Ecological Economics 197 (2022) 107428

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Do environmentally-friendly cocoa farms yield social and economic co-benefits?

Lina Tennhardt [a,b,*], Gianna Lazzarini [a], Rainer Weisshaidinger [a], Christian Schader [a]

[a] Research Institute of Organic Agriculture, Ackerstrasse 113, Frick, Switzerland
[b] Université catholique de Louvain, Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research (TECLIM), 1348 Louvain, La-Neuve, Belgium

ARTICLE INFO

Keywords:
Cocoa
Sustainability
Global value chain
Co-benefit
Trade-off
SMART-Farm Tool (RRID:SCR_018197)

ABSTRACT

Downstream companies in chocolate supply chains are increasingly engaged in improving the sustainability of cocoa production, which requires a multidimensional understanding of cocoa farms' sustainability performance. However, prior research has insufficiently addressed the multiple sustainability dimensions of cocoa production or the interrelationships between dimensions. This study explores farm sustainability using our comprehensive data set of 395 cocoa farms in Ecuador and Uganda and identifies social and economic co-benefits and trade-offs of environmentally-friendly cocoa production. For this, farms were grouped according to environmental performance and then compared. This approach revealed lowest sustainability performance in the social and governance dimension. We identified important social and economic co-benefits of environmentally-friendly cocoa production regarding human health benefits from reduced pesticide use and resource conservation for farms' long-term productivity, although at the expense of farm investments and profitability. Future interventions require approaches that target underrepresented sustainability issues and enable synergistic effects between environmental, social, and economic sustainability for cocoa farms.

1. Introduction

Cocoa (*Theobroma cacao*) is an important agricultural commodity traded globally and with continuously increasing demand (Voora et al., 2019). Cocoa cultivation, however, is associated with numerous environmental, social, and economic issues, including deforestation, child labour, or farmer poverty (Fountain and Huetz-Adams, 2020; Lambin et al., 2018). This leads to public and consumer pressure (Mithöfer et al., 2017a, 2017b) and an increasing demand for sustainably-produced cocoa (Meier et al., 2020). Consequently, cocoa traders/processors and chocolate companies have started addressing farm-level sustainability through supply chain mechanisms, such as voluntary certification or in-house schemes (Barrientos, 2011; Grabs and Carodenuto, 2021; Thorlakson et al., 2018). These sustainability mechanisms, nonetheless, have also received criticism. For example as certification schemes lack farmer inclusion in decision-making and the ability to trigger large-scale transformation (Glasbergen, 2018; Mithöfer et al., 2017a,b; Mithöfer et al., 2017b). Sustainability mechanisms in cocoa focus on – with differing degrees – agronomic, environmental, and social aspects (Grabs and Carodenuto, 2021; Thorlakson, 2018) and have largely relied on farmer trainings or input provision to increase productivity. Economic deficiencies for cocoa farmers have lately been highlighted within the living income debate, resulting in the creation of the Living Income Community of Practice. Despite these efforts, cocoa farming's environmental, social, and economic challenges remain (Fountain and Huetz-Adams, 2020).

Past research on cocoa sustainability has mostly focused on only a few topics. These include salient issues like child labour (Berlan, 2013; Busquet et al., 2021), the environmental impact of cocoa farms, and the relationship between environmentally-friendly farming practices and profitability. Within the latter, ecosystem services provided by agroforestry systems and the economic outcomes for farmers in terms of cocoa yields have been at the centre of research: identifying both trade-offs (e.g. Blaser et al., 2018; Middendorp et al., 2018; Tothmihaly et al., 2019) and synergies (e.g. Schroth et al., 2016; Somarriba et al., 2013). Economic co-benefits of cocoa agroforests through income diversification have also received some scientific attention (Blare and Useche, 2013; Cerda et al., 2014; Niether et al., 2020; Tschora and Cherubini, 2020). Environmentally-friendly production practices, such as agroforestry systems and phytosanitary measures, increase farm labour demand

* Corresponding author at: Department of Socio-Economic Sciences, Research Institute of Organic Agriculture FiBL, Ackerstrasse 113, Postfach 219, 5070 Frick, Switzerland.

E-mail addresses: lina.tennhardt@fibl.org (L. Tennhardt), gianna.lazzarini@fibl.org (G. Lazzarini), christian.schader@fibl.org (C. Schader).

https://doi.org/10.1016/j.ecolecon.2022.107428
Received 28 April 2021; Received in revised form 15 February 2022; Accepted 26 March 2022
Available online 8 April 2022

but can generate economic co-benefits due to higher system and cocoa yields (Armengot et al., 2016; Armengot et al., 2019). Compared to the economic co-benefits of environmentally-friendly cocoa production practices, very little research has addressed social co-benefits, mirroring a more general research gap in understanding social-ecological interactions in agriculture (Rasmussen et al., 2018). This might be influenced by the lack of a common understanding of social sustainability in agriculture and conceptual frameworks as well as difficulties in their operationalization (Janker and Mann, 2018). Beneficial effects of lower pesticide use include the reduced health risk for farm workers (Franzen and Borgerhoff Mulder, 2007), while agroforestry systems appear to result in social benefits such as food security (Cerda et al., 2014; Mbow et al., 2014) or fuelwood self-sufficiency (Tschora and Cherubini, 2020). Few qualitative studies paint a more nuanced picture of trade-offs and co-benefits in cocoa systems (Rueda et al., 2018).

The perspectives of existing research have tended to be rather narrowly focused on single sustainability dimensions or topics, yet a broader perspective is needed to get a comprehensive sense of sustainability issues in cocoa production systems. Furthermore, interrelations between agronomic, environmental, social, and economic sustainability remain poorly understood (Eichler Inwood et al., 2018; Martin et al., 2018). Understanding these relationships, however, can provide critical information for the future development of both public and private interventions to promote sustainable cocoa production by taking co-benefits and trade-offs into account.

In this study, we therefore aim to identify which major sustainability issues exist in cocoa systems when viewed under a comprehensive sustainability lens. Furthermore, we aim to evaluate whether measures to improve the environmental sustainability of cocoa farms also lead to social and economic co-benefits. We hypothesised that economic co-benefits would be evident on environmentally-friendly cocoa farms due to diverse income (Armengot et al., 2016; Niether et al., 2020) but that there would be few social co-benefits, such as women's access to land or credit (Ingram et al., 2016), as these are highly influenced by the social and cultural setting in which farmers operate and are less commonly addressed by cocoa supply chain mechanisms (Thorlakson, 2018).

To test our hypotheses, we first examine the general sustainability performance of cocoa farms within two case studies using a comprehensive sustainability assessment tool. Then, we explore specific interactions between the environmental dimension and the social and economic dimensions of sustainability. As all sampled farms form part of a certification and in-house sustainability program, we do not aim at drawing general conclusions about the impact of these supply chain mechanisms on cocoa farm sustainability. We hope to identify co-benefits and trade-offs arising from environmentally-friendly production practices within our samples and thus draw more general conclusions. For this, we group farms within our sample based on their environmental performance and test for simultaneous performance in the other dimensions. This approach allows us to cover a large number of social and economic sustainability topics and to test for co-benefits across diverse indicators.

2. Materials and methods

2.1. Case study selection and farm sampling

We addressed our research questions with a case study approach. In this study, an eligible case is defined as a global cocoa-chocolate supply chain, with a minimum of three nodes, which spans from one producer group at the upstream end through at least one intermediary to one Swiss chocolate brand at the downstream end of the supply chain, and with a sustainability mechanism in place. Two Swiss chocolate companies were selected as industry partners and we jointly chose the producing country in each case according to these criteria. While we are aware that a large part of cocoa is still traded outside of sustainable supply chain mechanisms, choosing two very different supply chains with distinct sustainability mechanisms in place provides comprehensive insights into the sustainable cocoa segment. One of the Swiss chocolate companies is relatively large and sources raw cocoa through a multinational trader and their own in-house sustainability program from traditional cocoa production regions in Ecuador. The second Swiss chocolate brand is smaller and sources certified cocoa through a small export company from new cocoa production regions in Uganda.

