

1 **Title**

2 Multidimensional benefits of smallholder farmers' good practices

3 **Subtitle**

4 A case study in Kampong Thom, Cambodia

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14 **Abstract**

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

34	Table of contents	
35	Abstract	2
36	Table of contents	3
37	1. Introduction	4
38	2. Material and methods	8
39	2.1. Overall methodology	8
40	2.2. Questionnaire formulation	9
41	2.3. Sampling	9
42	2.4. Database and Statistical analysis	11
43	3. Results	12
44	4. Discussion	17
45	5. Conclusion.....	20
46	References	22
47	Appendix A	24
48	Appendix B	26
49		

50 **1. Introduction**

51 Agriculture is the traditional mainstay of the Cambodian economy, accounting for almost
52 90% of the Gross Domestic Product (GDP) and employing around 85% of the work force
53 with an average agricultural land holding of 1.6 hectare per family (National Institute of
54 Statistics 2014). Agricultural practices remain mostly traditional even if intensification
55 appears chaotically in some regions. Most of the smallholder farmers are trying to meet first
56 their consumption needs and are cultivating almost exclusively rice using traditional farming
57 practices. This situation leads to low average yields (about 3 tons of rice per hectare in
58 average) and makes farmers extremely vulnerable economically (Royal Government of
59 Cambodia and Ministry of Planning 2013). Their production is also highly dependent on the
60 annual weather conditions and many of them already feel the consequences of climate change
61 (Ros Bansok, Nang Phirun, and Chhim Chhun 2011).

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

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

90 Though sustainable development is a complex, multiply defined notion whose most quoted
91 definition was given by the Brundlandt commission: “sustainable development is
92 development that meets the needs of the present without compromising the ability of future
93 generations to meet their own needs” (WCED 1987). Agriculture because of its particular
94 primary goal of food production and its narrow link with the environment, plays a key-role in
95 the transformation of our lifestyle towards sustainability (FAO 2014). Sustainable agriculture
96 can be defined as “the management and conservation of the natural resource base, and the
97 orientation of technological change in such a manner as to ensure the attainment of continued
98 satisfaction of human needs for present and future generations. Sustainable agriculture
99 conserves land, water, and plant and animal genetic resources, and is environmentally non-
100 degrading, technically appropriate, economically viable and socially acceptable” (FAO 2014).

101 Sustainability in agriculture is usually itemized by the combination of four generally agreed
102 goals: the right quality of life for farmer, workers and the society as a whole; the economic
103 viability of agriculture; the environmental respect of the resources and last but not least the
104 food and by-products (such as biofuel) production (National Research Council and National
105 Research Council 2010). Nevertheless it encompasses so many distinct aspects and remains
106 such a complex concept that there is no perfect common viewpoint about its precise
107 definition, scale and components (Hayati, Ranjbar, and Karami 2010). In last decades,
108 hundreds of methods evaluating either particular pillars of sustainability or the sustainability
109 as a whole have been developed at different scales and for various objectives (see among
110 many others: Paracchini et al. 2015; Bockstaller et al. 2009; Bechini and Castoldi 2009).

111 Because of the indicator and method diversity, several authors examined issues related to
112 specific choices trying to justify the use of a particular method in a specific context or to
113 provide a general approach such as the MESMIS operative structure (López-Ridaura, Masera,
114 and Astier 2002). To structure these indicators, several typologies have been presented in the
115 literature based on the causality between the farming practices and the consequent impacts
116 (Bockstaller et al. 2009). Three main categories of indicators exist: means-based indicators

117 depending on farmer production practices, effect-based indicators evaluated through direct
118 measurements of the effects these practices have on its surrounding world (Van Der Werf and
119 Petit 2002; van der Werf, Kanyarushoki, and Corson 2009) and target-based indicators
120 focusing on whether the operation has plans or policies with clear targets with ratings based
121 on steps towards implementing them (FAO 2013). They aim at highlighting the link between
122 causes and impacts influenced by external factors, such as soil properties or climate (Lebacqz,
123 Baret, and Stilmant 2013). The first class of indicator focuses on the best practices and is
124 process-oriented assuming that good practices lead systematically to desired results (FAO
125 2013). The second category are outcome-oriented with a clear link between the objectives and
126 the measured indicators leaving the farmers free to choose the best means to reach the
127 sustainable goals according to their specific context. Finally the target-based indicators are
128 looking for a systematic vision and policy for the future of the farm/agricultural company.
129 Each type of indicators suffers from major drawbacks such as their substantial margin error
130 (means-based), their measurement cost (effect-based) or their remoteness with the present
131 (target-based) (Van Der Werf and Petit 2002). The indicators can also be compiled into single
132 indexes on the basis of an underlying model allowing researchers to measure
133 multidimensional concepts that cannot be captured by single indicators (OECD 2008).
134 Sustainability in agriculture is particularly relevant to be assessed by composite indicators
135 because of its intricacy and complexity.

