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Assessing the Sustainability of Horticultural Farms in Central Senegal: An Adaptation of the IDEA Method

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Abstract

This paper evaluates the sustainability of the different forms of horticulture farms (individual and collective) in the Groundnut Basin of Senegal using an adapted version of the IDEA method to the Senegal context.

Results show that collective farms have higher sustainability scores than individual farms. Also, collective farms are more sustainable in the agroecological scale while individual farms are more sustainable in the economic scale. Results also suggest that although IDEA can be adapted to both individual and collective horticulture farms of Senegal, there is a need to include a fourth scale that will integrate the institutional and organizational features of collective farms as well as the socio-political and research

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context that can enable or hinder the adoption of sustainable farm practices.

Keywords: farm sustainability; water user associations; horticulture; groundnut basin of Senegal; IDEA.

1. Introduction

Public awareness of the concept of sustainability came with the publication of the "*Limits to Growth*" report (Meadows et al., 1972), which drew attention to the finiteness of global resources and the importance of integrating environmental aspects in development objectives. An earlier definition is given by the 1987 Brundtland report, which defined sustainable development as an "economically viable, environmentally sound and socially acceptable development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987)[1]. Agricultural sustainability reflects the aforementioned definition. Francis and Youngberg (1990) define it as "ecologically sound, economically viable, socially just and human". Specifically, sustainable agriculture should satisfy human needs without destroying natural resources (Ikerd, 1993; Francis and Youngberg, 1990; Harwood, 1990). Relating to the specific case of Sub-Saharan African countries, agricultural sustainability implies the increase of agricultural output to meet food demand, under the constraints of environmental fragility (Kleemann 2013; Pretty et al. 2011; Pretty et al. 2003).

In Africa, agriculture plays an important role in economic development. The sector accounts for nearly half of the continent's gross domestic product and employs 60 percent of the labor force (FAO, 2016). However, in Sahelian countries like Senegal, agriculture is very dependent on rainfalls that are highly variable due to climatic hazards. To mitigate drought risks, investing in irrigation has been promoted since the 70s droughts. Among the public initiatives to develop the irrigation sector, horticulture

[1] The World Commission on Environment and Development (WCED) laid the foundation for the United Nations Conference on Environment and Development in 1992 and the adoption of the Agenda 21, the Rio Declaration and the Commission on Sustainable Development (United Nations 1992).

has been promoted through Water User Associations (WUAs), considered as a solution to decentralize water management, under the framework of government or donor-funded development projects not only to mitigate drought but also to diversify production and revenue sources in areas where rainfed agriculture is predominant and access to water resources is financially and technically constraining to farmers. In addition to public initiatives, in rainfed areas such as the Groundnut Basin where groundnut--as a cash crop--and millet are the main cultivated crops, there exist private initiatives that involve family farms increasingly oriented towards irrigated agriculture, particularly market gardening during the dry season. This has been motivated by the uncertainties associated with rainfed production and the government's withdrawal from the groundnut sector that has led to a deterioration of production conditions of family farms.

However, the practice of irrigated agriculture in the Groundnut Basin characterized by limited or inaccessible water resources and high temperatures could be difficult. Therefore, it becomes relevant to wonder whether market gardening that was previously practiced in wetlands such as the Niayes or the Senegal River Valley with high irrigation potential thanks to the presence of water resources, favorable temperatures, can be sustainable in an area where not only the irrigation potential is limited but also the temperatures are high. In addition to this, there are financial constraints associated with the high cost of inputs especially for horticultural crops that are input-intensive, inaccessibility to funding, organizational difficulties and inadequate infrastructures to ease market access. A field study of 12 horticulture-oriented WUAs in the Groundnut Basin has shown that most of them are abandoned after a few years of production (Robbiati et al., 2013). This strengthens the relevance of the sustainability issue of horticultural farms in rainfed areas such as the Groundnut Basin that has, to date not yet been studied carefully in the Senegal context. Moreover, future interventions to develop the irrigation sector in the area should learn from the successes and failures of the existing irrigation schemes.

Therefore, the main objective of this paper is to evaluate the sustainability of the different forms of market gardening (individual and collective) in the Groundnut Basin.

As suggests its definition, farm sustainability depends on environmental, economic and social factors. Compared to the most common measurement methods IDEA provides some important advantages. It allows measuring farm sustainability for each unit of observation. It has a holistic approach that includes all the dimensions of farm sustainability. It is easily adapted to different contexts. Finally, it is a useful tool for policymakers, analysts, practitioners, and farmers who intend to increase agricultural sustainability (Zahm et al. 2008). However, Zahm et al. (2008) pointed out that the IDEA method is hardly adaptable to the horticultural sector given its level of specialization.

Attempts to compare the sustainability of different forms of farm organization were made (Biret et al., 2019). However, comparisons focused on different forms of individual[2] farms; on livestock farms, etc. The comparison of individual and collective farms has not yet been a matter of interest. Also, there has been little to no interest in horticulture farms. This paper's contribution is threefold: i) the paper adapts the IDEA method to horticulture farms; ii) it compares the sustainability of two farm types based on their management system which can be individual or collective; iii) it discusses the necessity to include an institutional dimension in the IDEA method to analyze the sustainability of collective farms.

The main hypothesis of this research is that the IDEA method can be adapted to analyze the sustainability of both individual and collective horticulture farms in the Senegal context.

2. Materials and methods

2.1. The horticultural sector in the groundnut basin of Senegal

The Groundnut Basin is one of the six agro-ecological zones of Senegal.

[2] Here individual refers to the notion of one entity (family or an individual) managing the farm as opposed to a collective farm where many individuals not belonging to the same entity gather to commonly manage a farm.

Geographically, it is composed of central regions of Senegal, namely, Diourbel, Fatick, Kaolack, Kaffrine, Louga, and Thiès. Groundnut is historically the main produced cash crop in the area. The farming activity is majorly undertaken during the rainy season from June to September with groundnut and millet occupying most of the cultivated areas. However, in the face of climatic uncertainties, severe degradation of natural resources, inadequate infrastructure, and agricultural equipment, and strong land pressure, a reorganization of farm production systems is required. In addition, liberalization policies that occurred during structural adjustments between the end of the 1970s and the end of the 1990s led to the deterioration of production conditions of family farms and affected the functioning of the groundnut sector (Oya 2009; 2001; Boccanfuso and Savard 2008).