Within each case study's farm supplier base, we followed a randomized sampling approach. Due to the very high number of farmers (>6000) and wide geographical distribution in Ecuador, we decided to concentrate on north-western Ecuador in order to reduce regional differences within our sample. Then, we selected eight supplier groups in four provinces, from which a random subsample of 25 farmers per group was drawn, totalling 190 farmers. All supplying farmers in Uganda were located in one district in Central province with a group size of around 450, from which we randomly selected 204 cocoa farmers.

2.2. Sustainability analysis tool and data collection

To measure sustainability in a meaningful way, numerous analytical frameworks have been developed (Eichler Inwood et al., 2018; Hák et al., 2016; Singh et al., 2012), with great disagreement among experts of how to do this best (de Olde et al., 2017). The developed frameworks for farm-level sustainability assessment range from single-unit (e.g. greenhouse gas emissions) to diverse indicator and dimension approaches, each following a unique purpose with different scopes and precision that inhibits the comparison of results between approaches (Schader et al., 2014). As a response to this situation, the Food and Agriculture Organization (FAO) developed the SAFA Guidelines (Sustainability Assessment of Food and Agriculture systems) as a comprehensive and universally relevant framework to guide sustainability assessments of agricultural systems (FAO, 2014). Within the four sustainability dimensions of Good Governance, Environmental Integrity, Economic Resilience, and Social Well-Being (in the following referred to as governance, environmental, economic, and social dimensions), the SAFA Guidelines address 21 themes and 58 subthemes (FAO, 2014). For each subtheme, SAFA defines a corresponding goal, considering farms' areas of influence via decisions in procurement, management, and sales.

The Sustainability Monitoring and Assessment RouTine (SMART) Farm Tool operationalizes the SAFA Guidelines through indicators that influence each of the 21 SAFA themes and 58 subthemes (Schader et al., 2016) and thus enables farm-level sustainability assessments. So far, the SMART-Farm Tool has been applied on over 5000 farms across different regions and farm types (e.g. Curran et al., 2020; Ssebunya et al., 2019; Winter et al., 2020). Based on both qualitative and quantitative indicators, a farm's performance within each indicator is translated into an indicator score, expressed as a percentage based on pre-defined levels. For example, the indicator "Does the farm have a professional agricultural accounting procedure that is also used for the farm management?" is answered in a qualitative way (No, Partly, Yes) and then translated into a percentage rating (0, 50, 100%). The number of indicators assessed per farm ranged from 188 to 266 in Ecuador and 182 to 263 in Uganda, depending on the number of farm enterprises and complexity of farm activities. Using a multi-criteria approach and following the standardized use of the SMART-Farm Tool, sets of weighted indicators are aggregated for each subtheme, in which the weight reflects an indicator's relative importance ("impact") in achieving the subtheme goal. Each indicator may interact with multiple subthemes simultaneously based on a weight scale from −1 to +1 (e.g. non-use of pesticides has a positive impact on species diversity and a negative impact on stability of production). Individual indicators weights were developed in an expert-based Delphi process (Schader et al., 2019) and form part of every sustainability analysis using the SMART-Farm Tool. Based on the scores of indicators aggregated into subthemes and themes, the "degree of goal achievement" for each theme and subtheme is calculated in the SMART-Farm Tool, expressed as a percentage of the goal defined in SAFA (0% = no achievement and 100% = full goal achievement). For the analysis of this study and in order to identify topics with the most urgent need for improvement, each subtheme with a mean goal achievement in the Unacceptable (0–20%) or Limited (20–40%) ranges was defined as a major sustainability issue. We used a one-sample *t*-test to test whether the mean goal achievements in each case study and subtheme were significantly lower than the defined threshold of 40%.

Trained enumerators visited the selected farms between July and September 2019 in Ecuador and February and March 2020 in Uganda to undertake the one-time assessments at each farm using the SMART-Farm Tool questionnaire and software. The face-to-face interview with farm managers, including a farm tour, lasted around 3 h each. Indicator ratings mostly rely on verbal information provided by farm managers. While the contact with the farmers was organized by the cocoa buyers, strict confidentiality was assured to farmers. Farmers highly appreciated the interviews and the possibility to share their opinions. They were even willing to share sensitive information such as incompliance with regulations. In short, enumerators were transparent and independent and we consider the interviews to be held in an environment of trust with little fear of wrong answers.

2.3. Analysis of co-benefits and trade-offs

2.3.1. Grouping farms based on environmental performance

Similar to clustering techniques, latent profile analysis (LPA) is a mixture model approach that identifies discrete subgroups within a population based on a set of continuous variables (Oberski, 2016). LPA does this by assuming that observations can be classified with varying degrees of probabilities into categories with different profile attributes. We aimed at identifying farms within our Ecuadorian and Ugandan data sets with a relatively higher and lower environmental performance than other sampled farms, thus without fixed cut-off points of high or low environmental performance. We used LPA to identify these subgroups of farms within our data sets based on their level of goal achievement in five environmental themes *Atmosphere*, *Biodiversity*, *Land*, *Materials and Energy*, and *Water*. The SAFA theme *Animal Welfare* was excluded for LPA as it was considered less important for the sustainability of cocoa production. To identify the best latent profile model and thus the most suitable number of subgroups, we used the general model selection and comparison approach Bayesian information criterion (BIC)(Schwarz, 1978). BIC is used to avoid overfitting models by penalizing the addition of parameters and preference is given to models with lower BIC.

2.3.2. Comparison between high and low environmental performers

After allocating sampled farms to subgroups according to their environmental performance, the farms with high environmental performance and low environmental performance (hereafter referred to as HEP and LEP) were selected for further analysis. This division into subgroups was carried out purely for this research and does not reflect distinct treatment of subgroups through the supply chain (e.g. through performance-based price premiums). Certain trade-offs and synergies between (sub)themes are inherent within the SMART-Farm Tool, as single indicators can positively and/or negatively influence different (sub)themes at the same time. Therefore, we assessed differences between the HEP and LEP at indicator level, comparing indicator scores between the two subgroups.

As mentioned above, the selection of indicators that are relevant for each sustainability subtheme as well as their individual weights in the SMART-Farm tool was established in an expert Delphi process (Schader et al., 2019). To distinguish between those indicators that influence the environmental dimension and thus had an effect on the division of environmental performance subgroups and those indicators that do not, the former were marked with a superscript one in the following section. We defined co-benefits as the simultaneous existence of high performance in the environmental dimension and high performance at indicator level in one of the other sustainability dimensions. Conversely, high performance in the environmental dimension with simultaneous low performance at indicator level within the other sustainability dimensions was defined as a trade-off.

2.3.3. Statistical analysis

All comparisons between HEP and LEP were carried out using non-parametric statistics (Mann-Whitney *U* test for continuous variables). All statistical analyses were performed in R (vers. 3.6.3, R Project for Statistical Computing, RRID:SCR_001905), via RStudio (vers. 1.2.5033, RStudio, Q19 RRID:SCR_000432). The analysis was implemented in RStudio's RMarkdown script format, which integrates analysis, reporting, and export functions for highly reproducible research reports (Baumer and Udwin, 2015).

3. Results

3.1. Case study description

Given the focus of this study, the following case study description will mainly address the upstream end of the supply chain, i.e. the farm level, as well as sustainability mechanisms in place for farmers.

