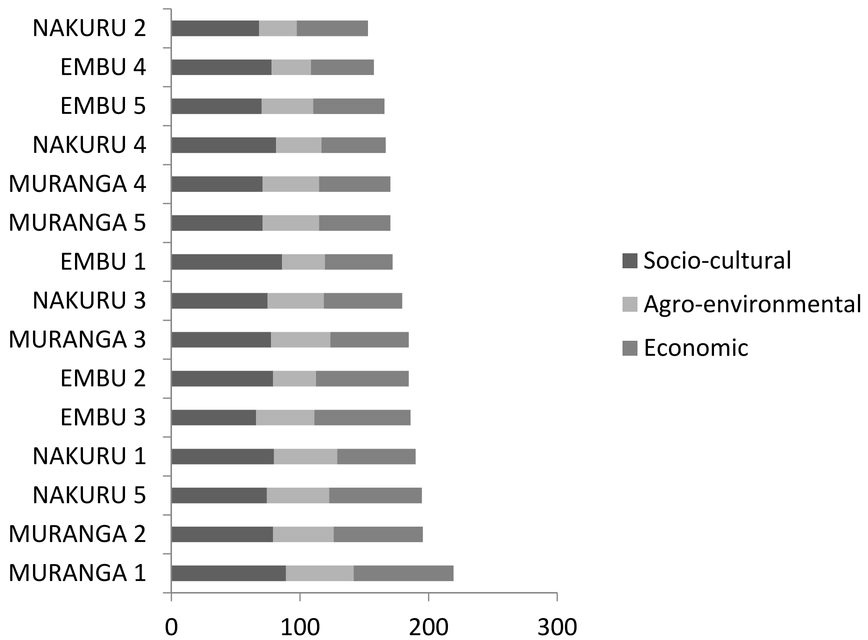

Figure 2. The score relative to the sustainability dimensions (Level 1) for each case study.

Furthermore, it shows how socio-cultural and economic sustainability are positive elements for all of the analyzed school gardens. In particular, the values reached by the socio-cultural scale underline how important the school garden is as a gymnasium for interpersonal relationships inside and outside students' school journey.

3.2. Application of SAEMETH-G: Level 2—Components

The radar graphs (Figure 3) show the distribution of the various components (expressed as percentages) in each garden, aggregated according to geographical location. It is one of the possible result representations. This way of gathering the data has been selected in order to look for the presence of a trend within the territorial context defined by the county (homogeneity of climate conditions, ethnicity know-how in garden management).