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

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

152 **2. Material and methods**

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

163 **2.1. Overall methodology**

164 The SAFA method consists in 21 themes and 56 subthemes in narrow relation with all the
165 aspects of sustainable agriculture gathered in four pillars (good governance, environmental
166 integrity, social well-being and economic resilience). All themes and subthemes and their
167 distribution in the respective pillar are summarized in Appendix A. In this table, the cell font
168 of subthemes is colored according to their relevance to the local context of the current farming
169 system in Kampong Thom: red if the subtheme can be omitted for smallholder farmers or if it
170 was impossible to assess based on sole interviews, black if the subtheme makes sense for the
171 particular situation and was kept until the end of the analysis. When no subtheme was retained
172 for a specific theme, then the complete theme was omitted and it is indicated by a red font for
173 the theme cell. The preliminary selection was based on FAO recommendations (a complete
174 description of the procedure can be found in the SAFA guidelines (FAO 2013)) and on
175 discussion with local experts from NGOs (MODE & LC) and University (Royal University of
176 Agriculture - RUA). In table A.1, the fourth column (“project”) indicates if the theme/sub-
177 theme is directly linked to the sustainable agriculture development project of MODE in
178 Cambodia (+), if it is considered as absent from the current project objectives list (-) or when
179 it is unconsidered in the current state of the project but could be included in future plans of
180 applications (o). Comparing the universal themes and the specific sub-themes with the local
181 context and the objectives of the project, 18 themes (out of 21), 35 (out of 56) subthemes and
182 53 (out of 105) core indicators were retained. Let us note that most of the omitted indicators
183 were part of the governance pillar. 30 core indicators were conserved in the environmental
184 pillar, 12 in the economic pillar, 8 in the social pillar and 3 in the good governance pillar and

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

188 **2.2. Questionnaire formulation**

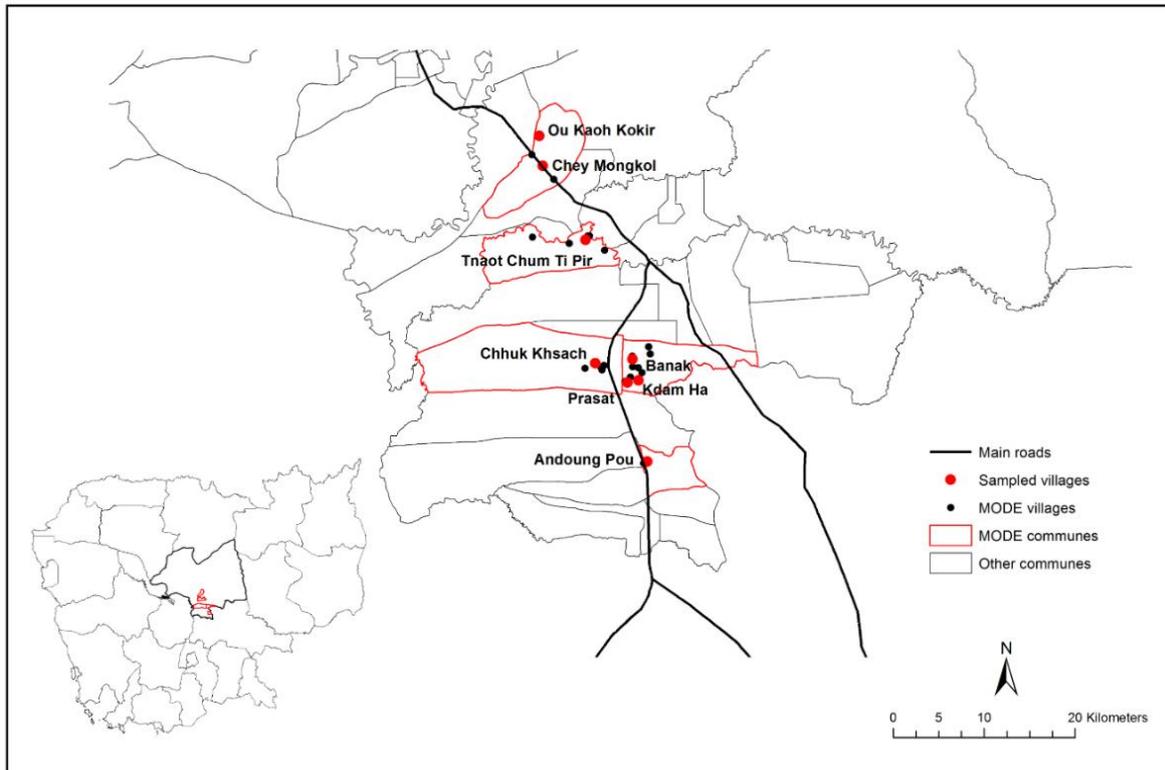
189 Based on this selection, a questionnaire was developed to reveal the current farming practices
190 of the interviewees, their economic status, the perception of the risks threatening their
191 enterprise (as listed by local actors, i.e. field facilitators, local NGO members and university
192 professors,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