In this context, farms have adopted diversification strategies that ensure the food security of their family by diversifying their production and their economic activities (Chia et al. 2006). Thus, farmers adopted diet and income diversification strategies by including non-agricultural activities, livestock, and horticulture activities (Chia et al. 2006). Consequently, the horticulture sector has steadily grown, becoming a promising new source of income. Horticultural crops are mainly grown during the dry season from October to June that is divided into two sub-seasons, the cold dry season (October to February) and the dry dry season (March to June)[3].

Although some big farms are involved in the horticulture sector, household farming dominates the sector.

The development of horticulture in the Groundnut Basin has been supported by development partners and extension services through water user associations. These latter are considered as collective farms that involve numerous individual farmers (from family farms) cultivating commonly shared land, sharing the management of the farm and the irrigation system. They are usually organized in a formal agricultural

[3] Due to climatic uncertainties, the duration of the two sub-seasons can be variable.

association that can be an Economic Interest Group[4] with men and women as members or a Women Producer Organization[5] that is only composed of women or another type of association. Besides these collectively organized farms, there are individual farms managed by a unique household or an individual producer.

2.2. Assessing sustainability at farm level

2.2.1. The IDEA method

The theoretical ground of agricultural sustainability assessment is the sustainability theory according to which sustainability involves environmental, economic and social dimensions. Therefore, as the definition of agricultural sustainability integrates these three dimensions, the methods to assess agricultural sustainability should also integrate the three pillars.

One of the primary challenges to finding a method to assess agricultural sustainability is the lack of consensus on methodology application (De Olde et al., 2017), which has led to the development of a wide range of composite indicators (Riley, 2001). In addition, for a long time, sustainability indicators focused on environmental impact, ignoring economic and social aspects (Latruffe et al., 2016; Binder et al., 2010; Hayati et al., 2010; Singh et al., 2009; Bell and Morse, 2008; Sadok et al., 2008).

Consequently, environmental indicators cover a multitude of themes (Lebacq et al., 2013), that Latruffe et al. (2016) classified into three main groups. Indicators that analyze local or global impacts (Halberg et al., 2005), those that study the action chain (Olsson, et al., 2009), and those focusing on the goal of the analysis (Bockstaller et al., 2009). Differently, economic indicators investigate the standard business themes like profitability, liquidity, stability, and productivity, whilst, social indicators consider the sustainability relating to the farming community and/or the society (Latruffe et al. 2016).

Nonetheless, several authors have developed indicators that include the three pillars

[4] GIE: "*Groupements d'Intérêt Economique*".

[5] GPF: "*Groupement de Promotion Feminine*".

of sustainability[6] (Bertocchi et al., 2016; Paracchini et al., 2011; Dantsis et al., 2010; Gomez-Limon and Sanchez-Fernandez, 2010; Rodrigues et al., 2010; Meul et al., 2008; Zahm et al., 2008; Van Cauwenbergh et al., 2007; van Calker et al., 2006; López-Ridaura et al., 2005; Rasul and Thapa, 2004; Tzilivakis and Lewis, 2004; Häni et al., 2003, etc.).

Using six selection criteria, De Olde et al. (2016) restrict the choice to four main methods, that are RISE (Häni et al., 2003), SAFA (FAO, 2014), PG (Gerrard et al., 2012) and IDEA (Zahm et al. 2008)[7]. However, PG has an emphasis on public-goods instead of sustainability and SAFA applies to a wider scope by extending through supply chains in agriculture, forestry, and fisheries (De Olde et al. 2016). Thus, only the IDEA and RISE take account of farm-level sustainability.

According to the criteria proposed by Marchand et al. (2014)[8], we believe that the IDEA method of Zahm et al. (2008) is the most appropriate in Sub-Saharan African (SSA) countries. Indeed, the three dimensions of the approach are in line with the definition of a sustainable farm. It is adaptable to different agricultural contexts. It requires information that is easy to collect in a context where information accessibility is low. It analyses the three pillars of sustainability through multiple criteria, allowing a thorough analysis of each sustainability aspect. Last but not least, it evaluates sustainability both at farm and sector levels, representing a useful tool for policy advice at different levels (Binder et al. 2010; Bockstaller et al. 2009; Galan et al. 2007).

On the contrary, RISE requires a set of information that can be difficult to obtain in the Senegalese context, like some technical analysis on energy impact, water resources, soil composition, and fertilizer environmental impact and is thus time-consuming (De Olde et al. 2016).

[6] An exhaustive list of the major sustainability assessment methods is presented in De Olde et al. (2016).

[7] RISE: Response-Inducing Sustainability Evaluation; SAFA: Sustainability Assessment of Food Agricultural Systems; PG: Public Goods.

[8] Marchand et al. (2014) suggest that the key characteristics of the criteria for choosing sustainability indicators are the balance of time requirement, the output accuracy and the complexity in relation to the use and tool function.

IDEA is technically structured into 16 objectives grouped together to form three sustainability scales: agroecological, socio-territorial and economic. Each of these scales is subdivided into three to four components for a total of ten, which in turn are composed of a total of 42 indicators[9] in the third version (18 in the agro-ecological and socio-territorial scales and 6 in the economic scale). Each indicator is composed of one or several criteria that are given a score. The final score of an indicator is the sum of the scores of the criteria within it. In the same way, within each scale, the values of the different indicators are added together to have the final score of the scale. Therefore, there is compensation between the criteria of a given indicator and between indicators of a given component and scale. This means for instance that within a scale "favorable practices will offset practices with a harmful effect" (Zahm et al., 2008).

The calculation procedure is based on a grading system with an upper limit. The three sustainability scales are of equal weight and range from 0 to 100 points. The final sustainability score is the lowest value obtained among the three scales, thus, sustainability is achieved when the farm reaches a score equal to or higher than 60 points in each scale. The initial IDEA is detailed in Zahm et al. (2008).

2.2.2. The adaptation of IDEA to horticulture farms in the Groundnut Basin

IDEA was developed from the recommendation of Mitchell et al. (1995) and Girardin et al. (1999) on the case study of French farms; thus Zahm et al. (2008) suggest that any use of IDEA in a different context needs a specific adaptation. However, it has been mainly adapted in Central America and North Africa. Specifically, in Mexico Salas-Reyes et al. (2015) and Fadul-Pacheco et al. (2013) adapted IDEA to dairy farms. M'Hamdi et al. (2009) in Tunisia and Srour et al. (2009) in Libya applied IDEA to dairy farms and small livestock farms respectively. Ghadban et al. (2013) compared organic and conventional small farms in Lebanon, as well as, Baccar et al. (2016) analyzed three types of farms in the Saïs plain of Morocco. Elfkih et al. (2012) analyzed olive farms in

[9] There was initially 41 indicators in the first version of the IDEA method.

