Title

Multidimensional benefits of smallholder farmers' good practices

Subtitle

A case study in Kampong Thom, Cambodia

Authors

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Abstract

Agriculture is the backbone of the Cambodian economy, accounting for almost 90% of the national gross domestic product and employing around 85% of the workforce. Agricultural practices remain mostly traditional and vulnerable with low levels of mechanization, inputs and diversification. In the central province of Kampong Thom, a non-governmental organization, Minority Organization for Development of Economy, spends time among vulnerable farmers to teach and spread organic agricultural good practices to take them on the road to sustainability. A survey was conducted in the region to assess the benefits of such an approach five years after the beginning of the project (2011). 80 farmers equally distributed in two groups (target and control) were interviewed to assess the agricultural sustainability of the local farming system and differences between the two groups. This survey revealed significant differences between the two groups distributed in the four pillars of sustainability. In particular, using sustainable farming practices increased the net incomes, the food production diversity and number of risk mitigation planned or already taken actions. The global index resulting from the combination of all core indicators revealed increase of global sustainability index for project beneficiaries practicing sustainable agriculture practices as well. However the global level of sustainability remains low to very low in the region (0.3 on a normalized scale comprised between 0 and 1). This is at least partly due to the lack of agricultural knowledge of the local farmers and traditional farming practices still widespread in the province.

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1. Introduction

Agriculture is the traditional mainstay of the Cambodian economy, accounting for almost 90% of the Gross Domestic Product (GDP) and employing around 85% of the work force with an average agricultural land holding of 1.6 hectare per family (National Institute of Statistics 2014). Agricultural practices remain mostly traditional even if intensification appears chaotically in some regions. Most of the smallholder farmers are trying to meet first their consumption needs and are cultivating almost exclusively rice using traditional farming practices. This situation leads to low average yields (about 3 tons of rice per hectare in average) and makes farmers extremely vulnerable economically (Royal Government of Cambodia and Ministry of Planning 2013). Their production is also highly dependent on the annual weather conditions and many of them already feel the consequences of climate change (Ros Bansok, Nang Phirun, and Chhim Chhun 2011).

In this context, several local, regional, national or international stakeholders help smallholder farmers to increase their agricultural knowledge and to improve their farming practices towards sustainability (Royal Government of Cambodia and Ministry of Planning 2013). In the central province of Kampong Thom, a non-governmental organization called Minority Organization for Development of Economy (MODE) spreads organic agricultural good practices to local vulnerable farmers encouraging them to develop environmentally friendly crop production systems and to diversify their incomes. MODE is working with vulnerable farmers (i.e., farmers with low yields and incomes or farmers whose family members include people with disability or people affected by non-communicable chronic diseases) in 8 communes of the Cambodian central province providing them seven-day training on sustainable agriculture, field demonstrations and agricultural kits to modify their system of food production and processing and to increase their incomes. The trainings and the kits focus on different topics related to food diversification and organic farming system: goods practices in chicken raising, system of rice sustainable intensification, method for developing an aquaculture production, methodology for composting and cultivating vegetables in the house garden, lessons for edible fruit tree planting and food processing. Trainings are then followed by regular formal and informal follow-up by MODE field facilitation team during several months. At least three formal follow-ups are devoted to each single farmer in the very first weeks and months following the first training. Exemplar farmers are also selected during the project and help further spreading the diffusion of good organic practices. Meetings are also organized between participants to reinforce their knowledge and collaboration.

Five years after the launch of the sustainable agriculture project (started in 2011) and after almost a thousand beneficiaries, it was time for the organization and its supports to assess the benefits of learning and applying sustainable agricultural practices for smallholder farmers in the impacted communes. Among the supports of the organization, Louvain Coopération au Développement plays a major financial and technical role. To do so, a framework to assess the agricultural vulnerability or sustainability and compare project beneficiaries applying sustainable agricultural practices from other vulnerable farmers was necessary.

Though sustainable development is a complex, multiply defined notion whose most quoted definition was given by the Brundlandt commission: “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987). Agriculture because of its particular primary goal of food production and its narrow link with the environment, plays a key-role in the transformation of our lifestyle towards sustainability (FAO 2014). Sustainable agriculture can be defined as “the management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable” (FAO 2014). Sustainability in agriculture is usually itemized by the combination of four generally agreed goals: the right quality of life for farmer, workers and the society as a whole; the economic viability of agriculture; the environmental respect of the resources and last but not least the food and by-products (such as biofuel) production (National Research Council and National Research Council 2010). Nevertheless it encompasses so many distinct aspects and remains such a complex concept that there is no perfect common viewpoint about its precise definition, scale and components (Hayati, Ranjbar, and Karami 2010). In last decades, hundreds of methods evaluating either particular pillars of sustainability or the sustainability as a whole have been developed at different scales and for various objectives (see among many others: Paracchini et al. 2015; Bockstaller et al. 2009; Bechini and Castoldi 2009). Because of the indicator and method diversity, several authors examined issues related to specific choices trying to justify the use of a particular method in a specific context or to provide a general approach such as the MESMIS operative structure (López-Ridaura, Masera, and Astier 2002). To structure these indicators, several typologies have been presented in the literature based on the causality between the farming practices and the consequent impacts (Bockstaller et al. 2009). Three main categories of indicators exist: means-based indicators