196 **2.3. Sampling**

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

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

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



215
 216 **Figure 1: Location of the initial zone of influence of MODE (red lines are sampled communes) and the**
 217 **sampled villages (red dots). In this map, the other MODE villages (in these communes) are located by**
 218 **dark point and the global situation of the Kampong Thom province in Cambodia is indicated in the lower**
 219 **left corner.**

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

222 **Table 1: Sampled villages and number of interviewees for beneficiaries (B) and other vulnerable farmers**
 223 **(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

224 B = Beneficiaries, NB = Non-Beneficiaries

225
 226 One of the main issues of the methodology was to select non-beneficiary farmers at a level of
 227 vulnerability similar to the one of farmers selected for benefiting the project: a bias could be
 228 introduced by systematically interviewing NB farmers at higher vulnerability level. A
 229 preliminary survey allowed the interviewers selecting non-beneficiary farmers on the basis of

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

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

235 **2.4. Database and Statistical analysis**

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

241 **3. Results**

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

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

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

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

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

280 **Table 2: summary of some of the principal outcomes of the interviews. Mean, minimal and maximal**
 281 **values for different aspects of the farm are given for both beneficiaries and non-beneficiaries and analysis**
 282 **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***

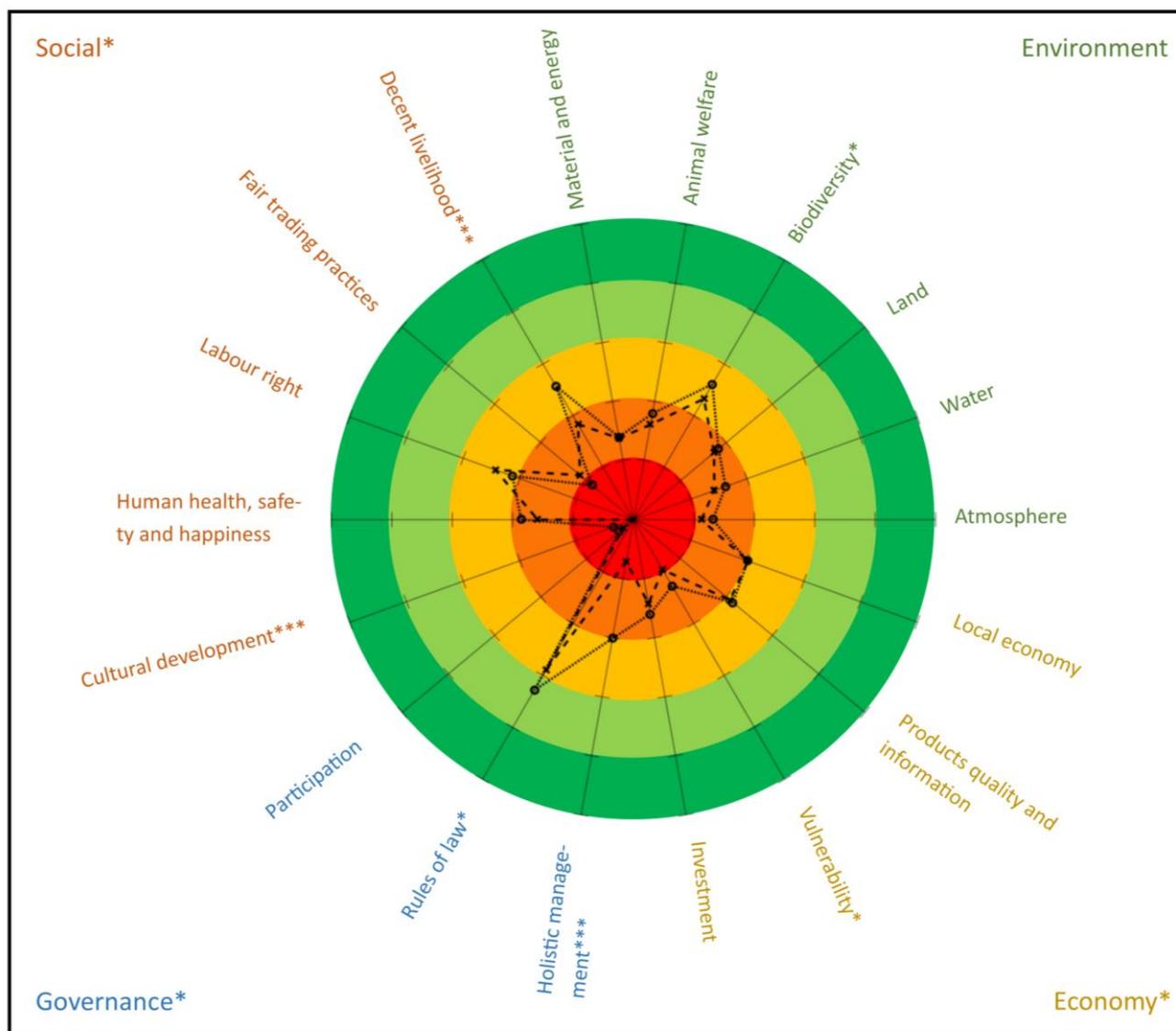
283
 284 *significant at P = 0.05 and *** significant at P = 0.01