Tunisia and De Castro et al. (2009) examined farms in the São Pedro Valley in the Brazilian State of São Paulo. Biret et al. (2019) also adapted the IDEA method to assess the sustainability of different forms of farming systems in Thailand. Recently, Agossou et al. (2017) have adapted the IDEA for the analysis of farms in the Ouémé lower valley in Benin.

Therefore, following the same approach, we adapted the IDEA grid to the specificities of our case. We consider the specific issues relating to the relationship between the territory and the farm as well as the agricultural characteristics. In that sense, we apply a twofold adaptation: (i) to horticultural farms and (ii) to agronomic practices, social values and economic accounting of Senegal's farms.

In total, our adapted IDEA retained the three scales and ten components. The major changes were made on the indicators to fit the specificities of our case study. Therefore, the adapted IDEA contains 36 indicators, thus leading to a new notation system. This latter is established based on the principle of compensation between criteria within the same component (Zahm et al., 2008), and on the relevance of the criteria to the horticulture farms in the groundnut basin of Senegal.

As suggests Elfkih et al. (2012), the adaptation and new scoring should not have major negative effects. Indeed, thanks to the compensation criteria within components, "the removal or the substitution of any indicators can be compensated by the retained indicators of the same component". Furthermore, "the calculation of the components scores is obtained through the cumulative number of basic sustainability units of indicators that is usually higher than its ceiling value; this offers more flexibility in adapting scoring punctuation".

Table 1 shows the selected and adapted indicators in comparison to the third IDEA version. In total, 6 indicators were removed. In addition, we adapted the criteria of some indicators. The reasons for these modifications are explained as follows:

- The removed indicators are those associated with livestock activities, i.e. indicator A3 (animal diversity), A9 (contribution to environmental issues), A10 (valorization of space), A11 (management of fodder areas), A15 (veterinary treatments) and B13 (animal well-being). This is done because of two reasons: (i) as explained horticulture farms in the groundnut basin are either individual or collective. The latter type is only specialized in horticulture with no livestock activities associated with it. Therefore, to allow a fair comparison between the two types of farms we decided to remove livestock-related indicators; (ii) as stated previously, an individual farm can be a household or an individual; therefore their respective households might have livestock activities. However, due to the concerns raised in point (i) and the risk of loss of information related to a lengthy questionnaire, we decided not to include information on their respective households' activities.

- Concerning the criteria of indicators, the agroecological scale is adapted by considering the agronomic techniques as recommended by agricultural research in Senegal. These recommendations have been collected during interviews[10] with researchers at the national center for the development of horticulture of the Senegalese Institute of Agricultural Research (ISRA-CDH)[11]. Generally, this scale analyses the ability of the farming system to use agricultural inputs without compromising the ecosystem.
- The socio-territorial scale is adapted to capture the role that agriculture plays in rural communities in terms of food access and supply, or in terms of labor supply and farm training. Overall, this scale assesses the quality of life of farmers and the services that the farm provides to the community. Finally, the economic scale is adapted following the standard norms of general accounting because most farms are not officially registered; so they do not have any formal account ledgers.

[10] We undertook one on one interviews with scientists at the national center for the development of horticulture. These interviews covered agronomic norms related to crop association, rotation, the practice of fallow, crop diversification, organic farming practices, animal control, water use and management, crop water requirements, seed conservation, etc. The interview guide is available from the authors.

[11] *"Centre pour le Développement de l'Horticulture"*.

Table A1 in the appendices shows the adapted IDEA grid that we applied to our sample.

Table 1. Adaptation of the original IDEA (version 3)

Scales and components	Indicators	Original IDEA score	Adapted IDEA score	Maximum value of each component
Agroecological scale				
Diversity	A1-Diversity of annual and temporary crop	14	24	33
	A2-Diversity of perennial crops	14	12	
	A3-Animal diversity	14	Removed	
	A4-Enhancement and conservation of genetic heritage	6	12	
Organization of space	A5-Cropping pattern	8	11	33
	A6-Dimension of plots	6	8	
	A7-Organic matter management	5	14	
	A8-Ecological regulation zones	12	9	
	A9-Contribution to the environmental issues	4	Removed	
	A10-Valorization of space	5	Removed	
	A11-Management of fodder area	3	Removed	
Farming practices	A12-Fertilization	8	9	33
	A13-Liquid organic effluents	3	3	
	A14-Pesticides	13	14	
	A15-Veterinary treatment	3	Removed	
	A16-Soil resource protection	5	5	
	A17-Water resource management	4	4	
	A18-Energy dependence	10	11	
Total of the agroecological scale				100
Socio-territoriale scale				
Qualité des produits et du terroir	B1-Quality approach	10	7	33
	B2-Enhancement of building and landscape heritage	8	3	
	B3-Inorganic waste management	5	5	
	B4-Space accessibility	5	4	
	B5-Social involvement	6	14	
Employment and services	B6-Short marketing channel	7	7	33

	B7-Autonomy and Promotion of local resources	10	9	
	B8-Services, multi-activities	5	6	
	B9-Employment contribution	6	6	
	B10-Collective work	5	4	
	B11-Probable farm sustainability	3	3	
Ethics and human development	B12-Contribution to world food balance et à la gestion durable des ressources planétaires	10	8	
	B13-Animal well-being	3	Removed	
	B14-Training	6	10	
	B15-Labour intensity	6	6	34
	B16-Quality of life	6	8	
	B17-Isolation	3	3	
	B18-Reception, hygiene, and safety	4	3	
Total of the socioterritorial scale				100
Economic scale				
Viability	C1-Economic viability	20	20	30
	C2-Economic specialization rate	10	10	
Independence	C3-Financial autonomy	15	22	25
	C4-Reliance on subsidies	10	3	
Transferability	C5-Economic transferability	20	20	20
Efficiency	C6-Process efficiency	25	25	25
Total of the economic scale				100

Source: authors' elaboration

2.3. The dataset

2.3.1. Sampling strategy

The study concerns three regions of the Groundnut Basin, i.e. Diourbel, Fatick, and Thiès[12]. Most of the horticulture farms in the Groundnut Basin are not formally registered and there is no existence of a nation-wide census of horticulture farms in Senegal. Therefore, to select farmers we constructed a sampling frame by undertaking a census of horticulture farms in the three regions of the study in 2015. We found 246 horticulture farms among which were drawn a sample of 65 horticultural farms for all

[12] These are the three regions where the project that funded this research intervened.

the growing seasons during which horticultural crops were cultivated in 2015.