depending on farmer production practices, effect-based indicators evaluated through direct measurements of the effects these practices have on its surrounding world (Van Der Werf and Petit 2002; van der Werf, Kanyarushoki, and Corson 2009) and target-based indicators focusing on whether the operation has plans or policies with clear targets with ratings based on steps towards implementing them (FAO 2013). They aim at highlighting the link between causes and impacts influenced by external factors, such as soil properties or climate (Lebacq, Baret, and Stilmant 2013). The first class of indicator focuses on the best practices and is process-oriented assuming that good practices lead systematically to desired results (FAO 2013). The second category are outcome-oriented with a clear link between the objectives and the measured indicators leaving the farmers free to choose the best means to reach the sustainable goals according to their specific context. Finally the target-based indicators are looking for a systematic vision and policy for the future of the farm/agricultural company. Each type of indicators suffers from major drawbacks such as their substantial margin error (means-based), their measurement cost (effect-based) or their remoteness with the present (target-based) (Van Der Werf and Petit 2002). The indicators can also be compiled into single indexes on the basis of an underlying model allowing researchers to measure multidimensional concepts that cannot be captured by single indicators (OECD 2008). Sustainability in agriculture is particularly relevant to be assessed by composite indicators because of its intricacy and complexity.

In order to clarify the situation, the Food and Agriculture Organization (FAO) created a holistic and global framework for the assessment of sustainability along food and agriculture value chains establishing an international reference for assessing trade-offs and synergies between all dimensions of sustainability (FAO 2013): the Sustainability Assessment of Food and Agriculture systems (SAFA). As many of the strategies to measure the agricultural sustainability, this method is based on individual assessments of certain key-aspects of the food production and processing (Gayatri 2016). Indicators-based sustainability assessment tools are generally structured following three or four hierarchical levels (de Olde et al. 2016). In SAFA, the indicators (lowest level) aim reflecting the different components of four pillars (highest level) defining the sustainability: good governance, environmental integrity, social well-being and economic resilience (FAO 2013). The SAFA method declines themes for all pillars and provides core indicators for each single subtheme which is a part of the considered theme. SAFA is applicable to any part of the world and is relevant for each component of the value chain. We decided to apply the SAFA framework to assess the agricultural

sustainability of the Cambodian province of Kampong Thom because of the exhaustiveness, robustness and flexibility of the method.

2. Material and methods

In this section, we describe the methodology we designed for assessing the effects of the project promoting the sustainable agriculture in Kampong Thom, Cambodia. We used the SAFA framework developed by the FAO (FAO 2013). The study was based on structured qualitative and quantitative interviews carried out with smallholder beneficiaries from the project (target) and other vulnerable farmers (control). All people interviewed were located in the central province of Kampong Thom, where MODE is active. We first briefly explain the overall methodology and the step of themes and subthemes selection in the frame of the project (subsection 2.1). We also give information about the translation of indicators into questions for farmers during interview (2.2), sampling (2.3) and our database and the related statistical analysis (2.5).

2.1. Overall methodology

The SAFA method consists in 21 themes and 56 subthemes in narrow relation with all the aspects of sustainable agriculture gathered in four pillars (good governance, environmental integrity, social well-being and economic resilience). All themes and subthemes and their distribution in the respective pillar are summarized in Appendix A. In this table, the cell font of subthemes is colored according to their relevance to the local context of the current farming system in Kampong Thom: red if the subtheme can be omitted for smallholder farmers or if it was impossible to assess based on sole interviews, black if the subtheme makes sense for the particular situation and was kept until the end of the analysis. When no subtheme was retained for a specific theme, then the complete theme was omitted and it is indicated by a red font for the theme cell. The preliminary selection was based on FAO recommendations (a complete description of the procedure can be found in the SAFA guidelines (FAO 2013)) and on discussion with local experts from NGOs (MODE & LC) and University (Royal University of Agriculture - RUA). In table A.1, the fourth column (“project”) indicates if the theme/sub-theme is directly linked to the sustainable agriculture development project of MODE in Cambodia (+), if it is considered as absent from the current project objectives list (-) or when it is unconsidered in the current state of the project but could be included in future plans of applications (o). Comparing the universal themes and the specific sub-themes with the local context and the objectives of the project, 18 themes (out of 21), 35 (out of 56) subthemes and 53 (out of 105) core indicators were retained. Let us note that most of the omitted indicators were part of the governance pillar. 30 core indicators were conserved in the environmental pillar, 12 in the economic pillar, 8 in the social pillar and 3 in the good governance pillar and

were evaluated through questionnaires whose design is explained in the next subsection. Such a strategy (SAFA adaptation through questionnaires) was successfully applied in different contexts in other locations of the world, see for example (Gayatri 2016).

2.2. Questionnaire formulation

Based on this selection, a questionnaire was developed to reveal the current farming practices of the interviewees, their economic status, the perception of the risks threatening their enterprise (as listed by local actors, i.e. field facilitators, local NGO members and university professors, and the SAFA recommendation) and their perspectives in a changing world. The questionnaire was optimized to maximize the number of measured indicators under constraints of time/length of the interview and difficulty of understanding. The questionnaire was iteratively improved and corrected by on-field tests on volunteer farmers.

2.3. Sampling

We selected a panel of 80 farmers equally divided in two groups: a target group, made of MODE project beneficiaries (B) and a control group, constituted by vulnerable farmers non-beneficiary (NB) of the project. The 2 to 3 hours long in-depth interviews took then place in 8 villages selected among 5 representative communes. The villages were chosen because they were the first ones where project beneficiaries were selected, trained and followed up and consequently the most susceptible to present significant differences in terms of farming practices or results. An equal number of interviewees were selected in each single village among the two groups and the corresponding numbers were chosen according to the total number of project beneficiary farmers in each village with respect to the global number of project beneficiaries.