3.1.1. Case study 1: Fine flavour cocoa from Ecuador

Ecuador was the world's fifth largest producer of cocoa in 2019, with over 283,000 t produced (FAO, 2021a), and was the largest producer of fine flavour cocoa, known in Ecuador as Cacao Nacional (Anecacao, n. d). Around 105,800 t were certified under the labels organic, Fairtrade, Rainforest Alliance, and UTZ in 2019 (FiBL-ICT-SSI Survey, 2021). The majority of the 525,435 ha of land used for cocoa cultivation in Ecuador in 2019 (FAO, 2021b) was located in the coastal area (INEC, 2020), which is also the location of sampled farmers in this case study (Fig. 1). The majority of farmers sell their produce to middlemen in nearby towns, who in turn sell to a large multinational trader as an export company, which then exports cocoa to the large Swiss chocolate company. Farmers, middlemen, and the export company form part of the chocolate company's in-house sustainability program, which was initiated in 2014 and is implemented by the export company. Farmers in the program undergo several modules of training with a focus on good agricultural practices and environmental protection. The program does not provide price premiums for fine flavour cocoa, yet farmers receive in-kind premiums, such as fertilisers, fungicides, or small machinery (e. g. motorised grass cutters for a group of 4–5 farmers). Additionally, the program started some community development projects. There are no minimum requirements or contracts for farmers to join the program. As participants of the program, farmers are expected to separate fine flavour and hybrid cocoa at time of sales and to regularly sell to program intermediaries, otherwise they no longer receive in-kind premiums. Anecdotal evidence suggests that participating farmers highly valued the sustainability program, mainly due to the in-kind premiums they receive and because, for many, it is the only source of training and advisory service available.

3.1.2. Case study 2: organic cocoa from Uganda

Until recently, cocoa was of minor importance in Uganda (Jones and Gibbon, 2011). In comparison to Ecuador, Uganda had a much smaller cocoa production in 2019 of almost 35,000 t (FAO, 2021a) harvested from 72,369 ha (FAO, 2021b). Around 10,240 t were certified under the organic, Fairtrade, Rainforest Alliance, or UTZ standard in 2019 (FiBL-ICT-SSI Survey, 2021). While Uganda is not a major cocoa producer today, the suitability for cocoa production in Central and East Africa is predicted to increase due to climate change (Bunn et al., 2017). Major cocoa producing areas in Uganda are Bundibugyo in the Western Region and Mukono in the Central Region, the latter corresponding to the location of sampled farmers in our case study supply chain (Fig. 1).

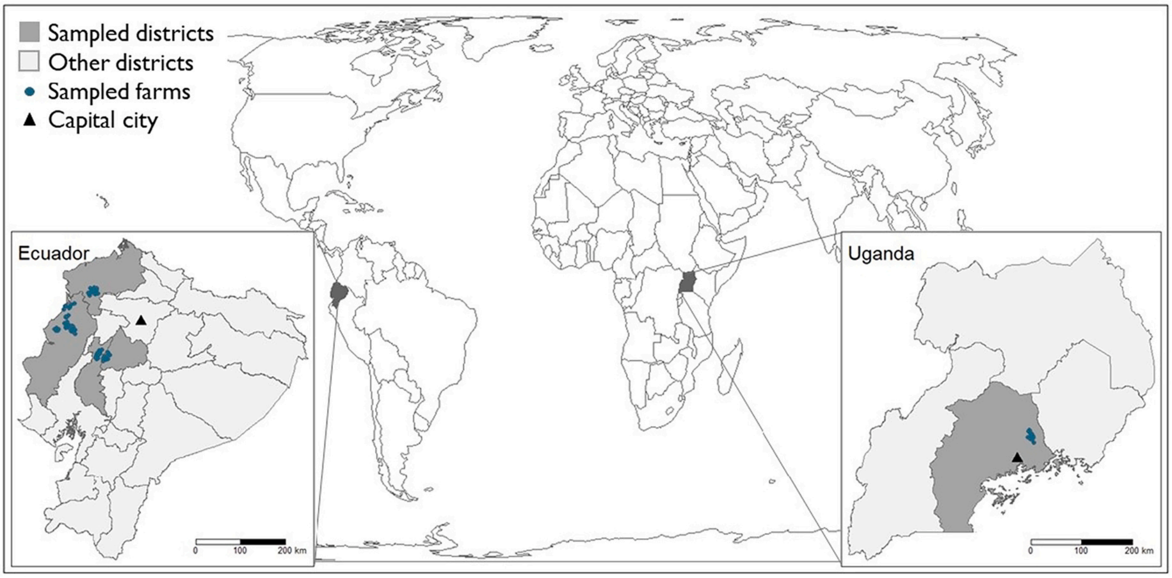

Fig. 1. Map of study sites in Ecuador (Manabí, Esmeraldas, Los Ríos, and Cotopaxi Provinces; Ecuador shown here without Galapagos) (farm sample $n = 190$) and Uganda (Central Province) ($n = 204$). Illustration based on Open Street Map and geoBoundaries data, developed using Tmap and rgeoboundaries packages in RStudio.

These farmers currently sell their cocoa to different national intermediaries and international traders. However, the group has been undergoing conversion to organic certification since 2017. This conversion is being organized by the future buyer, who is a national export company that will buy farmers' cocoa with a price premium once certified. As the external certification audit had not yet taken place, no price premiums were paid at the time of data collection. Additionally, no contractual relationships were in place nor planned between farmers and buyer. During the conversion process, the export company established an internal control system to assure that group farmers comply with organic regulation. Additionally, a training program comprising several modules on organic farming and certification was offered to participating farmers. The small Swiss chocolate brand currently buys organic and 'Fair for Life' certified cocoa from the same trader but which is sourced in Western Uganda. The brand has expressed the intention to source cocoa from Mukono farmers once they are certified and intends to pay organic as well as additional voluntary living income price premiums.

3.2. Agronomic characteristics

Most of the surveyed farms were small, with areas below 4 ha (55%) with few farms of medium to large sizes above 10 ha (16%). However, there were significant differences between case studies: The median farm size in Ecuador was 7.0 ha and in Uganda 2.02 ha. In general, farmers in both countries differed in most demographic and farm characteristics, as shown in Table 1. Similarities existed only in farmers' age, land ownership, ability to hire workers, application of fungicides, and irrigation. Despite largely similar median yields of 0.181 t/ha in Ecuador and 0.210 t/ha in Uganda (compared to national averages of 0.540 t/ha in Ecuador and 0.484 t/ha in Uganda for 2019 (FAO, 2021b)), Ecuadorian farmers had significantly higher incomes from cocoa production (median of 1295 USD/year) than Ugandan farmers (median of 272 USD/year). This can be attributed to cocoa production areas (median of 4 ha in Ecuadorian sample and 1 ha in Ugandan) but also to producer prices, as Ecuadorian farmers received on average 1.91 USD/kg of dry cocoa and 0.76 USD/kg of fresh cocoa in 2018, and Ugandan farmers 5940 UGX/kg of dry cocoa (=1.61 USD/kg) and 2277 UGX/kg of fresh cocoa (=0.62 USD/kg) in 2019. Average world market prices in 2019 and 2020 were 2.34 USD/kg and 2.37 USD/kg,

Table 1
Farm characteristics in both case studies. Statistical analysis for comparison between case studies using a Mann-Whitney *U* test and Chi-square test.