Farms were selected based on a stratified random sampling method (each region being a stratum) that ensured to respect the regional representativeness of collective and individual farms in the sample.

Our sample is mainly composed of farms of the Thiès region (73.85%) where there are more horticultural farms, followed by Diourbel and Fatick regions that represent respectively 23.08% and 3.08% of the sample. Most farms are collective (55.38%, the remaining 44.62% being individual farms), which are large in size and use a high level of labor, especially female workers, and capital. In fact, as stated, collective farms are organized in agricultural associations.

2.3.2. Summary statistics of farms characteristics

Table 2 shows the characteristics of the two farming systems. It shows that collective farms have greater land endowments and thus exploit more land than individual farms. This can be explained by the fact that collective farms gather multiple individual farmers, exploiting a common space. These collective farms are commonly conceptualized as water user associations that have been promoted all around the world in the 1970s, to decentralize irrigation systems' management that was historically under the responsibility of national entities that failed to maintain irrigation systems (IWMI, 2018). They have been introduced in Senegal in the 1980s, 1990s mainly under donor or government-funded projects. That makes land and water access easier for them.

Table 2 also shows that collective farms have a higher number of workers. This is again explained by the collective nature of these farms. The active members contribute as labor force and are sometimes helped by their family members or paid labor. Each individual member or a group of members is allocated some small plot(s) under their responsibility. That ensures the participation of individual members in production activities. Therefore, since the average number of members is high, it is normal to have a higher number of workers contrary to individual farms. As for the higher number of female workers, it is explained by the higher number of active female members of

WUAs. The high number of female workers can be explained by the intervention logic of projects/programs or NGOs that are more likely to target women in order to contribute to reducing gender inequalities.

The value of capital (irrigation and agricultural equipment) is much more important for WUAs. This is also expected since WUAs are usually introduced by donor-funded projects or when they were initiated by farmers, they usually benefit from funding that finance the acquisition of the irrigation system shared among members. Therefore one would expect these to have higher capital.

Table 2. Summary statistics

	Individual farms	Collective farms
Land		
Cultivated land (ha)	0.53 (1.01)	2.98 (2.68)
Available land for cultivation	1.01	6.61
Labor force		
Number of active male members		10.63 (11.76)
Number of active female members		22.94 (22.35)
Number of male workers	2.0 (1.5)	10.6 (11.8)
Number of female workers	0.8 (1.8)	20.8 (18.4)
No. of not paid workers (plot owners or family labor)	5.3 (5.7)	36.6 (37.1)
Capital		
Capital value farm (LCU)	86,58 (203,91)	1,594,56 (3,801,57)
Per capita profit (LCU)	127,17 (301,63)	263,03 (692,96)
Total observations	29	36

Note: all values are means; standard deviation in parentheses. The local currency unit (lcu) is cfa franc (xof).

Source: authors' elaboration

3. Results and discussion

This section presents the results on the sustainability of the two types of farms. It first shows the results on the overall sustainability of farms (considering the three scales), showing the differences in the level of sustainability between the two types. It then presents the results for the different scales and their components by highlighting the main differences between the two types of farms and the reasons for such differences. This section finally discusses the results, the limits of the IDEA method and future methodological orientations to better assess horticulture farms' sustainability in the groundnut basin of Senegal and farms in general.

3.1. Sustainability analysis based on the type of farm management: collective vs individual

Results show that no farm reaches the IDEA sustainability level established at the threshold of 60 points for each scale (see table 3). Considering that sustainability is determined by the least sustainable scale, the table shows that on average collective farms appear closer to sustainability. When analyzing the scales individually, collective farms have higher mean scores for the agro-ecological and socio-territorial scales with more statistically significant differences (at 0.1 percent level) for the latter scale. Individual farms are more sustainable in the economic scale; however, for this scale, the difference between the two farm types is not statistically significant.

Table 3. Farms average sustainability scores

Scales	**Individual farm**	**Collective farm**	**t-test (means)[a,b]**
Agro-ecological	42,03	48,28	-2,05*
Socio-territorial	32,72	46,75	-6,11***
Economic	54,83	46,75	1,77
Observations	29,00	36,00	

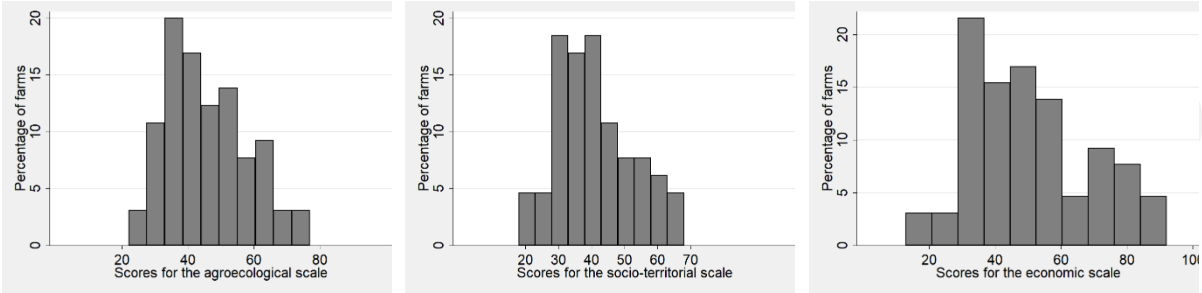
[a]t statistics: * $p<0.05$, **$p<0.01$, *** $p<0.001$

[b]t-test assumptions were validated before running the test. The Shapiro-Wilk test was used to test the normality assumption and Levene's test was used for the homoskedasticity (equality of variances) assumption.

Source: authors' elaboration

We analyzed farms individually to assess the intensity of the results. Figure 1 shows the distribution of farms' sustainability scores for each of the three scales. Distributions are light-tailed and skewed to the right. Indeed, most farms are slightly below the IDEA sustainability threshold for all the scales, demonstrating that there is room for increasing sustainability with few indicators improvement. The analysis also shows that many farms are sustainable in at least one scale (approximately 38 percent of individual farms and 47 percent of collective farms).