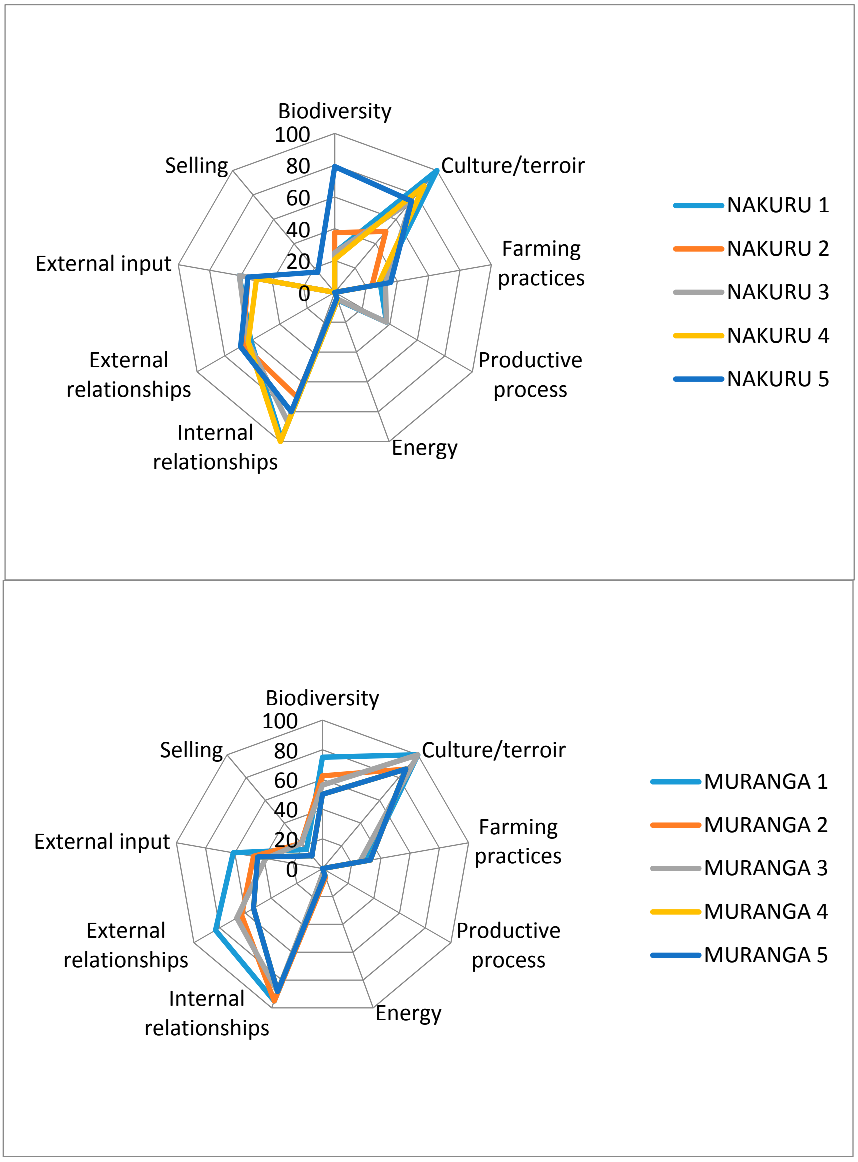

Figure 3. *Cont.*

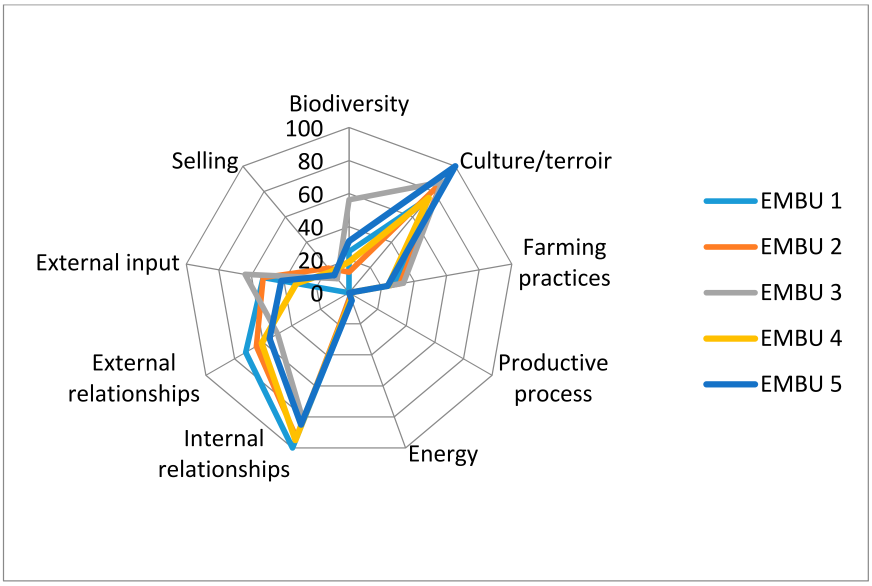

Figure 3. Each radar chart reports data coming from a county where five different school gardens have been analyzed; the differently colored lines evidence the sustainability value (ranging from 0 to 100) for the nine components.

In all of the three territories, and in all of the gardens, the internal relationships and culture and regional components reach values above 70%. It is particularly interesting to note that, in addition to the indicators regarding the involvement of women and youths, those that regard the internal relationship component, and most of all, the indicator for diet diversification, reached elevated thresholds. In contrast, external relationships were seen to be lacking, showing a certain difficulty by the schools to communicate their own activities to the outside world through any means of communication.