Farm characteristics	Ecuador (n = 190)	Uganda (n = 204)	p-value
	Median values (standard deviation) / percentage		
Farm manager male (% farmers)	80.0	68.3	0.008
Farm manager age (years)	53.0 (14.1)	53.0 (12.9)	0.424
Highest degree rewarded (% farmers)			0.000
No degree	4.3	35.8	
Primary	62.3	40.6	
Lower Secondary	21.0	16.0	
Higher Secondary	6.8	2.1	
Other (university EC & vocational training UG)	5.6	5.3	
Total farm area (ha)	7.0 (16.3)	2.02 (2.9)	0.000
Share cocoa (% farm area)	70.0 (31.1)	51.9 (24.0)	0.000
Share arable land (% farm area)	0.0 (13.3)	25.0 (19.3)	0.000
Share permanent grassland (% farm area)	0.0 (28.8)	0.0 (7.6)	0.000
Cocoa cropping density (% of cocoa area)	80.0 (25.8)	50.0 (23.2)	0.000
Cocoa yields (t/ha)	0.181 (0.338)	0.210 (0.455)	0.249
Cocoa revenue (USD/year)	1295 (9181)	272 (979)	0.000
Secure land tenure rights (% farmers)	90.5	87.3	0.311
Employment of paid workers (% farmers)	74.2	66.8	0.108
Access to credit (% farmers)	68.4	96.1	0.000
Livestock ownership (% farmers)	100.0	67.0	0.000
Use of synthetic pesticides (% farmers)	83.0	62.0	0.000
Use of organic fertilisers (% farmers)	14.2	65.9	0.000
Use of mineral fertilisers (% farmers)	85.8	37.1	0.000
Irrigation system in place (% farmers)	14.7	19.5	0.209

respectively (ICCO, 2021).

3.3. Overall sustainability performance

Here, we present the overall sustainability results for the farms in the two case studies and major sustainability issues at subtheme level including selected indicators that contribute to the poor performances. Unless indicated otherwise, all values presented in this part represent the arithmetic mean. A detailed description of each theme and subtheme, as well as goal achievement values from both case studies, is provided in Annex 1.

Across the samples, **average performance** per SAFA subtheme ranged between 11% and 92% of goal achievement. As can be seen from a comparison of boxplots in Fig. 2, the performance scores followed similar trends in both case studies for the majority of subthemes. Interquartile ranges overlapped in most subthemes across case studies, with exceptions in eight subthemes including *Energy Use*, *Conflict Resolution*, and *Stakeholder Dialogue*.

Major sustainability issues, i.e. those subthemes scoring significantly below the threshold of 40% of goal achievement, were mostly found in the social and governance dimensions. In each of these two dimensions, seven subthemes scored below 40%. The major issues in the social dimension included the subthemes *Support to Vulnerable People*, *Gender Equality*, and *Capacity Development*. Important indicators that flow into the calculation of these subthemes include social protection of farm workers (52% and 24% in Ecuador and Uganda, respectively), indicating that most farmers and their workers have no financial security in case they are not able to work. Additionally, farmers had limited

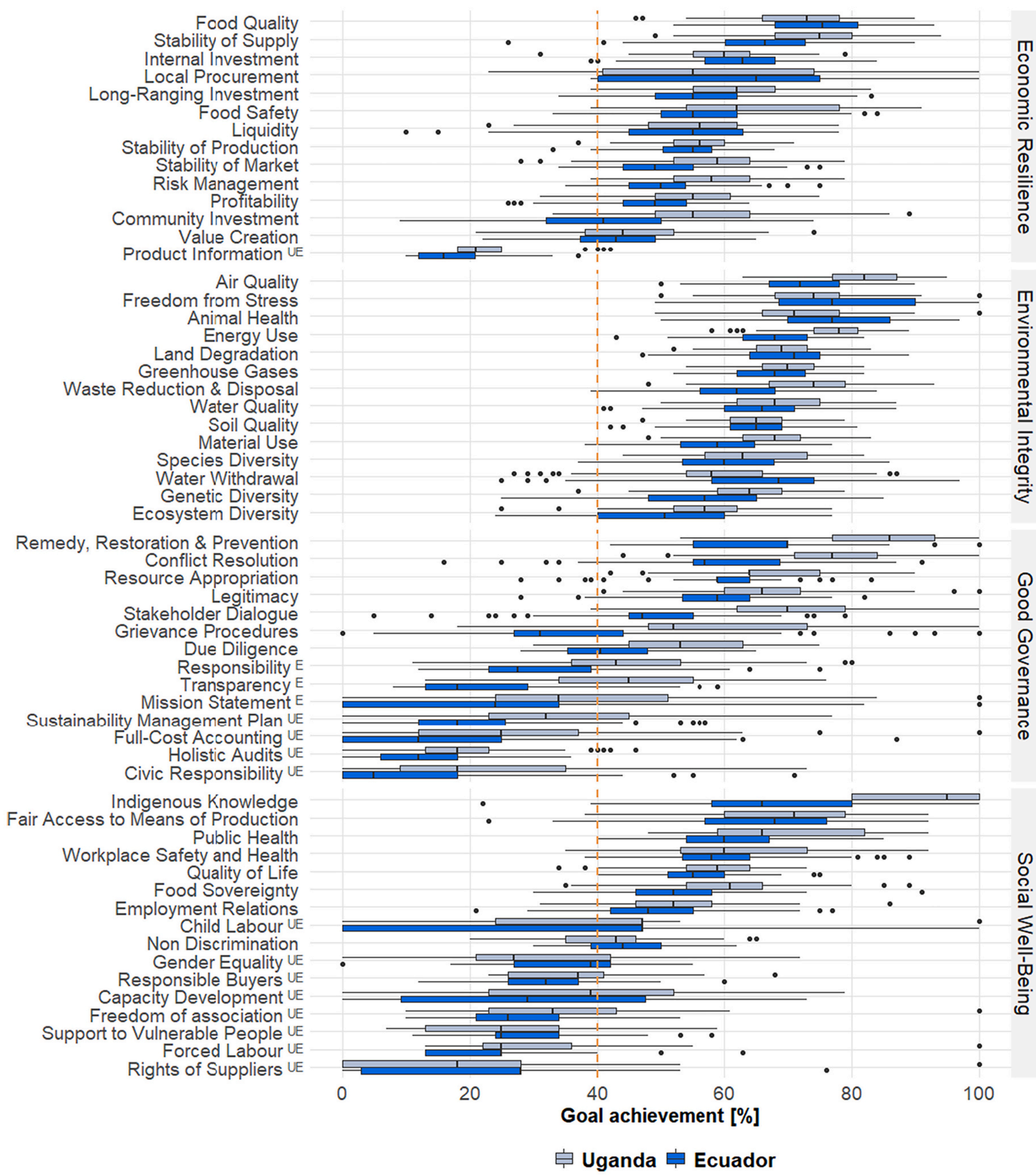

Fig. 2. Farmers' goal achievement (between 0 and 100%) in each SAFA subtheme and grouped by sustainability dimension. Identification of major sustainability issues (i.e. mean subtheme values significantly below the threshold of 40% of goal achievement) using a one-sided *t*-test. Subthemes with means significantly below threshold ($p \leq 0.05$) are indicated by the letter E for Ecuadorian and U for Ugandan case study.

access to important services such as training (51% and 45%) and advisory services (53% and 71%). While 74% and 67% of farmers in our samples employed paid workers, not all farmers paid male and female employees equally (79% and 94% in Ecuador and Uganda, respectively).

The subthemes *Sustainability Management Plan* and *Full-Cost Accounting* are among the major sustainability issues identified in the governance dimension. Important indicators in these subthemes include keeping agricultural accounts, which most farmers did not (14% in Ecuador and 7% in Uganda). Farmers in both case studies additionally had little knowledge of, and thus showed little commitment to, the principles of sustainability (21% and 54%) and had few plans to improve their farm accordingly (10% and 37%). Finally, farmers had little knowledge about climate change problems (26% and 34%, respectively).

We did not identify any major sustainability issues in the environmental dimension. *Product Information* was the only major issue in the economic dimension, indicating a general lack of product information flow along the supply chain. Low scores in this subtheme are influenced by the low level of direct sales (6% in Ecuador and 8% in Uganda) and the lack of voluntary social standards for farm produce (0% for both), as both organic certification and the corporate program focus on agri-environmental practices with less focus placed on social criteria.