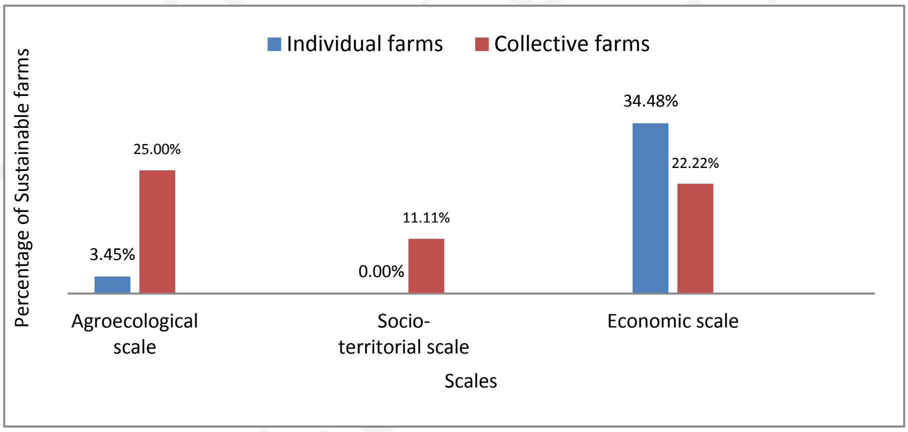
Figure 1. Farms distribution on each IDEA scale



Source: authors' elaboration

Looking at the distribution of those farms in the three scales (figure 2); results indicate that the 47 percent of sustainable collective farms are almost equally distributed across the agro-ecological and socio-territorial scales (25 percent are sustainable in the former and 22 percent in the latter). On the contrary, the 38 percent of sustainable individual farms are almost all sustainable in the economic scale (with no farm sustainable in the socio-territorial scale and only 3 percent sustainable in the agro-ecological scale).

Figure 2. Distribution of sustainable farms in the different scales



Source: authors' elaboration

To investigate further the results and understand the differences in the two groups, we analyzed the components of the sustainability scales, by

(i) plotting a star diagram (figure 3) that represents the mean score of the different farms for each component;

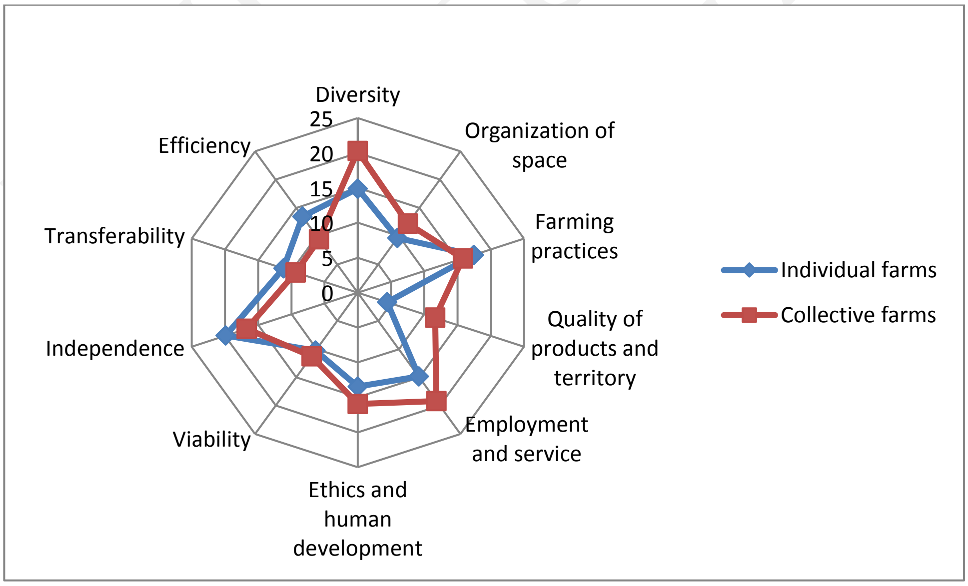
(ii) looking at the strengths and weaknesses of the farms for each component based on the scores of the criteria defining an indicator. A criterion is considered as strength for a farm type if the score obtained by a given farm for that criterion is at least half the maximum score of the criteria. Based on that logic, we designed table A2, in the appendix, which shows these strengths and weaknesses.

Both the star diagram and the table A2 show that for the agroecological scale, the diversity component is the most discriminating one when comparing the two types of farms and thus explains the higher performance of collective farms in that scale. Table A2 shows that collective farms cultivate a higher number of vegetable crops and varieties which can be related to the nature of collective farms that are mainly impulsed or supported by donors and governments through projects and programs. This allows them to benefit from support services, have access to new technologies including crop varieties.

When considering the socio-territorial scale, the quality of products and territory appears to make the biggest difference between the two farm types. Then follows employment and services to a lesser extent. The difference in the quality of products and territory is related to the higher level of women inclusion in collective farms and their participation in collective actions in the farming community of the study areas. Indeed as shown in table 2 and table A2, there are more female workers in collective farms and they have greater access to responsibility positions within collective farms. This result was expected. Indeed, it is more likely for collective farms to have a higher number of female workers since development interventions are very gender-sensitive and ensure gender balance. As for individual farms, they are more frequently headed by men who control productive resources. Therefore, women usually don't have equal access to productive resources such as land which reduces their likelihood to have responsible roles. Also, the affiliation to agricultural associations is more common in collective farms. As for the employment component, figure 3 does not show notable differences. However, when considering the strengths and weaknesses of the farms, table A2 shows that each farm type has some strengths over the other. Indeed, collective farms show positive external spillover effects within the community with a greater contribution to job creation. Also, they tend to commercialize more of their output locally compared to individual farms. This is also seen in the equality and human development component. However, individual farms have better interactions with other farms in terms of equipment sharing and services. This can also be explained by the fact that collective farms already have such interactions within them (between members) and might not necessarily feel the need to have such interactions with farms outside of their organization.

Concerning the economic scale, figure 3 shows that only the efficiency component displays notable differences between the two groups. This means that individual farms use production resources (inputs) in a less wasteful way. When looking at the other components of the economic scale, table A2 shows some weaknesses for the collective farms for the independence component. Indeed, individual farms have more financial autonomy. This can be explained by the fact that collective farms have greater possibilities to access to credit than individual farms. Therefore, they receive more financial support through loans which reduces their financial autonomy since they rely less on their own funding. For the viability and transferability components, we don't discuss the differences since they are small.

Figure 3: Star diagram of sustainability components



Source: authors' elaboration

3.2. Comparison of results with the literature

The increasing importance of sustainability is not a debate anymore. In the face of this, multiple studies have been undertaken around the world to perform sustainability-related analyzes for the agriculture sector (see in Biret et al., 2019; Baccar et al., 2016). Some of them compared the sustainability of different farm types and others compared different farm types under different farming systems. For instance, in SSA, particularly in Senegal, agricultural sustainability studies have mainly compared conventional and organic horticulture farms in the Niayes area of Senegal (Ba and Barbier, 2015; De Bon et al., 2019).