The 8 villages in which we selected our panel are highlighted in red dots while other villages where B farmers can be found are black-dotted in Figure 1. In this figure, the location of the central province of Kampong Thom in Cambodia (bold dark solid line in the frame) and the five first communes explored by MODE in their project (red solid lines in both the frame and the principal figure) are shown as well.

Table 1 summarizes the name of the height sampled villages and the corresponding number of interviewees by village for both beneficiaries (B) and other vulnerable farmers (NB), that were systematically identical.

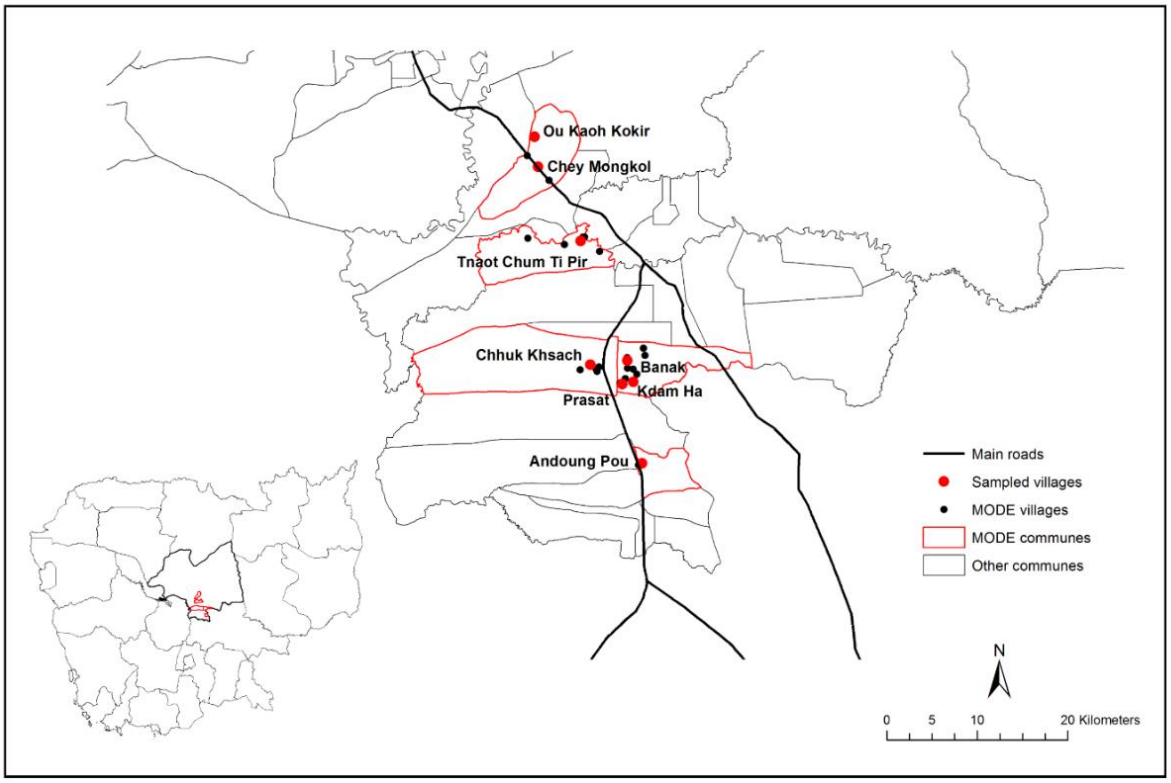

Figure 1: Location of the initial zone of influence of MODE (red lines are sampled communes) and the sampled villages (red dots). In this map, the other MODE villages (in these communes) are located by dark point and the global situation of the Kampong Thom province in Cambodia is indicated in the lower left corner.

We imposed for each beneficiary interviewee to have followed MODE trainings at least one year before the interview took place.

Table 1: Sampled villages and number of interviewees for beneficiaries (B) and other vulnerable farmers (NB)

Village	B	N
Andoung Pou	10	10
Ou Kaoh kohir	6	6
Banak	3	3
Chey Mongkol	7	7
Chhuk khsach	3	3
Kdam ha	4	4
Prasat	5	5
Thnaot Chum Ti Pir	2	2

B = Beneficiaries, NB = Non-Beneficiaries

One of the main issues of the methodology was to select non-beneficiary farmers at a level of vulnerability similar to the one of farmers selected for benefiting the project: a bias could be introduced by systematically interviewing NB farmers at higher vulnerability level. A preliminary survey allowed the interviewers selecting non-beneficiary farmers on the basis of

their main job, income sources and land size. If the farmers responded to similar criteria to benefit from the project, then they were included in the analysis as NB.

These interviews were conducted in Khmer by the local staff of the MODE organization and students from the Royal University of Agriculture (RUA) of Phnom Penh during the month of October 2016.

2.4. Database and Statistical analysis

Responses to the interviews were collected, scanned, translated in English and encoded in a common database which is available upon request. Analysis of variance was achieved using the groups (target *vs* control) as the explanatory variable. We used SAFA methodology to calculate normalized composite indicators at subtheme, theme and pillar and global levels. All statistical tests were performed using the statistical toolbox of Matlab.