We tested the robustness of the results on major sustainability by changing the specifications and cut-off points. The same number of subthemes scored significantly below 40% of goal achievement when the p-value was specified at 0.1, 0.05, and 0.01. When changing the cut-off points, 15 subthemes in the Ecuadorian case and 8 subthemes in the Uganda case scored significantly below 35% of goal achievement. 20 subthemes in Ecuador and 15 subthemes in Uganda scored significantly below 45%. These results were not substantial and did not indicate necessary changes in the definition of our cut-off.

3.4. Co-benefits and trade-offs

3.4.1. Characterization of high- and low environmental performers

Grouping the sampled farms according to their environmental performance led to the creation of subsets of high environmental performers (HEP) of $n = 46$ (Ecuador) and $n = 64$ (Uganda) as well as low environmental performers (LEP) of $n = 36$ (Ecuador) and $n = 30$ (Uganda). Differences in goal achievements within the five themes of the environmental dimension for both groups and countries were significant with p-values <0.001 as can be seen in Annex 2. **Fig. 3** shows the probability with which a farm with a specific goal achievement in each environmental theme is allocated to different subgroups. The best fitting model corresponded to three subgroups in both case studies: LEP represent Subgroup 1 and HEP Subgroup 3.

Significantly different scores between HEP and LEP were found in 52 and 36 environmental indicators in Ecuador and Uganda, respectively, and are provided in Annex 3. The most important differences in environmental farm management activities between the subgroups are provided in Table 2. HEP in both countries have, on average, smaller farms with a significantly higher share of cocoa production area and agroforestry systems and apply significantly less pesticides and fertilisers. LEP in Ecuador, however, have significantly higher cocoa yields and higher income from cocoa production.

3.4.2. Social co-benefits and trade-offs of environmentally-friendly farming practices

From 120 indicators that flow into the social dimension in the SMART-Farm Tool, 25 and 28 show significant differences in scores between the HEP and LEP in Ecuador and Uganda, respectively (description of indicators and mean scores among HEP and LEP provided in Annex 4). Four and nine of these (marked with [1] in **Fig. 4**) do not simultaneously influence the environmental dimension and thus did not affect the division of subgroups based on environmental performance. All indicators in the Ecuadorian case study show synergistic trends with social indicators scoring higher among HEP. The Ugandan case study shows six indicators with lower scores among HEP, indicating trade-offs.

A large proportion of indicators for which social co-benefits of environmentally-friendly production practices were identified (13 and 14 indicators for Ecuador and Uganda, respectively) are related to pesticide use. These include indicators that impact the environmental dimension, such as the number of active ingredients used by farmers, the share of farm area not sprayed with synthetic pesticides, and the toxicity of pesticides for nature and humans. These indicators also include some that did not impact the division of farmers based on environmental performance. For example, HEP used less seeds coated with agrochemicals and more often used protective gear, reducing risks for farm workers. HEP in the Ecuadorian case study were also significantly more engaged in community activities for environmental protection,

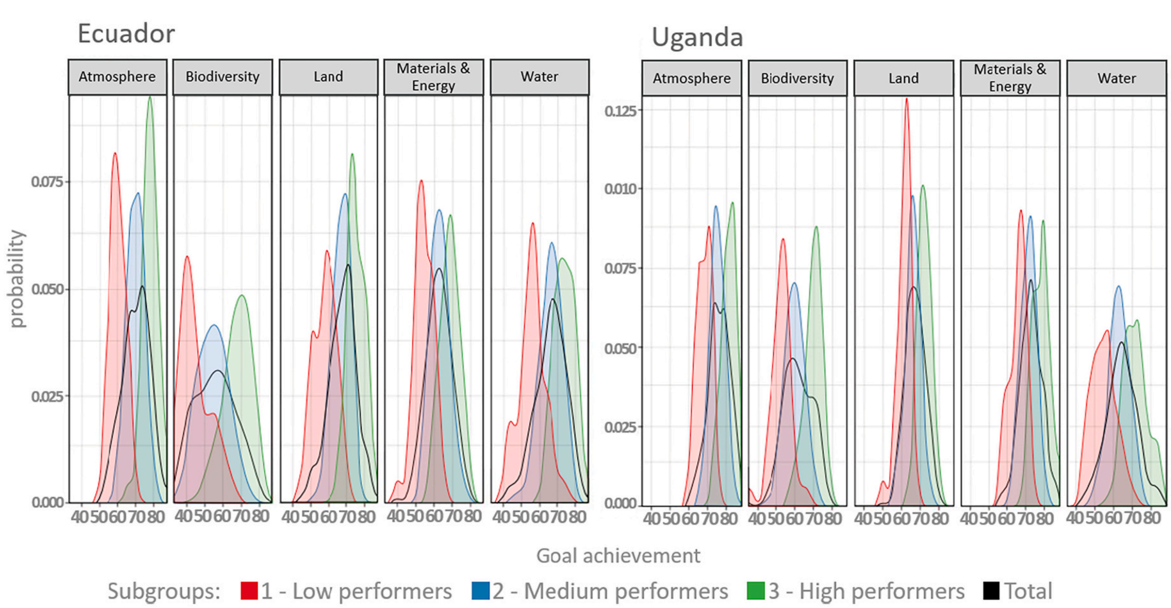

Fig. 3. Probability with which farmers with a specific goal achievement in the Environmental Integrity themes belong to subgroups identified through LPA. High environmental performers = Subgroup 3; Low environmental performers = Subgroup 1.

Table 2
Mean (standard deviation) of and share of farmers for key farm characteristics among high and low environmental performers in Ecuador and Uganda. Statistical analysis for comparison between subgroups using a Kruskal-Wallis Test.

	Ecuador			Uganda		
	High Environmental Performers (N = 46)	Low Environmental Performers (N = 36)	p-value	High Environmental Performers (N = 64)	Low Environmental Performers (N = 30)	p-value
Farm area [ha]	9.06 (8.77)	17.96 (23.03)	0.084	2.06 (1.65)	4.01 (4.34)	0.003
Arable land [% farm area]	0.02 (0.13)	0.04 (0.12)	0.049	0.22 (0.18)	0.39 (0.18)	0.000
Permanent grassland [% farm area]	0.17 (0.25)	0.31 (0.32)	0.031	0.02 (0.09)	0.02 (0.05)	0.227
Cocoa cultivation [% farm area]	0.70 (0.30)	0.55 (0.32)	0.047	0.64 (0.27)	0.41 (0.21)	0.000
Agroforest [% farm area]	0.57 (0.33)	0.12 (0.22)	0.000	0.67 (0.24)	0.51 (0.20)	0.000
Woodland [% farm area]	0.45 (0.81)	0.69 (1.96)	0.092	0.05 (0.22)	0.09 (0.31)	0.504
Area deforested in past 20 years [% farm area]	0.06 (0.22)	0.29 (0.37)	0.000	0.04 (0.16)	0.13 (0.29)	0.036
Cocoa yields [t/ha]	0.19 (0.21)	0.35 (0.38)	0.004	0.26 (0.28)	0.36 (0.36)	0.272
Income from cocoa sales [USD/year]	1816 (2402)	3172 (2621)	0.004	495 (714)	833 (1164)	0.182
Farmers owning livestock [% farmers]	1.0	1.0		0.50	0.70	0.070
Number of farm products sold [#]	3.17 (1.45)	3.63 (1.65)	0.255	3.48 (1.31)	5.43 (2.30)	0.000
Number of active substances of pesticides applied [#]	0.72 (0.72)	3.33 (2.04)	0.000	0.23 (0.58)	3.87 (1.76)	0.000
Farmers applying fungicide [% farmers]	0.11	0.36	0.006	0.00	0.43	0.000
Farmers applying herbicide [% farmers]	0.35	0.94	0.000	0.08	0.73	0.000
Farmers applying insecticide [% farmers]	0.11	0.36	0.006	0.09	0.97	0.000
Farmers with irrigation system [% farmers]	0.02	0.39	0.000	0.06	0.53	0.000
Farmers applying mineral fertiliser [% farmers]	0.74	1.00	0.000	0.06	0.70	0.000
Farmers applying organic fertiliser [% farmers]	0.15	0.22	0.418	0.50	0.80	0.006
Farmers owning the farm land / with secure tenure rights [% farmers]	0.91	0.92	0.954	0.88	0.87	0.911
Farmers employing paid workers [% farmers]	0.70	0.78	0.408	0.58	0.77	0.078
Participation in training [days]	4.19 (8.12)	2.08 (2.56)	0.637	2.42 (3.00)	1.61 (2.37)	0.386