The two types of studies were generally oriented towards individual (family) farms. Therefore, the comparison of our results with theirs will only be possible for some results. Due to the fact that the second type of study compared conventional and organic farms, it is hardly comparable to our results because our sample is only composed of conventional agriculture farms. Concerning the first type of studies, we can compare our results on (i) the discriminating scales and components between farm types; (ii) the higher performance of individual farms in the economic scale.

Concerning the discriminating scales, our results show that the socio-territorial scale displayed more differences between farm types followed by the agroecological scale to a lesser extent. Biret et al. (2019) compared different types of family farms based on land use and also found that those two scales were different in the three groups. Indeed, their results show that the agroecological scale was the most discriminating scale followed by the socio-territorial scale to a lesser extent. They also found that the economic scale was not discriminating (considering the statistical significance of the differences) when comparing their farm types.

Since the difference between the two farm types was not statistically significant for the economic scale and that the literature on farm sustainability assessment mainly concentrated on family/individual farms, our comparison for the economic scale will focus on individual farms. Our results on the score of individual farms that performed better in that scale can be compared to Biret et al. (2019) who also found a greater proportion of farms sustainable in the economic scale. We would be surprised if individual farms performed better on the other scales. Indeed, it is understandable that in a low-income context, the most urgent needs are met first regardless of the environmental impact of the practices. This relates to Baccar et al. (2016) who argue that "according to farmers' perception of sustainability, environmental issues do not represent a top priority for them, whatever their production system is. This does not mean that they are not aware of local environmental issues".

However, this performance of individual farms on the economic scale contrasts with the results of Salas-Reyes et al. (2015) and Fadul-Pacheco et al. (2013) who found that the economic scale displayed the lowest scores among the three scales.

At the component level, Biret et al. (2019) found that "only the diversity of agricultural production and the efficiency components showed any notable difference among the different types of farms". Although we did not have the same farm types, those two components were among the ones we found to show differences between farm types.

3.3. The importance of integrating an institutional/organizational scale to better assess collective farms sustainability

This study has also been the occasion to test the IDEA relevance on collectively organized farms that have not yet been investigated in the literature on agricultural sustainability. Our adaptation of the IDEA method to the two types of farms has shown that the IDEA method can be adapted and applied to specialized farms and particularly to individual horticulture farms of Senegal. Concerning collective farms, we have found that the three scales of IDEA are all relevant to analyze their sustainability. However, in collectively organized farms, there is an institutional and organizational dimension that plays a huge role in their sustainability (Meinzen-Dick et al, 1994; IWMI, 2018). A new IDEA version has been proposed in Zahm et al. (2019), however, it still does not include that dimension. The role of such a dimension in collective farms sustainability has been showed not only by our field experience but can also be easily demonstrated using the theory of collective action.

Indeed "in principle WUAs are legally constituted, farmer-run associations with an elected managerial board that supervises irrigation water management at the collective farm level" (Pia, 2015). This type of farm can be conceptualized as common pool resource institutions and analyzed by considering the theoretical framework of collective action in the New Institutional Economics (NIE), specifically Ostrom's (1990) work on governing the commons; the latter representing here the irrigation system developed for the farm. In Senegal, such associations offer other services to their members related to input acquisition, group commercialization, facilitation of credit access, etc. Therefore, they can have other committees for each service, in addition to the committee managing the irrigation system. When any of these committees fail, that can impact the sustainability of the farm. This is, for instance, the case when the irrigation system has dysfunction and that there is no cost recovery mechanism that allows repairing it; thus highlighting the importance of that institutional and organizational dimension.

Based on this, we believe that there is a need to include another scale in the IDEA grid, at least for adaptations to collective farms that would be composed of institutional and organizational sustainability indicators. That scale would include specific indicators that would consider organizational matters that can hinder or favor collective farms' sustainability that heavily relies on their internal rules and organization. The new dimension can be developed using Ostrom's work and the large body of literature on WUAs (Meinzen-Dick et al, 1994; IWMI, 2018).

This proposition also holds for the alternative methods analyzing farms' sustainability such as the RISE method.

In addition to that, the institutional scale can include (for both farm types) broader institutional indicators that take into account the local political and research context that are not internal to farms. Such indicators would include (i) the ability of research to provide innovations that are adapted to farmers' needs and ensure farming sustainability, (ii) farmers' willingness to adopt sustainable friendly innovations, (iii) the existence of policies encouraging and enabling sustainability of irrigation systems. The importance of such factors is illustrated in Baccar et al. (2016) who reported that farmers "think that the sociopolitical context, in which they operate, encourages the adoption of intensive practices. The public bodies aim to increase production, so they promote directly (by irrigation subsidy) or indirectly (by importing and manufacturing of fertilizers and crop protection products) the intensive practices". This highlights how the socio-political context can encourage or discourage sustainable practices.

Conclusion

This study adapted the IDEA method to two types of horticulture farms in rural Senegal that differ in their management strategy (collective and individual).

Our results show that, with the current version of the adapted IDEA, horticulture in the Groundnut Basin of Senegal appears not sustainable in holistic terms as on average, no farm type reaches the IDEA sustainability level established at the threshold of 60 points for each scale.

For individual farms, their average sustainability score is lowest for the socio-territorial scale followed by the agroecological scale while the economic scale displays the highest scores. This is mainly explained by the income-maximizing behavior of farmers in a context of poverty. Although this behavior can lead to short to medium-term economic gains, it might lead to long term negative effects on the environment and natural resources such as soil and water which in turn would lead to lower economic returns. This highlights that sustainability-driven agriculture should be encouraged through policies, projects and programs that sensitize farms about sustainability issues. Fostering agroecological transition, which is still timid in Senegal, could be an avenue to ensure sustainable farm practices.

Concerning collectively organized farms, results show that contrary to individual farms, on average, their highest sustainability score is noted for the agroecological scale followed by the socio-territorial and economic scales that display the same score. This greater sustainability of collective farms on the agroecological scale can be explained by the nature of collective farms that are mainly impulsed or supported by donors and governments through projects and programs. This allows them to benefit from agricultural support services, have access to new technologies including crop varieties. This suggests that to enhance individual farms sustainability in those scales, access to agricultural support services should be strengthened for individual farms.

Comparing the two farm types, on average collective farms have higher scores, compared to individual farms, on the different scales except the economic scale. Results also show that on average, collectively organized farms appear more sustainable than individual farms with their limiting scales (the socio-territorial and economic scales) having higher scores than individual farms limiting scale (the socio-territorial scale). Also, considering individual scores of the entire sample in the three scales, the percentage of collective farms sustainable is higher.