285 B = Beneficiaries, NB = Non-Beneficiaries

286
 287 These results along with responses to other questions during the interviews could then be used
 288 for calculating the core indicators selected among the SAFA list. The latter could then be
 289 collected into composite indicators to assess the different hierarchical levels of sustainability
 290 defined in the FAO methodology from subtheme to pillar levels. The farmer performance for
 291 each single sustainability theme is plotted in Figure 2 as a function of the status of the farmer:
 292 the dotted black line represents the beneficiaries from the project, the dashed line the other
 293 vulnerable farmers. For each theme, several core indicators were compiled to obtain a
 294 sustainability index comprised between 0 (less sustainable) and 1 (more sustainable). The font
 295 colour represents to which pillar each single theme belongs: green for the environmental
 296 pillar, red for the social component, yellow for the economic resilience and blue for the good
 297 governance. The analysis revealed that 12 core indicators significantly differ between the two
 298 groups: for all of them, the project beneficiaries performed better than the other vulnerable
 299 farmers. As a consequence, when gathering the information to a higher hierarchical level,
 300 height subthemes and six themes were shown to be statistically different. The corresponding
 301 themes and subthemes are indicated in Figure 2 and Table A.1, respectively, by the same
 302 notation: * when the p-value generated by variance analysis is lower than 0.05, *** when the
 303 p-value is lower than 0.01. Out of these height subthemes, six were expected to have

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

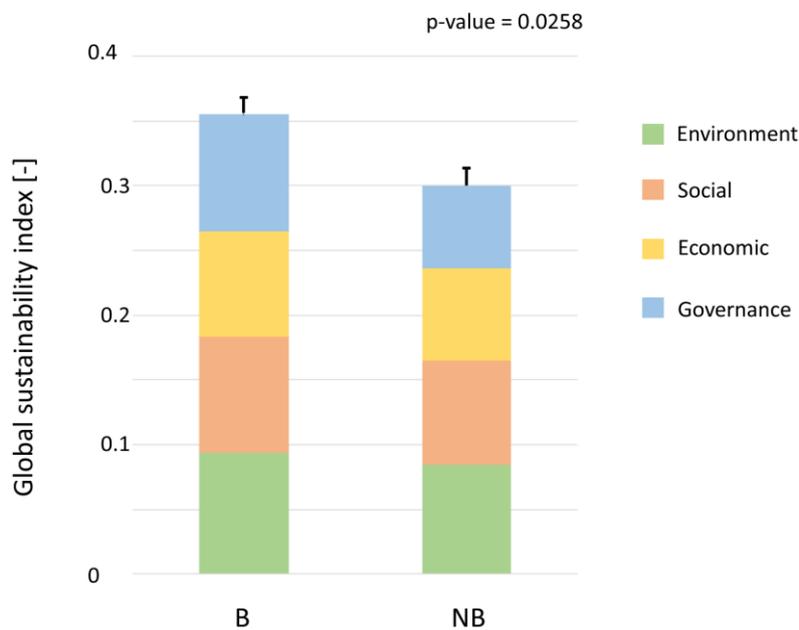
317 In SAFA methodology, the performance of an indicator, subtheme, theme or pillar is
318 classified in between five categories: from very low sustainable value (red) to very high
319 sustainable value (dark green). Intermediate classes are orange, yellow and light green from
320 low to high vulnerability.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