Regarding the components of the agro-environmental dimensions, no particularly virtuous situations are to be seen, with the exception of the biodiversity component, which reaches values near 80% (most of all in Nakuru and Muranga 1).

All of the schools taken into consideration consumed all of what they grew in their gardens (in the school canteen and/or events), so that the sales component was 0. Even if the schools tended to own the land and not use synthetic products, the acquisitions component (in particular seeds and forest plants) was moderately elevated. In particular, the Embu 3 and Muranga 3 garden were the least self-sufficient.

3.3. Principal Components Analysis (Level 2) and Cluster Analysis (Level 3)

With the aim of evaluating which of the Level 2 components were the most influential in determining the value of sustainability, a PCA was carried out with the data relative to all of the gardens in all of the geographic locations.

The primary purpose of the PCA is to reduce the nine components (representatives of analyzed phenomenon as derived from their articulation into indicators) in some latent variables by performing a linear transformation of the variables. Therefore, the variable with higher variance (highlighted in bold) is drawn on the first axis, the second on the second axis, and so on. In order to reduce the complexity, the main (for variance) among the new latent variables (factors) is usually analyzed.

As can be observed in Table 6, Factor 1 is explained by the indicators aggregated in an input and acquisition process. Factor 2 is connected to the agro-environmental indicators, grouped into Biodiversity and Agricultural Practices, while Factor 3 emphasizes aspects that are more socio-cultural and regard generational exchange such as culture, region, and internal relationships. The fact that these three principal components are represented by factors included in the three considered dimensions (socio-cultural, agro-environmental, and economic) clearly shows that the indicators chosen by the stakeholders for these representations are reliable and demonstrates the relevance of all three dimensions (Figure 4).

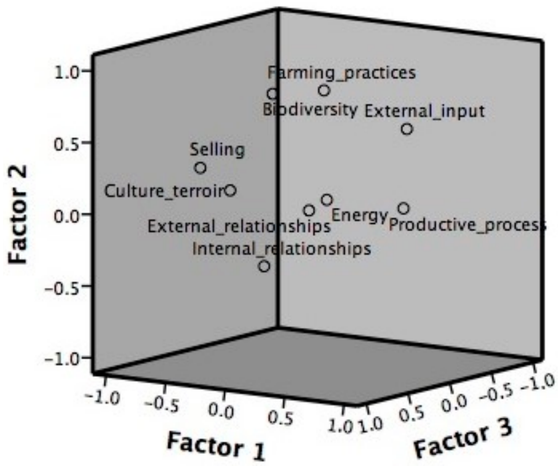

Figure 4. Graphic representation of components performed by using the data of all the gardens analyzed through the PCA (principal component analysis). The environmental dimension is well represented by the components on Factor 2, while Factors 1 and 3 are explained by components that belong indistinctly to socio-cultural, environmental, and economic dimensions.

Table 6. The rotated component matrix where the factor loadings were obtained by performing a PCA (principal component analysis).

Component	Factor				
	1	2	3	4	5
Internal_relationships	0.156	−0.270	**0.863**	0.163	0.133
External_relationships	−0.021	−0.013	0.072	0.986	−0.012
Productive_process	**0.842**	0.103	0.171	−0.079	−0.004
Biodiversity	−0.495	**0.717**	−0.169	0.241	0.223
Culture_terroir	−0.134	0.229	**0.857**	−0.065	−0.088
Farming_practices	0.133	**0.845**	0.113	−0.155	−0.031
Energy	0.106	0.069	0.041	−0.011	0.979
External_input	**0.644**	0.590	−0.152	0.320	0.030
Selling	−0.785	0.238	0.287	−0.015	−0.379

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalization. The factor loadings with the highest positive impact on factor expression are typed in bold. Factor 1 is well explained by the agro-environmental and economic dimensions, Factor 2 from agro-environmental dimension, and Factor 3 from both the socio-cultural and the agro-environmental dimensions.

Finally, to show the homogenous presence able to characterize the sustainability of the analyzed gardens, a cluster analysis (Figure 5) was carried out taking into consideration all of the Level 3 elements (indicators). The cluster analysis is a multivariate statistical analysis technique able to logically group the countings in order to minimize the differences inside the groups and to maximize the differences among groups.