Concerning methodological features, the adapted IDEA can be used as a monitoring and evaluation tool to better guide development interventions for the improvement and strengthening of the horticultural sector in the Groundnut Basin and other areas of Senegal. However, the results show that the IDEA method needs further improvements to better fit the assessment of collective farms' sustainability. Indeed, by considering the theoretical framework of collective action in the New Institutional Economics, specifically Ostrom's (1990) work on governing the commons and the broad literature on Water User Associations, collective farms can be conceptualized as Common Property Institutions or Common Pool Resources and display characteristics of Water User Associations.

Therefore, organizational/institutional aspects are important to analyze their sustainability as suggested by Ostrom's eight principles for the governance of common pool resources. Based on this, we believe that there is a need to include another scale in the IDEA grid, at least for adaptations in the Sub-Saharan Africa context that would be composed of institutional and organizational sustainability indicators. For collective farms, the development of such a scale can be based on Ostrom's work and the literature on Water User Associations.

In addition to that, there are context-specific attributes related to the socio-political environment that could be favorable or unfavorable to farm sustainability. Therefore, an institutional/organizational scale can also include (for both farm types) broader institutional indicators that take into account the local socio-political and research context.

In conclusion, although further improvements are needed to adapt IDEA to the Sub-Saharan African context and collectively organized farms, IDEA is easily applied to different contexts and agricultural sectors. Specifically, the analysis should be extended to assess sustainability by considering the institutional and socio-political environment enabling or hindering sustainability. Nevertheless, our adaptation of the IDEA method proves to be a useful tool both to assess farm sustainability and to guide policymakers and development interventions.

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Appendices

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Table A4: Adapted IDEA grid

Scales	Components	Indicators	Criteria		Maximum Scores	
Agroecological scale	Diversity	A1-Diversity of annual and temporary crops	No. of vegetable crops	14	24	33
			No. of vegetable varieties	3		
			Dynamics of the number of cultivated vegetable crop	3		
			No. of other crops (cereal and legume)	4		
		A2-Diversity of perennial crops	No. of perennial crops (arboreal and agroforestry)	12	12	
		A4-Valorisation and conservation of genetic heritage	No. of local vegetable crop (okra, african eggplant, bissap)	12	12	
	Organization of space	A5-Cropping patterns	Presence and type of crop rotation	4	11	33
			Presence and type of crop association	4		
			% of land left to fallow	3		
			Presence of monocropping (last 2 years)	-3		
		A6-Dimension of fields	% of used land on total land	4	8	
			% of land of two main crops on used land	2		
			Average plot size by worker	2		
		A7-Organic matter Management of organic matter	Quantity of organic fertilizer by hectare and by crop	7	14	
			Quantity of compost by hectare and by crop	7		
		A8-Ecological regulation zone	Farm position respect to the village	2	9	
			Presence of natural elements (hedge; groves; paths)	7		
	Farming practices	A12-Fertilization	Quantity of chemical fertilizer (nitrogen) by hectare and by crop	8	9	34
			Use of wild shrubs for fertilization (ngere, ratt)	1		
		A13-Liquid organic effluents	Presence of fertigation	3	3	
		A14-Pesticides	Use of natural products (neem, pyrethrum)	2	14	
			Use of integrated or biological control practices (against weeds and parasites)	2		
			Typology of pesticides (herbicides, fungicides, insecticides, nematodes, other)	8		

			Presence of a register for pesticide use program and/or treatment practices	2		
		A16-Soil resource protection	Anti-erosion and soil restoration practices (zai, stony ropes, bunds)	2	5	
			Mulching practice	1		
			Management of ravaging and animal attacks	1		
			No tillage practice	2		
		A17-Water resource management	Irrigation system (drip, furrow, sprinkler, hand watering)	3	4	
			Source of water supply (open well, drilling, volumetric meter)	1		
		A18-Energy dependence	Quantity of fuel consumed (EFH l/ha)	8	11	
			Use of solar energy	3		
Socio-territorial scale	Quality of the products and territory	B1-Quality approach	Use of product storage techniques	2	7	33
			Use of seed conservation techniques	2		
			Presence of organic agriculture	1		
			Presence of product transformation	2		
		B2-Enhancement of buildings and landscape heritage	Presence and maintenance of buildings	3	3	
		B3-Inorganic waste management	Non-organic waste recycles	3	5	
			Non-organic waste disposal	2		
			Non-organic waste burning and burial	0		
		B4-Space accessibility	Presence of fencing devices to protect plot from animals and no-allowed people	2	4	
			Presence of paths for product transport	2		
		B5-Social involvement	% of female workers on total worker	3	14	
			Agricultural association membership	3		
			Confederation agricultural association membership	3		

		% of responsibility position held by female workers	3		
		Presence of ROSCA (rotating savings and credit association)	2		
Employment and services	B6-Short trade promotion	% of local trade on total trade	2	7	33
		Presence of short trade (no more than one mediator)	1		
		Presence of packaging materials (gunny bags and box)	2		
		Presence of transport equipment (cart, motorcycle and vehicles)	2		
	B7-Promotion of local resources	% of owned seed on total seed	5	9	
		Use of crop residues (feed for animals)	4		
	B8-Services, multi-activities	Presence of school field	2	6	
		Training services for other farmers	2		
		Presence of agricultural membership fees	2		
	B9-Employment contribution	Use of local and external workers	6	6	
	B10-Collective work	Sharing of equipment and services within farm	1	4	
		Sharing of equipment and services between farms	1		
		Work exchange within farm	1		
		Work exchange between farms	1		
	B11-Probable farm sustainability	Self-estimation of farm survival (No. of years)	3	3	
Ethics and human development	B12-Contribution to world food balance	% of vegetable quantity sold in the village	3	8	34
		Presence of self-consumption	3		
		Presence of reduced price for the villager	2		
		% of vegetables sold for export	0		
	B14-Training	Participation to training courses	4	10	
		Participation to extension services	3		
		Presence of internship	3		
	B15-Labour intensity	% of overburdened cropping operations on total cropping operations	6	6	
	B16-Quality of life	Educational level of farmers	3	8	
		Distance from health centre	1		
		Distance from primary school	1		
		Needs covered by farm income (child enrolment, family health, food needs)	3		