330
 331 **Figure 2: Distribution of the smallholder farmer performance in the different themes of vulnerability. The**
 332 **theme font colour indicates the pillar membership (blue = governance, green = environment, yellow =**
 333 **economy and red = social). All performances are comprised between 0 (inner red circle) and 1 (outer dark**
 334 **green circle). The dotted dark line represents the project beneficiaries (B) performance while the dashed**
 335 **line show the NB performance. When significant differences appear for a specific theme or pillar, it is**
 336 **indicated by a symbol: * means significant at $p = 0.05$, *** means significant at $p = 0.01$.**

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

346 pillar, the total number of measured indicators of this category was also particularly high,
 347 which somehow diluted the significance.
 348 Finally when assembled at the highest level (the pillars mixed together into a single composite
 349 indicator), the mean value of the global sustainability index (also comprised between 0 and 1)
 350 presents a significant difference as well with a small increase for the project beneficiaries.
 351 This can be seen from Figure 3 where the bars stand for the two groups: B on the left and NB
 352 on the right. The colours represent the pillar components of the index with the same colour
 353 legend as the previous figure. Their contributions are substantially the same. The standard
 354 deviations of the global sustainability index for both groups are indicated as well.



355
 356 **Figure 3: Global sustainability index and its components (the colours are kept the same with respect to the**
 357 **previous figure for the pillars) for both the smallholder beneficiaries (B) and the other vulnerable farmers**
 358 **(NB). The mean value is significantly different between the two groups.**

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

363 **4. Discussion**

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

375 Globally the sustainability of the smallholder farming practices in Kampong Thom was
376 assessed low: the mean value of the global sustainability index for both groups was close to
377 0.3, almost equally distributed in the four pillar for both groups. This indicates that even
378 though trainings could increase the agricultural sustainability, much remains to be done. The
379 study also revealed the lack of agricultural knowledge of farmers of both groups. The number
380 of irrelevant replies to mitigation action against risks (data not shown), for example, is a
381 concrete illustration of the low level of qualification of farmers in the studied area and
382 potentially also in the province. Much could be done to teach them agricultural basics of food
383 production and processing. As stressed out in the results section, few other organizations seem
384 to deliver farming practices training to farmers in this region, at least in the studied communes
385 and villages. So much is still to do to fill the gap and to improve the agricultural
386 sustainability, as a consequence.

387 Of course when investigating sustainability, many changes are time-consuming and effects
388 could sometimes be seen only on long-term while our study took place five years after the
389 project launch (2011). Some of the interviewed farmers followed MODE training only a year
390 before the study. One of the key-message delivered by our analysis is that the smallholder
391 farming practices is far from being sustainable at the different pillars of sustainability.
392 Some of the themes presenting statistical differences have been observed in other similar
393 studies such as the biodiversity, thanks to the larger food production diversity (McLaughlin
394 1995) and the decent livelihood, due to increased incomes among others (Bechini and
395 Castoldi 2009). On the other hand, some of the group-contrasted indicators are more

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

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

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

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

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

449 **5. Conclusion**

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

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539

540 **Appendix A**

541 **Table A.1: List of subthemes contained in the SAFA method, categorised by themes and pillars. The last**
 542 **two columns indicate if the corresponding subtheme is regarded by MODE project and the significance of**
 543 **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	0	
	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	0	
	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.4 Equity	S.3.4 Employees' freedom of association and right to bargaining		
		S.4.1 Non-discrimination		
		S.4.2 Gender equality		
	S.5 Human health, safety and happiness	S.4.3 Support to vulnerable people		
		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			

544

545

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				

546 ¹ **omitted in our analysis** // taken into account in our analysis

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

548 ³ * significant at p = 0.05, *** significant at p=0.01

549 **Appendix B**

550 **Table B.1: list of measured core indicators and mean values for both project beneficiaries and other**
 551 **vulnerable farmers. The last column indicates the significance of the p-value calculated using analysis of**
 552 **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****

553

554

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