3. Results

In Table 2, we summarized some of the raw outcomes of the questionnaires when sorting the responses according to the group belonging. For each variable (presented as a row), mean, maximal and minimal values are given as well as the p-value of the variance analysis and its significance. Let us note that through our complete work, we always considered two levels of significance for mean comparison: p-value lower than 0.05 (*) and lower than 0.01 (***). No significant difference could be observed between the two groups (p-value = 0.73) in terms of farm size (first row of Table 2). This result reinforced the idea that both groups were similar in terms of vulnerability. The farm size is indeed highly determinant in the Cambodian countryside for the standard of living. The two groups can thus be confidently compared. No significant differences could neither be observed in terms of family structure or access to natural resources (such as water) or facilities (such as distance to main roads) between the two groups (data not shown).

However, several aspects appeared different between beneficiaries and other vulnerable farmers. First as shown in the second row of the same table, the total number of distinct products is significantly larger for the project beneficiaries. This suggests an increased diversity of food production thanks to the adoption of the good agricultural practices lessons and the provision of agricultural kits (p-value = 10^{-5}). This difference mainly comes from an increased number of produced vegetables and planting trees and a more diverse animal husbandry. The p-values for the two latter tests reach 2.10^{-6} and 10^{-3}, respectively.

Similarly, the net income of the project receivers is significantly higher than similar farmers (p-value = 0.0485). This is a direct consequence of the previous point: a broader food production diversity increases the income sources since farming is the main working activity of the interviewees. In addition, the new products (such as fruits or animals) usually can usually be sold at higher prices.

The project-recipient group is also much more aware of risks that may threaten their farm. The risk list was established by local experts and local field facilitators (from MODE) based on their experience and systematically presented to each interviewee. On average, the beneficiary farmers recognized 9.55 risks identified by local partners against less than 7 for the NB group (p-value = 0.0429). Among these risks, the main differences concerned the problem of soil and water quality, the low availability of water resources, the climate changes and the lack of agricultural knowledge. Interestingly these risks are often discussed during training as problematic introduction.

Finally, significant differences could also be found in the number of relevant risk mitigation actions already taken or planned in the near future (p-value = 0.006) with beneficiary farmers having already taken more mitigation measures than the NB group. For each single recognized risk, interviewees had to explain how they are or would be fighting in the future it to avoid negative consequences for their farm. Among their answers, we only selected relevant actions based on FAO recommendations or general literature.

Table 2: summary of some of the principal outcomes of the interviews. Mean, minimal and maximal values for different aspects of the farm are given for both beneficiaries and non-beneficiaries and analysis of variance is given as well as the potential significance

	B			NB			p-value
	Mean	Min	Max	Mean	Min	Max	
Farm size [ha]	1.4	0.01	7.08	1.51	0.04	4.56	0.73
Number of products [-]	8.07	3	14	5.44	2	11	10^{-5***}
Income [$/month]	119	0	1066.7	54.9	0	503	0.0485*
Number of detected risks [-]	9.55	1	20	6.9	0	12	0.043*
Number of taken and planned risk mitigation measures [-]	8.17	2	18	7.2	0	20	0.006***

*significant at P = 0.05 and *** significant at P = 0.01

B = Beneficiaries, NB = Non-Beneficiaries

These results along with responses to other questions during the interviews could then be used for calculating the core indicators selected among the SAFA list. The latter could then be collected into composite indicators to assess the different hierarchical levels of sustainability defined in the FAO methodology from subtheme to pillar levels. The farmer performance for each single sustainability theme is plotted in Figure 2 as a function of the status of the farmer: the dotted black line represents the beneficiaries from the project, the dashed line the other vulnerable farmers. For each theme, several core indicators were compiled to obtain a sustainability index comprised between 0 (less sustainable) and 1 (more sustainable). The font colour represents to which pillar each single theme belongs: green for the environmental pillar, red for the social component, yellow for the economic resilience and blue for the good governance. The analysis revealed that 12 core indicators significantly differ between the two groups: for all of them, the project beneficiaries performed better than the other vulnerable farmers. As a consequence, when gathering the information to a higher hierarchical level, height subthemes and six themes were shown to be statistically different. The corresponding themes and subthemes are indicated in Figure 2 and Table A.1, respectively, by the same notation: * when the p-value generated by variance analysis is lower than 0.05, *** when the p-value is lower than 0.01. Out of these height subthemes, six were expected to have

beneficiated from the project and two exhibited unexpected differences (see Table A.1) and will be discussed in the next section of this manuscript. In Appendix B (Table B.1), we give an exhaustive list of on-field measured core indicators, their mean values for the two groups (B = target, NB = control) when significant differences were observed and the significance of the analysis of variance for these indicators. As stressed above, 12 core indicators were significantly different and for all of them, the target group performed better (indicator value closer to one). They were: greenhouse gas mitigation practices, water conservation practices, biodiversity connectivity, diversity of production, waste reduction practices, free prior and informed consent, sustainability management plan, risk management, long-term profitability, right of fair access to land and means of production, public health and food sovereignty. They were distributed as well in the four pillars of sustainability as following: five in the environmental integrity pillar, three in the social well-being pillar, two in the economic resilience pillar and two in the good governance pillar.