The analyzed gardens were aggregated according to the geographic areas, with the exception of the Nakuru 4 and Embu 5 gardens. This kind of analysis made it possible to show how the similar climate conditions and the cultural component of the local populations had a particular influence on every-day actions. In fact, the Muranga county gardens, all aggregated into a single cluster, were able to strongly influence the practices and processes characteristic of the Kikuyu culture, the ethnicity dominant in the area [33].

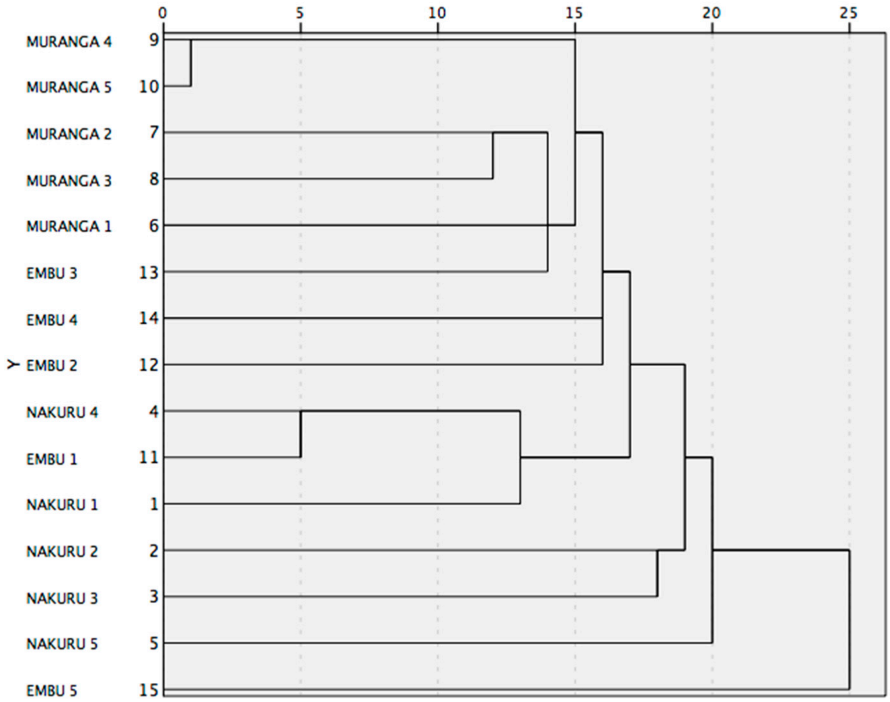

Figure 5. Dendrogram showing homogenous groups of the school gardens case studies. The Ward's method of hierarchical clustering produces a cluster which evidences homogenous groupings per county with respect to values accounting for all of the selected indicators. Classes of similar school gardens are grouped all together.

4. Discussion

SAEMETH-G is an interpretative framework for assessing and monitoring the sustainability of school gardens, inspired by the SAEMETH method [26] for evaluating small-scale crops. It is based on the parity of socio-cultural, agro-environmental, and economic dimensions of sustainability (in terms of weight due to an acknowledgement of the same level of relevance) with the aim of facilitating a synthetic vision of the school gardens, as a multifaceted learning tool [34].

Its application on the 15 case studies in Kenya has demonstrated the functionality of a method proposed for a wide-spectrum and integrated evaluation of school gardens as a mix of quantitative and qualitative data. For some components and indicators of the agro-environmental and economic dimensions in particular, a quantitative approach has been possible (for example, the evaluation of the lifecycle and of the calculation of net margins). However it is clear that there are several constraints to exactly measuring some features of school gardens: the cost of the harvest and analysis of the data might be high and, furthermore, quite often these data are unavailable. The choice of using a large number of qualitative indicators, on one hand, penalizes the possibility of a precise analysis of a single indicator but, on the other hand, allows for a wider perspective of the capacity of an environmentally-, economically-, and most of all socially-sustainable system inside a school curriculum [9]. The method has shown a substantial flexibility and, thus, can also be applied to different models of school gardens (managed by teachers, by local agricultural officers, by local NGOs). In fact, the analyzed gardens include all of the aspects of experiential education tied to local knowledge even though they represent different school garden programs. There are good reasons to believe that the garden micro-system as a sustainable action (albeit with variable margins of improvement according to the specific situation). It is a way of working on the approach children have toward sustainability [9]. Thus, it is hoped that these kinds of learning laboratories will continue to spread.