including collective work called “minga” to clean rivers and roads from trash. Finally, burning of farm residues and managing riparian strips, i.e. cultivation and/or pesticide use within three meters of surface waters, which provides benefits for human health through reduced contamination of air and water, was less common among HEP in Ecuador. The Ugandan sample additionally presented six social trade-offs. Compared to LEP, HEP perceived household food security in terms of meals per day and dietary diversity to be lower and created fewer new jobs on their farms.

3.4.3. *Economic co-benefits and trade-offs of environmentally-friendly farming practices*

The economic dimension in the SMART-Farm Tool is influenced by 187 indicators. Out of these, 24 and 25 scored significantly differently between HEP and LEP in the Ecuadorian and Ugandan case study, respectively (for a description of indicators and scores among subgroups see Annex 4). Out of these, six and 17 indicators did not flow into the calculation of the environmental performance (marked with [1] in Fig. 5). Many economic indicators with significantly different values between HEP and LEP show synergistic effects. Yet, some trade-offs can be identified, especially in the Ugandan case.

The identified economic co-benefits of environmentally-friendly production practices in both case studies mostly address sustaining the productivity of the farm in the long term. By having more legumes on their arable land and a larger share of agroforestry systems, by implementing measures for soil fertility management, such as humus accumulation, or by promoting beneficial organisms, HEP assure their farm’s long-term productivity. These indicators also flow into the environmental dimension and thus influence the division into HEP and LEP. Additionally, HEP in the Ecuadorian sample were more committed to the principles of sustainability and had plans to improve the farms in this regard. HEP in the Ugandan sample additionally had a more secure supply of farm inputs.

However, diverse trade-offs were identified in both case studies, especially with respect to indicators in the subthemes of liquidity, profitability, and internal investments: Ecuadorian HEP were less frequently able to make long-term investments on the farm and the farm infrastructure was consequently in worse shape. These farms also more commonly reported profits to have been declining over the past five years than LEP. In the Ugandan case study, HEP more often experienced decreasing profits, a lack of liquidity, and yield losses. HEP were also more dependent on one major buyer and generally had fewer customers, made fewer long-term investments, and less often kept agricultural accounts. Finally, HEP in the Ugandan sample were less informed about future market or political challenges that could affect their farms than LEP.

4. Discussion

4.1. *Cocoa farm sustainability, co-benefits and trade-offs*

4.1.1. *Overall farm sustainability*

The primary aim of this study was to identify major sustainability issues in cocoa production by viewing farms through a comprehensive sustainability lens. We found that the farms within our sample of Ecuadorian and Ugandan cocoa farmers scored between poor and well within different sustainability dimensions. We identified similar patterns between both case studies, implying that farmers in different countries largely experience similar challenges and opportunities.

The highest goal achievement in both case studies was in the environmental dimension due to the small holdings and low input systems in which cocoa is mostly grown. These results are in line with other studies applying the same methodology for coffee production in Uganda, Ethiopia, and Brazil (Ssebunya et al., 2019; Winter et al., 2020). The

Fig. 4. Ratio of mean indicator values between high (HEP) and low environmental performers (LEP) within the Social Well-Being dimension and with significant differences between these subgroups. Ratios >1 indicate co-benefits with environmental performance; ratios <1 indicate trade-offs. Indicators that influenced the calculation of results in the Environmental Integrity dimension in the SMART-Farm Tool are marked with a superscript one.

economic dimension scored on average second-highest, with good mean values in subthemes regarding security of input provision and food quality. This is also due to the nature of cocoa systems involving relatively low external inputs that might affect food quality and few inputs facing risk in their supply or availability. Subthemes like profitability or value creation on average scored much lower, mirroring the dire economic situation of many cocoa farmers (Fountain and Huetz-Adams, 2020). This topic has recently gained momentum through the living income debate and the Living Income Community of Practice.

We identified most major sustainability issues in the social and governance dimension of sustainability, highlighting the importance of comprehensive sustainability assessments. This is partly influenced by indicators defined for high-input, market-oriented farms or farms in industrialised countries, so smallholder farmers score lower. We still included these indicators in our manuscript to highlight issues that could be addressed by other actors along the supply chains (e.g. buyers, cooperatives, governments) although we do not intend to hold smallholder farmers accountable for additional and partly unrealistic requirements.

Many of the identified issues in the social dimension concerned labour rights, such as low wages of farm workers and the lack of worker organizations, which are known problems in cocoa production (Fountain and Huetz-Adams, 2020). Major social issues additionally included gender and discrimination, which also represent recognized problems in cocoa (Ingram et al., 2016). We detected only a few cases of child labour that impaired school education or included hazardous work, which is often associated with cocoa production, however, more commonly in West Africa (Berlan, 2013; Fountain and Huetz-Adams, 2020).

Identified major issues in the governance dimension, such as transparency and holistic audits, were to be expected. Farmers in both case studies were not formally organized in cooperatives, which often take

Fig. 5. Ratio of mean indicator values between high (HEP) and low environmental performers (LEP) within the Economic Resilience dimension and with significant differences between these subgroups. Ratios >1 indicate co-benefits with environmental performance; ratios <1 indicate trade-offs with environmental performance. Indicators that influenced the calculation of results in the Environmental Integrity dimension in the SMART-Farm Tool are marked with a superscript one.

over governance tasks in contexts of smallholder farmers (Ssebunya et al., 2019). While these governance aims are difficult to reach for individual smallholder farmers, including them in sustainability assessments can guide supply chain management in improving supply chain sustainability. The higher performance of the Ugandan sample in this dimension might be a result of several observed factors. Farmers in our Ecuadorian sample were very independent with little collaboration with other farmers. In our Ugandan sample, in contrast, farmers were highly engaged at community level and partly holding official positions like chairpersons or community leaders. Thus, SMART-Farm Tool indicators like "Social involvement outside the farm" or "Communication with stakeholder groups" within the governance dimension scored higher among Ugandan farmers than among Ecuadorians.

4.1.2. Social and economic co-benefits and trade-offs

Grouping farms based on their environmental performance and consequently comparing high and low performers provided answers to our second aim which was to identify whether environmentally-friendly cocoa farms yield social and economic co-benefits. HEP in our samples were characterized by smaller farm sizes with higher shares of cocoa and agroforestry systems as well as the use of less external inputs, however, also by lower cocoa yields and reported incomes compared to LEP.

We started this study hypothesizing that social co-benefits of environmentally-friendly farms within our data set were low because social sustainability rather depends on the broader socio-political and cultural farm setting. For example, social and cultural settings might determine women's access to land or credit as well as participation in farm work and decision-making (Ingram et al., 2016). We found a major social co-benefit of environmentally-friendly production practices in the reduced risk for farmers and workers due to lower pesticide use, as previously identified by Franzen and Borgerhoff Mulder (2007) and Ramankutty et al. (2019). Safer use of agrochemicals and thus reduced health risk is a general positive social outcome of voluntary sustainability certification (Meemken et al., 2021). However, in line with our hypothesis, we identified few additional co-benefits or trade-offs. Among the identified social trade-offs of environmentally-friendly farms in our Ugandan sample was food security (number of meals per day). LEP in the Ugandan sample had higher shares of arable land, which was mainly used for staple production, such as cassava or sweet potato, and thus might improve food security. Past studies have shown a positive influence of associated crops in cocoa agroforests on household food security (Cerda et al., 2014; Mbow et al., 2014). More generally, however, our findings in Uganda mirror the generally perceived trade-off between ecosystem services conservation and food security (Hanspach et al., 2017).