In SAFA methodology, the performance of an indicator, subtheme, theme or pillar is classified in between five categories: from very low sustainable value (red) to very high sustainable value (dark green). Intermediate classes are orange, yellow and light green from low to high vulnerability. In SAFA, the indicators are normalized between 0 and 1 and the transition limits are 0.2, 0.4, 0.6 and 0.8. The overwhelming majority of the analysed themes were located in the second more vulnerable class indicating the low level of sustainability reached by the smallholder farming practices in the studied area. Interestingly, all four pillars were characterized by similar levels of sustainability indexes, indicating no specific delay in a particular sustainability domain. Remarkably, all the themes, even when no significant, show increases for beneficiaries as compared to other vulnerable farmers, with the notable exception of the labour right that includes employment relationships and child labour and whose mean value was relatively high as compared to other sustainability themes. But for the labour right indicator thus the difference was not statistically significant.

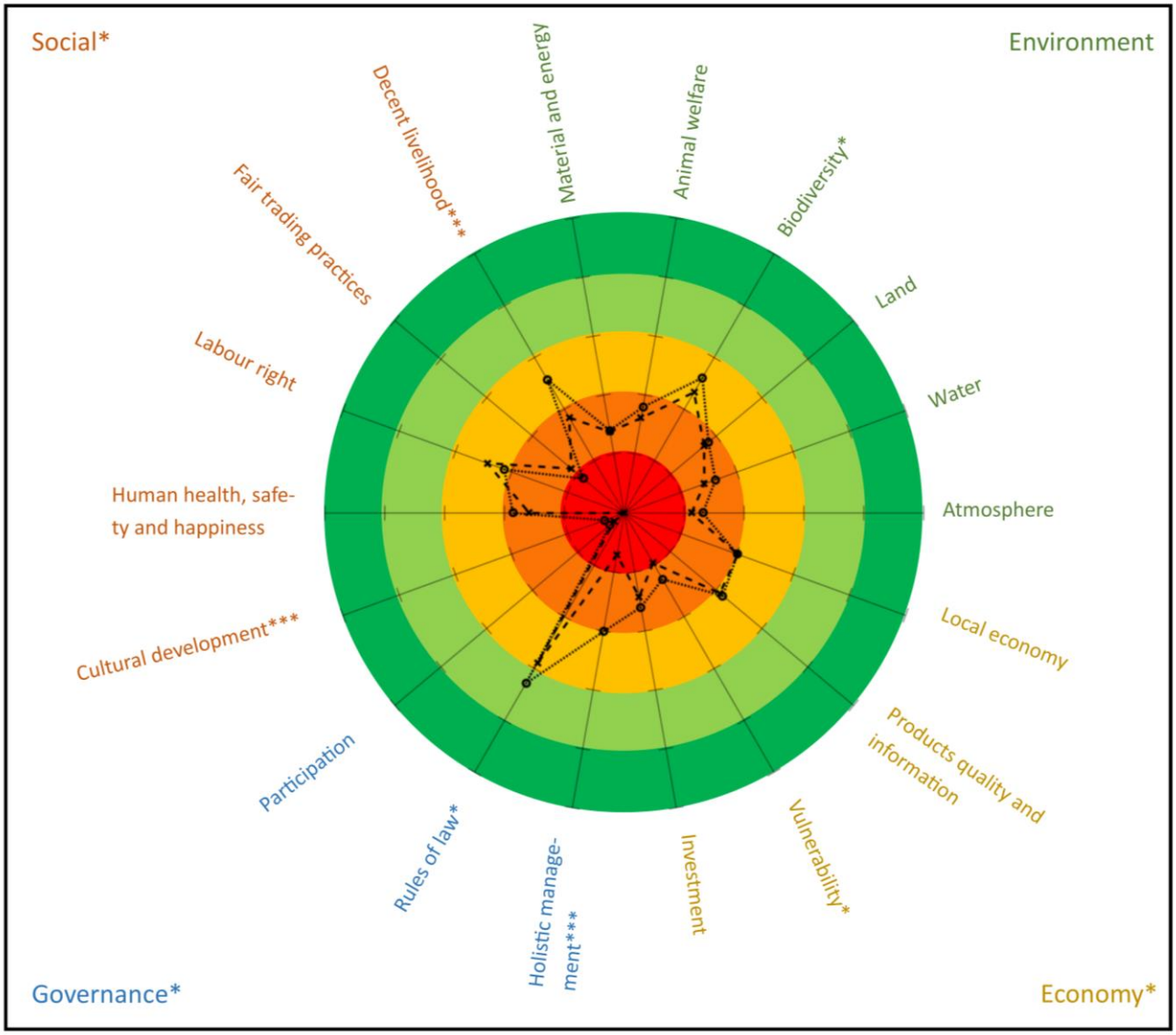

Figure 2: Distribution of the smallholder farmer performance in the different themes of vulnerability. The theme font colour indicates the pillar membership (blue = governance, green = environment, yellow = economy and red = social). All performances are comprised between 0 (inner red circle) and 1 (outer dark green circle). The dotted dark line represents the project beneficiaries (B) performance while the dashed line show the NB performance. When significant differences appear for a specific theme or pillar, it is indicated by a symbol: * means significant at p = 0.05, * means significant at p = 0.01.**

The six sustainability themes showing a significant increase for project beneficiaries are: biodiversity, decent livelihood, cultural development, vulnerability, rules of law and holistic management. They were found in the four pillars: environment (one out of the six themes exhibit significant differences), social (2/5), economic (1/4) and governance (2/3). This is the direct consequence of the diversity of core indicators that were shown significantly different, as explained just before. When the indicators were compiled at the pillar level, the three latter also showed significant differences between the two groups. The environmental integrity did not show up statistical differences between the target and the control groups. This could be explained by the fact that, even if the largest number of significant indicators belonged to this

pillar, the total number of measured indicators of this category was also particularly high, which somehow diluted the significance.