According to the ecological principal of interdependence [35], in which variations in an ecosystem's components produce variations of other components, virtuous processes at a scholastic level can also generate changes at the family and community level [36].

The participation of all of the subjects involved in the realization and management of school gardens together with experts, including those outside the academic world, in various phases of the methodology has, furthermore, carried out a fundamental role in the development of SAEMETH-G, the importance of which has already been shown in other works, such as that of Olsson and Folke [37].

Aside from analyzing single SAEMETH-G gardens, the methodology was seen to be useful for comparing different systems at a school level, and could also be applied in the future to analyze school garden in other geographical contexts as well as other kinds of gardens such as community gardens. It could also become a supporting tool for monitoring the sustainability performance of school gardens over time by identifying possible spaces for improvement.

However, it is important to strengthen this research with other case studies with the objective of better understanding the importance of the synergies between the components and indicators in order to further refine the point-system criteria. In addition, the analysis of these synergies could reduce the number of indicators and make the method more widely applicable for explaining complex systems in simple ways. At the moment the framework is also still weighed down by the remarkable training that is necessary for those carrying out the data collection.

5. Conclusions

Among the different instruments that can favor an interdisciplinary and every-day approach to sustainability, caring for a school garden has revealed itself to be particularly effective across different nations and cultures. Furthermore, many different school subjects can be involved in the educational activities connected to it and it can play a fundamental role in bridging the gap perceived by new generations between the production and consumption of food.

Clearly, the school garden offers a "learning space" that is potentially more innovative and experiential than traditional school contexts. It should also be recognized that the school garden experience is not always as easy to implement as it seems because it requires not only adequate space and tools, but also teachers with appropriate skills (theoretical and practical management).

SAEMETH-G has shown itself to be an analysis method that is sufficiently flexible to be applied to models that are managed in different ways, even if based on approaches with a similar foundation. Additionally, even though the selected case studies received a good sustainability score on average, the method has contributed to showing the necessity of intervening in the training and productive processes with the aim of improving some fundamental aspects of sustainability, most of all in the agro-environmental field. Gardens may suffer when practical and theoretical skills are lacking, particularly when training is unavailable. In such cases, school-garden experiences can be improved by providing the teachers who manage the gardens (and activities related to them) with more scientific and informative support and by designing the school garden to be a complete agro-ecological system, complete and as independent as possible from external inputs and the associated negative externalities. In this way, the resulting garden can become a key part of a systemic education that supports an understanding of local and global issues.