		B17-Isolation	Distance from main cities Distance from main roads Distance from sell markets	1 1 1	3	
		B18-Reception, hygiene and safety	Use of protective equipment during storage, preparation and distribution of pesticides	3	3	
Economic scale	Economic viability	C1-Available income per worker compared with the national legal minimum wage	Profit= [Revenue- (direct cost + indirect cost + other cost)]/No. of non-paid worker Profit per capita=Profit/national legal minimum wage	20	20	30
		C2-Economic specialization rate	Share of product sold to main customer Herfindahl-Hirschman index (HHI) for vegetables revenue	4 8	10	
	Independence	C3-Financial autonomy	Level of indebtedness: Debt ratio=expected credit to pay / profit Ability to cover production cost (direct cost): Cost ratio=profit/direct cost	11 11	22	25
		C4-Reliance on subsidies	Receiving of aid Input purchase by credit	1 2	3	
	Transferability	C5-Economic transferability	Ability to generate income: Income=profit/total cost Ability to recreate equipment: Equipment ratio= [maintenance case- (total equipment value-amortisation)]/maintenance case Ability to refund total debt: Debt ratio= profit/total credit Ability of management and planning (presence of administrative and accounting books; of equipment depreciation plan; of repair fund plan)	6 6 6 3	20	20
	Efficiency	C6-Process efficiency	Data Envelopment Analysis (DEA): $e_o = \max \sum_r \mu_r y_{ro} - \mu_o$ $s.t. \sum_i \varphi_i x_{io} = 1$ $\sum_i \mu_r y_{rj} - \mu_o - \sum_i \varphi_i x_{ij} \leq 0, \quad \forall j$ $\mu_r \geq \varepsilon, \quad \varphi_i \geq \varepsilon, \quad \forall i, r,$ $\mu_o \; unrestricted$ Where output is total revenue and inputs are land, capital value and labour	25	25	25

Source: authors' elaboration

Table A2: Strengths and weaknesses of the farms

Component	Strength	Weaknesses	Exceptions specific to collective farms
Diversity	• On average, the number of vegetable crops cultivated over the years remains stable or increases	• The number of vegetable crops and varieties cultivated is limited • Almost no presence of other crops such as cereals or legumes that play an important role in soil restoration • The number of perennial crops is limited for both farm types and there is hardly any practice of agroforestry • Very limited cultivation of local vegetables (gombo, african eggplant, bissap) which shows a low valorization of local heritage	The weakness related to the diversity of vegetable crops cultivated is not observed for collective farms
Organization of space	• There little practice of monocropping • Percent of the used land on total land	• Practice of crop rotation not very common and when it is so, the type of rotation is often not as recommended by research. • As for crop association, farms that practice it do not do it well • On average, the amount of land left to fallow is little to nothing • The main cultivated crops occupy much space, thus leaving fewer possibilities for crop diversification. This is more observed for individual farms • The average plot size per worker is either too small or too high • The quantity of organic fertilizer by hectare and by crop--no use or not enough quantity of OF used • The quantity of compost by hectare and by crop--no use or not enough quantity of compost used • Farm position respect to the village--on average farms are either to close to villages (<1km) or too far from villages (>1.5km) • Presence of natural elements (hedge; groves; paths)--little to no presence	
Farming practices	• The quantity of chemical fertilizer (nitrogen) by hectare and by crop • Mulching practice	• Use of wild shrubs for fertilization (ngere, ratt) • Presence of fertigation	

	• Management of ravaging and animal attacks • No tillage practice • Irrigation system (drip, furrow, sprinkler, hand watering) • The quantity of fuel consumed (EFH l/ha)	• Use of natural products (neem, pyrethrum) • Use of integrated or biological control practices (against weeds and parasites) • Typology of pesticides (herbicides, fungicides, insecticides, nematodes, other) • Presence of a register for pesticide use program and/or treatment practices • Anti-erosion and soil restoration practices (zai, stony ropes, bunds) • Source of water supply (open well, drilling, volumetric meter) Use of solar energy	
Quality of products and territory	• Presence of fencing devices to protect plot from animals and no-allowed people • Presence of paths for product transport • Agricultural association membership	• Use of product storage techniques • Use of seed conservation techniques • Presence of organic agriculture • Presence of product transformation (thus showing a low effort to increase product value. Also, transformation allows to differ sales when prices at harvest are too low…) • Presence and maintenance of buildings • Processing of non-organic waste • % of female workers on total worker • Agricultural association membership • % of responsibility position held by female workers • Presence of ROSCA (rotating savings and credit association)	**Strengths for collective farms** : • % of female workers on total worker • % of responsibility position held by female workers • Agricultural association membership
Employment and sevices	• Presence of short trade (no more than one mediator) • Presence of packaging materials (gunny bags and box) • Presence of transport equipment (cart, motorcycle, and vehicles) • Use of crop residues (feed for animals) • Sharing of equipment and services within the farm • Sharing of equipment and services between farms • Work exchange within the farm • Work exchange between farms • Self-estimation of farm survival (No. of years)	• % of local trade on total trade • % of owned seed on total seed • Presence of school field • Training services for other farmers • Presence of agricultural membership fees • Use of local and external workers	**Strength for collective farms** • % of local trade on total trade • Use of local and external workers **Weakness for collective arms** • Sharing of equipment and services between farms

Ethics and human development	• Presence of self-consumption • % of vegetables sold for export • Education level of farmers • Distance from primary school • Isolation	• % of vegetable quantity sold in the village • Presence of reduced price for the villager • Participation in training courses • Participation in extension services • Presence of internship • % of overburdened cropping operations on total cropping operations • Distance from the health center • Needs covered by farm income (child enrolment, family health, food needs) • Use of protective equipment during storage, preparation and distribution of pesticides	**Strength for collective farms** • % of vegetable quantity sold in the village
Viability	• Share of product sold to main customer	• Available income per worker compared with the national legal minimum wage • Herfindahl-Hirschman index (HHI) for vegetable crops revenue	• Herfindahl-Hirschman index (HHI) for vegetable crops revenue strength for collective farms
Independence	• Level of indebtedness: Debt ratio=expected credit to pay / profit • Ability to cover production cost (direct cost): Cost ratio=profit/direct cost • Receiving of aid • Input purchase by credit		• Ability to cover production cost (direct cost): Cost ratio=profit/direct cost: weakness for collective
Transferability	• Ability to generate income: Income=profit/total cost • Ability to refund total debt: Debt ratio= profit/total credit	• Ability to recreate equipment: Equipment ratio= [maintenance case-(total equipment value-amortisation)]/maintenance case • Ability of management and planning (presence of administrative and accounting books; of equipment depreciation plan; of repair fund plan)	• Ability to generate income: Income=profit/total cost: weakness for collective farms
Efficiency	• Process efficiency		• Process efficiency: weakness for collective farms

Source: authors' elaboration