From an economic point of view, being environmentally friendly held both trade-offs and co-benefits for the farmers in our case studies. Most co-benefits regarded the assurance of farm's long-term productivity like soil fertility management and thus do not reflect the parameters typically considered in economic calculations like yields and profitability. Our hypothesis that environmentally-friendly farms would yield economic co-benefits due to reduced expenses for inputs or income diversification is only partly confirmed. While it was found that HEP in our sample used less external inputs, they also sold a lower number of different farm products despite a higher share of the farm area covered by agroforestry. This contradicts Cerda et al. (2014) and Armengot et al. (2016), who found economic benefits in diversified cocoa agroforests. A diverse product range is especially important for cash crops with highly volatile market prices and has been found to be a major economic benefit of agroforests (Tschora and Cherubini, 2020).

Yields were lower among HEP, which is in line with the results from Middendorp et al. (2018) or Tothmihaly et al. (2019), who reported lower cocoa yields from agroforests. The literature review of Martin et al. (2018) highlights that most studies on ecosystem services provision and human well-being (mainly income) in low- and middle income countries find trade-offs between these two aspects. Past studies in cocoa production systems, however, have shown that the trade-offs between ecosystem services provision from agroforests or shade trees and cocoa yields or farm income are not linear: Co-benefits occur until a certain shade level before yields decline, resulting in a trade-off (e.g. Blaser et al., 2018; Waldron et al., 2012). One reason for this observation might be that intermediate shade balances habitats of different cocoa pests and diseases, as some favour shade while others favour sun (Jagoret et al., 2020). Due to similarities in production systems, research on coffee can provide valuable lessons for cocoa. In Guatemala and Costa Rica, coffee farms with medium shade levels were most productive (Haggar et al., 2021), highlighting the importance of good shade balance. Conversely, coffee farms in Nicaragua had lower productivity with rising carbon stocks and tree diversity (Haggar et al., 2017).

However, much research on environmental-economic co-benefits in smallholder farming systems focussed on the effects of voluntary sustainability certification (like organic) on farm profitability (e.g. Bolwig et al., 2009; Haggar et al., 2017; Ramankutty et al., 2019), allowing only limited comparison with our results because HEP in our samples are not remunerated for their environmental performance.

In general, farms in the HEP and LEP subgroup showed substantial structural differences, such as farm size and income (see Table 2), which might partly explain the economic disadvantages faced by HEP. This echoes findings from (Beuchelt and Zeller, 2011), who found coffee farmers with organic certification in Nicaragua to have smaller coffee areas, lower per capita coffee incomes, and higher poverty levels than conventional farmers.

4.2. Implications for future sustainability interventions in cocoa supply chains

Understanding the sustainability performance of a company's supplier base represents the basis for sustainability interventions. The fact that supply chain interventions have mainly addressed agronomic and environmental issues of cocoa production might rather be related to external pressures, reputation risks, and companies' needs for continuous cocoa supply. Our results indicate that they might not address the most severe sustainability issues of the cocoa production system.

To achieve higher co-benefits and reduce trade-offs for farmers, future interventions should be thought through in a comprehensive way. An exemplary aim of reducing pesticide use should provide farmers with knowledge about alternative pest and disease management strategies and assure that farmers have the necessary financial, physical, and social assets to implement these alternatives. Providing financial incentives for high environmental performance or high cocoa quality might create economic co-benefits. The latter is relevant for farmers in Ecuador, for example, who receive the same price for the high quality and traditionally shade-grown fine flavour variety Cacao Nacional as they do for higher yielding modern varieties grown in full-sun systems. As a result, many plots are converted to high yielding and less environmentally-friendly systems because farmers' efforts are not economically valued (Rueda et al., 2018). Furthermore, also governmental advisory services in Ecuador have rather been promoting felling shade trees to increase productivity (Waldron et al., 2012). By engaging in long-term contracts with farmers, companies could demand environmental performance criteria linked to higher prices (Waarts et al., 2019). Voluntary certification schemes provide evidence that price premiums for environmentally-friendly production practices can have positive economic outcomes (Ingram et al., 2018) and price premiums in turn provide farmers with the financial capacities to comply with sustainability requirements (Dietz et al., 2021). This is justified, as environmentally-friendly production practices, such as pruning or phytosanitary measures, often require a higher workload (Armengot et al., 2016; Armengot et al., 2019). Additionally, initial financial incentives for female participants would enable them to engage in environmentally-friendly production practices, such as agroforestry systems, which otherwise might be too costly to implement (Benjamin et al., 2018).

To address broader social and governance issues, companies might need to rethink their approach: while agronomic decisions are taken by individual farmers and thus justify farm-level interventions, social and governance decisions rather depend on the socio-political system in which farmers operate or the farmer group in which they organize. Additional interventions that go beyond the farm level, address systemic issues (Barrientos, 2011; Ingram et al., 2016) in collaboration with different stakeholders (Barrientos, 2011; Nelson and Phillips, 2018; Thorlakson, 2018; Waarts et al., 2019), and link much stronger to broader policy levers (Mausch et al., 2020) might be required. This includes renegotiating roles and responsibilities of foreign companies with producer country governments, whose involvement has been limited despite being crucial players in any intervention's success (Fountain and Huetz-Adams, 2020; Waarts et al., 2019). This also includes the role of voluntary sustainability certification, which has been criticized in the past for generating power asymmetries in global supply chains in favour of downstream actors (Krauss and Barrientos, 2021). Corporate in-house sustainability programs have not yet received the same level of scientific attention and it remains to be seen if these programs will decrease power imbalances between smallholder cocoa farmers and large chocolate manufacturers. While multi-stakeholder and shared learning and responsibility (like the living income community) are already implemented in some geographical regions and for some sustainability topics, such as zero deforestation initiatives in West Africa (Carodenuto, 2019), we did not find such engagement in our case studies.

The results of this study demonstrate the importance of comprehensive sustainability assessments and the evaluation of interlinkages between sustainability dimensions, which should be considered by future research on the sustainability of cocoa production systems in order to capture the true sustainability situation. Finally, the impacts of supply chain mechanisms on farm sustainability remain understudied and should be addressed in the future (Lambin et al., 2018; Thorlakson et al., 2018), including long-term co-benefits and trade-offs between outcomes.