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References

1. Desmond, D.; Grieshop, J.; Subramanium, A. *Revisiting Garden-based Learning in Basic Education*; Food and Agriculture Organisation of the United Nations: Rome, Italy, 2002.
2. Bailey, L.H. *The Nature Study Idea*; McMillan: New York, NY, USA, 1909.
3. Dresher, A.W. Improving child nutrition and agricultural education through the promotion of School Garden Programs. In *First Draft Concept Note on School Gardens*; FAO: Rome, Italy, 2002.
4. Blair, D. The child in the garden: An evaluative review of the benefits of school gardening. *J. Environ. Educ.* **2009**, *40*, 15–38. [CrossRef]
5. Cheng, M.H. Asia-Pacific faces diabetes challenge. *Lancet* **2010**, *375*, 2207–2210. [CrossRef]
6. Frerichs, L.; Brittin, J.; Sorensen, D.; Trowbridge, M.J.; Yaroch, A.L.; Siahpush, M. Influence of school architecture and design on healthy eating: A review of the evidence. *Am. J. Public Health* **2015**, *105*, e46–e57. [CrossRef] [PubMed]
7. Harmon, A.; Lapp, J.L.; Blair, D.; Hauck-Lawson, A. Teaching Food System Sustainability in Dietetic Programs: Need, Conceptualization, and Practical Approaches. *J. Hunger Environ. Nutr.* **2011**, *6*, 114–124. [CrossRef]
8. FAO. *World Food Summit Five Years Later, Related Events. School and Hospital Gardens*; FAO: Rome, Italy, 2002. Available online: http://www.fao.org/WorldFoodSummit/sideevents/papers/Y6824e.htm (accessed on 3 April 2016).
9. Varela-Losada, M.; Vega-Marcote, P.; Pérez-Rodríguez, U.; Álvarez-Lires, M. Going to action? A literature review on educational proposals in formal Environmental Education. *Environ. Educ. Res.* **2016**, *22*, 390–421. [CrossRef]
10. Oluoch, M.O.; Pichop, G.N.; Silué, D.; Abukutsa-Onyango, M.O.; Diouf, M.; Shackleton, C.M. Production and harvesting systems for African indigenous vegetables. Chapter 5. In *African Indigenous Vegetables in Urban Agriculture*; Shackleton, C.M., Pasquini, M.W., Drescher, A.W., Eds.; Earthscan: London, UK, 2009.
11. De Neergard, A.; Drescher, A.W.; Kouame, C. *Urban and Peri-Urban Agriculture in African African Indigenous Vegetables in Urban Agriculture*; Earthscan: London, UK, 2009; pp. 36–64.
12. Chen, H.M.; Huang, Y.L. The theory and application of horticultural therapy. *J. Chin. Soc. Hortic. Sci.* **2005**, *51*, 135–144.
13. Tenkouano, A. The nutritional and economic potential of vegetables. In *State of the World 2011: Innovations that Nourish the Planet*; Starke, L., Ed.; Norton: New York, NY, USA, 2011; pp. 27–38.
14. Skinner, E.A.; Chi, U. The Learning-Gardens Educational Assessment Group, Intrinsic Motivation and Engagement as "Active Ingredients" in Garden-Based Education: Examining Models and Measures Derived from Self-Determination Theory. *J. Environ. Educ.* **2012**, *43*, 16–36. [CrossRef]
15. Keatinge, D.H.; Chadha, M.L.; Hughes, J.A.; Easdown, W.J.; Holmer, R.J.; Tenkouano, A.; Yang, R.Y.; Mavlyanova, R.; Neave, S.; Afari-Sefa, V.; et al. Vegetable gardens and their impact on the attainment of the Millennium Development Goals. *Biol. Agric. Hortic.* **2012**, *28*, 71–85. [CrossRef]
16. BMVBS/BBR (Bundesministerium für Verkehr, Bau und Stadtentwicklung/Bundesamt für Bauwesen und Raumordnung). *Städtebauliche, Ökologische und Soziale Bedeutung des Kleingartenwesens. Forschungen Heft 133 (Importance of Allotment Gardening for Urban Planning, Ecological and Social Aspects)*; BMVBS/BBR: Berlin, Germany, 2008. (In German)
17. Torquebiau, E. Are tropical agroforestry home gardens sustainable? *Agric. Ecosys. Environ.* **1992**, *41*, 189–207. [CrossRef]
18. Seidu, R.; Heistad, A.; Amoah, P.; Drechsel, P.; Jenssen, P.D.; Stenström, T.A. Quantification of the health risk associated with wastewater reuse in Accra, Ghana: A contribution toward local guidelines. *J. Water Health* **2008**, *6*, 461–471. [CrossRef] [PubMed]
19. Galluzi, G.; Eyzaguirre, P.; Negri, V. Home gardens: Neglected hotspots of agrobiodiversity and cultural diversity. *Biodivers. Conserv.* **2010**, *19*, 3635–3654. [CrossRef]
20. Gari, J.A. *Agrobiodiversity Strategies to Combat Food Insecurity and HIV/AIDS Impact in Rural Africa*; FAO: Rome, Italy, 2003.
21. Sterling, S. Educazione Sostenibile. 2006. Available online: http://www.animamundi.it/HOME.html (accessed on 11 August 2016). (In Italian)