Finally when assembled at the highest level (the pillars mixed together into a single composite indicator), the mean value of the global sustainability index (also comprised between 0 and 1) presents a significant difference as well with a small increase for the project beneficiaries. This can be seen from Figure 3 where the bars stand for the two groups: B on the left and NB on the right. The colours represent the pillar components of the index with the same colour legend as the previous figure. Their contributions are substantially the same. The standard deviations of the global sustainability index for both groups are indicated as well.

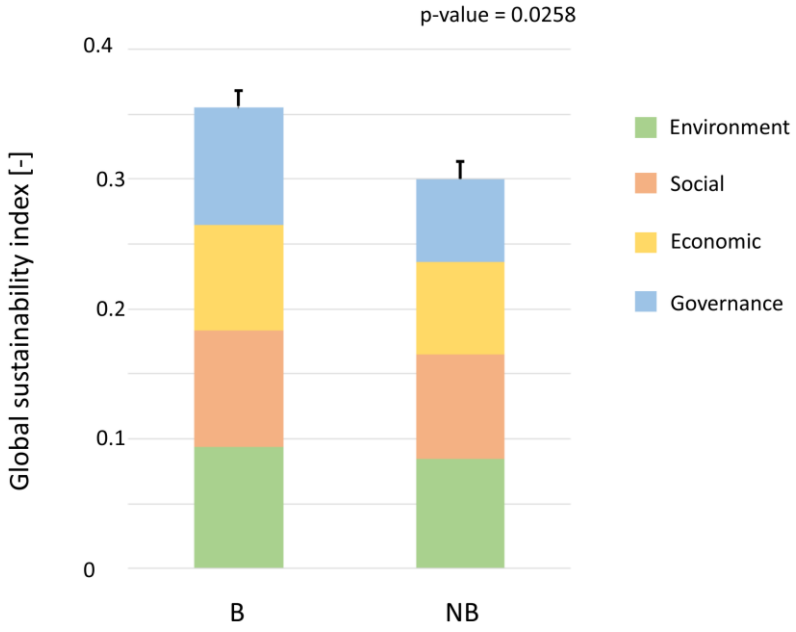

Figure 3: Global sustainability index and its components (the colours are kept the same with respect to the previous figure for the pillars) for both the smallholder beneficiaries (B) and the other vulnerable farmers (NB). The mean value is significantly different between the two groups.

Investigations also divulged that 97.5% of the interviewed beneficiaries were satisfied or very satisfied by the trainings delivered by MODE. An overwhelming majority of the interviewees never followed other agricultural trainings than those delivered by MODE, which illustrates their lack of agricultural knowledge.

4. Discussion

Recent publications illustrated the use of the SAFA framework to assess local agricultural sustainability (see for example Gayatri (2016) in Indonesia and Omare (2014) in Kenya). Our work follows in the footsteps of such kinds of studies. We suggested a novel adaptation of the FAO methodology using questionnaires and collaboration between researchers and development organization members in an original context (i.e. to assess differences between two groups whose one was taught sustainable agricultural practices). If SAFA is a recent tool, it presents many advantages and strengths such as its ease of use, its flexibility and its exhaustiveness. Despite all the criticisms that can be raised against composite and normalized indicators (see for a complete discussion (OECD 2008)), SAFA offers an existing and solid framework that can be easily adapted to any part of the value chain and to any region of the world.

Globally the sustainability of the smallholder farming practices in Kampong Thom was assessed low: the mean value of the global sustainability index for both groups was close to 0.3, almost equally distributed in the four pillar for both groups. This indicates that even though trainings could increase the agricultural sustainability, much remains to be done. The study also revealed the lack of agricultural knowledge of farmers of both groups. The number of irrelevant replies to mitigation action against risks (data not shown), for example, is a concrete illustration of the low level of qualification of farmers in the studied area and potentially also in the province. Much could be done to teach them agricultural basics of food production and processing. As stressed out in the results section, few other organizations seem to deliver farming practices training to farmers in this region, at least in the studied communes and villages. So much is still to do to fill the gap and to improve the agricultural sustainability, as a consequence.

Of course when investigating sustainability, many changes are time-consuming and effects could sometimes be seen only on long-term while our study took place five years after the project launch (2011). Some of the interviewed farmers followed MODE training only a year before the study. One of the key-message delivered by our analysis is that the smallholder farming practices is far from being sustainable at the different pillars of sustainability.

Some of the themes presenting statistical differences have been observed in other similar studies such as the biodiversity, thanks to the larger food production diversity (McLaughlin 1995) and the decent livelihood, due to increased incomes among others (Bechini and Castoldi 2009). On the other hand, some of the group-contrasted indicators are more

surprising such as the greenhouse gases reduction or the conflict resolution which were not directly targeted by MODE in their project. They appear then as a side effect of the development plan and activities of the project.

If our analysis suggested significant differences between the target group and the control one, we must highlight the fact that it does necessarily mean that MODE trainings and follow-ups of farmers are the only one cause of these sustainability improvements: means difference does not necessarily imply causality, see for a deeper discussion (Baker and others 2016). Since the trainings are only proposed to vulnerable farmers, they are always followed on voluntary basis. This suggests that the project beneficiaries could be intrinsically different from other vulnerable farmers: they could be for example more prone to learn new practices and to adapt their activities. The group effect would then reflect another aspect of the farmer behavior. The last statement could allow us to explain why untargeted subthemes revealed group-averaged differences. Interestingly however, most of the indicators, subthemes and themes emerging from the analysis were seen *a priori* as targeted by MODE trainings and follow-ups which reinforces our feeling that the trainings and follow-ups provided by the staff are at least one of the explanatory variable of the differences.

As explained in the introduction section of this manuscript, several categories of indicators exist, each of them presenting pros and cons. In this study, we mostly used target-based and practice-based indicators because they could be easily estimated using interviews only and did not require any scientific experience in various fields that MODE staff does not possess. The choice was made to provide the Cambodian organization with the capacity to assess quantitatively the benefits of their project by associating them to each single step of the study (from the choice of methodology to the statistical analysis). With such an approach unfortunately and because of this choice, we can unfortunately only assess whether the farmers intend to act in the future or whether they already took action to adapt their practices, and not whether positive results happened from their behavior change (de Olde et al. 2016). As we did not use many performance-based indicators, we did not measure much effective sustainability consequences of such practices or action plans. This probably constitutes the main drawback of our methodology. Another weakness of this study is the indicator selection that was necessary in the early beginning of our work. If some core indicators clearly did not make sense for smallholder farmers with a familial structure, others had to be set aside for various reasons. Some required concepts difficult to understand for low qualified workers and were consequently forgotten in our study, others were voluntarily withdrawn because of the local political context. The late statement partially explains why so few core indicators

belonged to the good governance pillar. Finally another weakness of our study was the small size of the sample. We indeed interviewed 80 farmers in 8 different villages and equally distributed in two groups. This number can look quite low but we need to keep in mind that each single interview lasted 2 to 3 hours, which can represent a long time for farmers. In addition, all other steps, including data translation, encoding and verification were also very time-consuming for MODE staff with frequent calls to farmers for clarifications and even sometimes returns to villages to complete questionnaires.

Our study thus allowed MODE organization to quantitatively assess the benefits and weaknesses of their current and past project. We developed a reproducible and collaborative method that was mainly used to efficiently target future application plans and to professionally communicate and share their outcomes to their supports and other organizations. Another side effect of our study was to give to the local organization MODE the keys to assess by themselves the strengths and weaknesses of their action using a scientific method. As the staff was involved in each single step of the procedure (methodological choice, indicator selection, questionnaire designing and writing, field, database building and statistical analyses), the whole methodology could be repeated in theory in the future to assess parts or projects as a whole. Actually, since sustainable agriculture is only one of their action field, the organization staff had already the intention to transpose the whole study to their main other predilection domain: public health.

5. Conclusion

A methodology to adapt the SAFA agricultural sustainability assessing tool was successfully applied to local farmers of the rural province of Kampong Thom, Cambodia. This method consisted in selecting relevant indicators of the exhaustive list made by the FAO, transformed them into a questionnaire submitted in October 2016 to two groups (with 40 interviewees per group): a target group made by smallholder farmers recipient of a developing project of a local NGO and a control group constituted by other vulnerable farmers and to measure sustainability indexes at different hierarchical levels. The variance analysis unveiled significant differences between the two groups for 12 core indicators, 8 subthemes and 6 sustainability themes distributed between the four pillars of sustainability. As a consequence three of the latter were shown significantly different and a global sustainability index integrating all the collected information displayed similar results. When differences were observed, the increase was always in favor of the project beneficiaries. We can conclude that sustainable agriculture practices taught by MODE led to substantial and measurable benefits for human well-being and economic growth without harming the environment. However the global level of sustainability was calculated as low, which indicates that much is left to do. Further research is also necessary for digging in the causality of the observed significant differences.

Acknowledgements

This research was financially supported by the Belgian Development Cooperation and activities were implemented in Cambodia by MODE with the technical support of the University Belgian NGO Louvain Coopération au Développement. F.M. and C.M. were supported by Louvain Coopération au Développement as well and are thankful to this organization for its technical support and its confidence. When preparing this manuscript, F.M. was supported by the “Fonds National de la Recherche Scientifique” of Belgium (FNRS) as Research Fellow and is grateful to this fund for its financial support.

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Appendix A

Table A.1: List of subthemes contained in the SAFA method, categorised by themes and pillars. The last two columns indicate if the corresponding subtheme is regarded by MODE project and the significance of the mean comparison between project beneficiaries and other vulnerable farmers.