22. Lorenzini, G. Educazione Ambientale: I Principi e le Pratiche Biologi Italiani Giugno. 2012. Available online: http://www.ceeauniba.net/files/EdAmb_principi_e_pratiche.pdf (accessed on 11 August 2016).
23. Stapp, W.B. The concept of environmental education. *Environ. Educ.* **1969**, *1*, 30–31.
24. Hermann, J.; Parker, S.; Brown, B.; Siewe, Y.; Denney, B.; Walker, S. Afterschool gardening improves children's reported vegetable intake and physical activity. *J. Nutr. Educ. Behav.* **2006**, *38*, 201–202. [CrossRef] [PubMed]
25. Ruiz-Gallardo, J.-R.; Verde, A.; Valdés, A. Garden-based learning: An experience with "at risk" secondary education students. *J. Environ. Educ.* **2013**, *44*, 252–270. [CrossRef]
26. Peano, C.; Tecco, N.; Dansero, E.; Girgenti, V.; Sottile, F. Evaluating the sustainability in complex agri-food systems: The SAEMETH framework. *Sustainability* **2015**, *7*, 6721–6741. [CrossRef]
27. Astier, M.; Speelman, E.N.; Lopez-Ridaura, S.; Masera, O.R.; Gonzalez-Esquivel, C.E. Sustainability indicators, alternative strategies and trade-offs in peasant agroecosystems: Analysing 15 case studies from Latin America. *Int. J. Agric. Sustain.* **2011**, *9*, 409–422. [CrossRef]
28. De Mey, K.; D'Haene, K.; Marchand, F.; Meul, M.; Lauwers, L. Learning through stakeholder involvement in the implementation of MOTIFS, an integrated assessment model for sustainable farming in Flanders. *Int. J. Agric. Sustain.* **2011**, *9*, 350–363.
29. Slow Food Foundation for Biodiversity. Available online: http://www.fondazioneslowfood.com/en/ (accessed on 2 January 2016).
30. Patton, M.Q. Qualitative Research. In *Encyclopedia of Statistics in Behavioral Science*; John Wiley & Son: New York, NY, USA, 2005.
31. Van Calker, K.; Berentsen, P.; de Boer, I.; Giesen, G.; Huirne, R. An LP-model to analyze economic and ecological sustainability on Dutch dairy farms: Model presentation and application for experimental farm de Marke. *Agric. Syst.* **2004**, *82*, 139–160. [CrossRef]
32. Meul, M.; van Passel, S.; Nevens, F.; Dessein, J.; Rogge, E.; Mulier, A. MOTIFS: A monitoring tool for integrated farm sustainability. *Agron. Sustain. Dev.* **2008**, *28*, 321–323. [CrossRef]
33. Dewees, P.A. *Household Economy, Trees and Woodland Resources in Communal Areas of Zimbabwe Mimeo*; Oxford Fresty Institute, University of Oxford: Oxford, UK, 1992; p. 85.
34. Brunotts, C.M. School Gardening—A Multifaceted Learning Tool. An Evaluation of the Pittsburgh Civic Garden Centers Neighbors and Schools Gardening Together. Unpublished Master's Thesis, Duquesne University, Pittsburgh, PA, USA, 1998.
35. Kelly, J.G.; Ryan, A.M.; Altman, B.E.; Stelzner, S.P. Understanding and changing social systems: An ecological view. In *Handbook of Community Psychology*; Rappaport, J., Seidman, E., Eds.; Kluwer Academic/Plenum: New York, NY, USA, 2000; pp. 133–159.
36. Ozer, E.J.; Weinstein, R.S.; Maslach, C.; Siegel, D. Adolescent AIDS prevention in context: The impact of peer educator and classroom characteristics on the effectiveness of a school-based, peer-led program. *Am. J. Community Psychol.* **1997**, *25*, 289–323. [CrossRef] [PubMed]
37. Olsson, P.; Folke, C.; Hahn, T. Social-ecological transformation for ecosystem management: The development of adaptive co-management of a wetland landscape in southern Sweden. *Ecol. Soc.* **2004**, *9*, 2.