Pillars	Themes	Sub-themes[1]	Project[2]	Result[3]
E. Environmental integrity	E.1 Atmosphere	E.1.1 Greenhouse gases	-	*
		E.1.2 Air quality	-	
	E.2 Water	E.2.1 Water withdrawals	-	
		E.2.2 Water quality	-	
	E.3 Land	E.3.1 Soil quality	+	
		E.3.2 Land degradation	+	
	E.4 Biodiversity	E.4.1 Ecosystem diversity	-	
		E.4.2 Species diversity	+	
		E.4.3 Genetic diversity	+	
	E.5 Material and energy	E.5.1 Material use	+	
		E.5.2 Energy use	-	
		E.5.3 Waste reduction and disposal	o	
	E.6 Animal welfare	E.6.1 Health and Freedom from stress	+	
S. Social well-being	S.1 Decent livelihood	S.1.1 Right to quality of life		
		S.1.2 Capacity building	+	***
		S.1.3 Right of fair access to land and means of production	o	
	S.2 Fair trading practices	S.2.1 Responsible buyers	-	
	S.3 Labour right	S.3.1 Employment relation	-	
		S.3.2 Forced labour		
		S.3.3 Child labour	-	
		S.3.4 Employees' freedom of association and right to bargaining		
	S.4 Equity	S.4.1 Non-discrimination		
		S.4.2 Gender equality		
		S.4.3 Support to vulnerable people		
	S.5 Human health, safety and happiness	S.5.1 Work place safety and health provision for employees	-	
		S.5.2 Public health	+	*
	S.6 Cultural development	S.6.1 Indigenous knowledge		
		S.6.2 Food sovereignty	+	***
G. Good governance	G.1 Corporate ethics	G.1.1 Mission statement		
		G.1.2 Due diligence		
	G.2 Accountability	G.2.1 Holistic audits		
		G.2.2 Responsibility		
		G.2.3 Transparency		
	G.3 Participation	G.3.1 Stakeholder dialogue		
		G.3.2 Grievance procedure		
		G.3.3 Conflict resolution	-	
	G.4 Rules of Law	G.4.1 Legitimacy		
		G.4.2 Remedy, restoration and prevention		
		G.4.3 Civic responsibility		
		G.4.4 Resources appropriation	-	*
	G.5 Holistic management	G.5.1 Sustainability management plan	+	***
		G.5.2 Full cost accounting		

C. Economic resilience	C.1 Investment	C.1.1 Internal investment	+	
		C.1.2 Community investment	+	
		C.1.3 Long-ranging investment	+	*
		C.1.4 Profitability	+	
	C.2 Vulnerability	C.2.1 Stability of supply	-	
		C.2.2 Stability of markets	-	
		C.2.3 Liquidity	+	
		C.2.4 Risk management	+	*
		C.2.5 Stability of production		
	C.3 Products quality and information	C.3.1 Food safety	-	
		C.3.2 Food quality	-	
		C.3.3 Products information		
	C.4 Local economy	C.4.1 Value creation	+	
		C.4.2 Local procurement		

[1] omitted in our analysis // taken into account in our analysis

[2] + expected project outcomes, - no expected project outcomes, o priority future project target

[3] * significant at p = 0.05, *** significant at p=0.01

Appendix B

Table B.1: list of measured crore indicators and mean values for both project beneficiaries and other vulnerable farmers. The last column indicates the significance of the p-value calculated using analysis of variance

Pillars	Core indicators	mean B value	mean NB value	Result[1]
E. Environmental integrity	E 1.1.1 GHG reduction target			
	E 1.1.2 GHG mitigation practices	0.16	0.05	0.0409*
	E 1.2.1 Air pollution reduction target			
	E 1.2.2 Air pollution prevention practices			
	E 2.1.1 Water conservation target			
	E 2.1.2 Water conservation practices	0.33	0.16	0.0463*
	E 2.1.3 Ground and surface water withdrawals			
	E 2.2.1 Clean water target			
	E 2.2.2 Water pollution prevention practices			
	E 3.1.1 Soil- improvement practices			
	E 3.1.3 Soil chemical quality			
	E 3.1.5 Soil organic matter content			
	E 3.2.1 Land conservation and rehabilitation plan			
	E 3.2.2 Land conservation and rehabilitation practices			
	E 4.1.3 Structural diversity of ecosystems			
	E 4.1.4 Ecosystem connectivity	0.63	0.47	0.0479*
	E 4.1.5 Land–use and land-cover change			
	E 4.2.1 Species conservation target			
	E 4.2.2 Species conservation practices			
	E 4.2.4 Diversity of production	0.84	0.62	10^{-5}***
	E 4.3.5 Saving of seeds and breeds			
	E 5.1.4 Intensity of material use			
	E 5.2.1 Renewable energy use target			
	E 5.2.3 Energy consumption			
	E 5.2.4 Renewable energies			
	E 5.3.1 Waste reduction target			
	E 5.3.2 Waste reduction practices	0.37	0.18	0.0201*
	E 5.3.4 Food loss and waste reduction			
	E 6.1.1 Integrated animal health practices			
	E 6.1.5 Animal health			
S. Social well-being	S.1.2.1 Capacity building			
	S.1.3.1 Right of fair access to land and means of production	0.82	0.54	0.0009***
	S.2.1.1 Suppliers' freedom of association and right to collective bargaining			
	S.3.1.1 Employment relation			
	S.3.3.1 Child labour			
	S.5.1.1 Work place safety and health provision for employees			
	S.5.2.1 Public health	0.65	0.53	0.0449*
	S.6.2.1 Food sovereignty	0.07	0.01	0.006****

C. Economic resilience	C 1.1.1 Internal investment			
	C 1.2.1 Community investment			
	C 1.3.1 Long-term profitability	0.13	0.05	0.0483*
	C 1.4.1 Net income			
	C 1.4.3 Price determination			
	C 2.1.1 Procurement channels			
	C 2.2.1 Stability of market			
	C 2.3.2 Safety nets			
	C 2.4.1 Risk management	0.11	0.07	0.0227*
	C 3.1.2 Hazardous pesticides			
	C 3.2.1 Quality standards			
	C 4.1.1 Regional workforce			
G. Good Governance	G.3.3.1 Conflict resolution			
	G.4.4.1 Free, prior and informed consent	0.66	0.58	0.0261*
	G.5.1.1 Sustainability management plan	0.41	0.14	0.0022***

555 B = Beneficiaries, NB = Non-Beneficiaries

556 [1] * significant at p = 0.05, *** significant at p=0.01