4.3. Limitations

The SMART-Farm Tool operationalizes the FAO-SAFA Guidelines, which were developed as a comprehensive framework covering all relevant aspects of sustainability. The tool offers a standardized multi-criteria assessment approach for benchmarking farms against the SAFA Guidelines transparently and comparing across different farming systems and regions. However, our results need to be interpreted against the limitations of this approach, namely, the lacking accuracy with respect to some indicators and subthemes (Ssebunya et al., 2019) and the uncertainty related to the indicator weights (Schader et al., 2019). Aiming at global applicability, the SMART-Farm Tool covers indicators that might not be relevant for all regions and farming systems. An additional compromise lies in the conversion of qualitative and quantitative indicators into percentage values (indicator scores). While conversion is easy for continuous variables (e.g. Share of farm area with mulch), it is more challenging for nominal and ordinal variables, as thresholds need to be introduced (e.g. Number of active substances used: 0 substances = 100%, 1 substance = 75%, 2–3 substances = 50%, 4–5 substances = 25%, >5 substances = 0%) or categorical variables (e.g. Is the farm's liquidity ensured? No = 0%, Partly = 50%, Yes = 100%). Conversion is also difficult for indicators without differentiation between positive performance and non-use (e.g. What proportion of plastic waste is delivered to recycling points or re-used? All plastic waste = 100%, No generation of plastic waste = 100%). These scoring guideline in the SMART-Farm Tool must be taken into account in the interpretation of results and when drawing conclusions. By aggregating indicators with simultaneous positive and/or negative influence in different subthemes calculation, the model already accounts for co-benefits and trade-offs. To create transparency, we differentiated between those indicators that contributed to the calculation of environmental performance and thus are co-benefits and trade-offs inherent to the model, from those indicators that did not by marking the former with a superscript one in the results figures (Figs. 4 and 5). These model effects also indicate that scoring a maximum value of 100% across all SAFA (sub) themes is unrealistic. Additionally, the SMART-Farm Tool allows testing for simultaneous occurrence of high indicators and (sub)themes scores. It does not, however, allow for a detailed analysis of causal relationships between identified co-benefits and trade-offs, which would require more in-depth quantitative data and should be considered in future studies on this topic. Moreover, our data only refers to a single reference year and to a sample of farmers from a specific cocoa-chocolate supply chain. Co-benefits and trade-offs surely depend on the temporal scale considered (Franzen and Borgerhoff Mulder, 2007) and affect diverse social groups in a different way (Rasmussen et al., 2018), which is not reflected by the current analysis but should be taken up by future research.

5. Conclusions

Our results on sustainability in two specific cocoa production systems identified major social and governance-related sustainability issues, which compared to the environmental and economic dimension of sustainability receive much less attention by research and are insufficiently addressed in food supply chain interventions by private companies. Such interventions rather concentrate on improving agronomic knowledge and environmental impacts with an apparently implicit expectation that further sustainability outcomes will occur indirectly. Results within our samples show that this focus yields some important social and economic co-benefits, especially regarding the direct advantages of reduced pesticide use for human health or internal investments for farms' long-term productivity. Our results, however, also suggest several social and economic trade-offs when farmers implement environmentally-friendly production practices. Improving social and economic sustainability on cocoa farms needs targeted interventions instead of relying on synergistic effects from environmentally-friendly production practices like financial incentives for adopting sustainable practices or for high quality cocoa. Using a comprehensive sustainability assessment methodology allowed us to identify often overlooked sustainability issues in the social and good governance dimensions at farm level and evaluate interrelationships more broadly. This approach enabled more nuanced findings compared to past research on cocoa sustainability, which has largely either addressed environmental impacts or economic outcomes with some studies addressing interrelationships between the two.

In order to provide more sustainable cocoa, companies of the cocoa-chocolate supply chain should broaden their sustainability mechanisms thematically to include the underrepresented social and governance sustainability dimensions. As these not only concern the farm level but rather systemic issues and the socio-cultural setting in which farmers operate, different strategies might be needed. Pure supply chain interventions might not be able to tackle wider societal challenges (Mausch et al., 2020). As an example, approaches of public-private partnerships or multi-stakeholder initiatives are being tested for particularly salient issues like hazardous child labour or deforestation in West Africa (Carodenuto, 2019; NORC, 2020). However, these multi-stakeholder initiatives and processes did not always include all stakeholders and thus values and visions in the past (Nelson and Phillips, 2018). Finally, much remains to be understood about how to create more synergistic effects between sustainability dimensions as well as the impacts of sustainability initiatives, which are essential to guide the future development of supply chain mechanisms and policies to improve sustainability in cocoa production.

Funding

This work was supported by the Swiss National Science Foundation [grant number 407340_172451].

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank all farmers who participated in this study, all extension officers and company staff assisting in the organization, as well as the two industry partner companies. Acknowledgements also go to the data collection teams in both countries (Moritz Egger, Elio Palmero, Brian Ssebunya, Kagimu Martin, Mwesigwa Lauben, Kawere Brasio Kigongo, Lilian Victor Nakirigya, Ajio Florence, Nathan Ruhiiga, and David Derrick Mubiru). The authors also thank Eric F. Lambin for his useful comments and helpful advice throughout the research process as well as Anja Heidenreich and Robert Home for valuable comments on this manuscript.

Appendix A. Annex

Annex 1
SAFA Themes and Subthemes with corresponding objectives as well as median (standard deviation) goal achievements within the Ecuadorian and Ugandan case study.

Dimension	Theme	Subtheme	Sub-theme objective	Median (sd) Goal achievement EC	Median (sd) Goal achievement UG
Good Governance	Corporate Ethics	Mission Statement	The enterprise has made its commitment to all areas of sustainability clear to the public, to all personnel and other stakeholders through publishing a mission statement or other similar declaration (such as a code of conduct or vision statement) that is binding for management and employees or members.	24 (22)	41 (24)
		Due Diligence	The enterprise is pro-active in considering its external impacts before making decisions that have long-term impacts for any area of sustainability. This is accomplished through the enterprise following appropriate procedures such as risk assessment and others that ensure that stakeholders are informed, engaged and respected.	40.5 (9)	53 (11)
	Accountability	Holistic Audits	All areas of sustainability in the SAFA dimensions that pertain to the enterprise are monitored internally in an appropriate manner, and wherever possible are reviewed according to recognized sustainability reporting systems.	12 (9)	18 (8)
		Responsibility	Senior management and/or owners of enterprise regularly and explicitly evaluate the enterprise's performance against its mission or code of conduct.	27.5 (11)	43 (13)
		Transparency	All procedures, policies, decisions or decision-making processes are accessible where appropriate publicly, and made available to stakeholders including personnel and others affected by the enterprise's activities.	18 (12)	45 (14)
	Participation	Stakeholder Dialogue	The enterprise pro-actively identifies stakeholders, which include all those affected by the activities of the enterprise (including any stakeholders unable to claim their rights), and ensures that all are informed, engaged in critical decision making, and that their input is duly considered.	47 (12)	70 (12)
		Grievance Procedures	All stakeholders (including as stated above, those who cannot claim their rights, personnel, and any stakeholders in or outside of the enterprise) have access to appropriate grievance procedures, without a risk of negative consequences.	31 (23)	52 (21)
		Conflict Resolution	Conflicts between stakeholder interests and the enterprise's activities are resolved through collaborative dialogue (i.e. arbitrated, mediated, facilitated, conciliated or negotiated), based on respect, mutual understanding and equal power.	57 (12)	77 (11)
	Rule of Law	Legitimacy	The enterprise is compliant with all applicable laws, regulations and standards voluntarily entered into by the enterprise (unless as part of an explicit campaign of non-violent civil disobedience or protest) and international human rights standards (whether legally obligated or not).	59 (9)	66 (10)
		Remedy, Restoration & Prevention	In case of any legal infringements or any other identified breach of legal, regulatory, international human rights, or voluntary standard, the enterprise immediately puts in place an effective remedy and adequate actions for restoration and further prevention are taken.	70 (10)	86 (10)
		Civic Responsibility	Within its sphere of influence, the enterprise supports the improvement of the legal and regulatory framework on all dimensions of sustainability and does not seek to avoid the impact of human rights, or sustainability standards, or regulation through the corporate veil, relocation, or any other means.	5 (14)	18 (19)
		Resource Appropriation	Enterprises do not reduce the existing rights of communities to land, water and resources, and operations are carried after informing affected communities by providing information, independent advice and building capacity to self- organize for the purposes of representation.	59 (8)	64 (8)
	Holistic Management	Sustainability Management Plan	A sustainability plan for the enterprise is developed which provides a holistic view of sustainability and considers synergies and trade-offs between dimensions, including each of the environmental, economic, social and governance dimensions.	18 (11)	32 (15)
		Full-Cost Accounting	The business success of the enterprise is measured and reported taking into account direct and indirect impacts on the economy, society and physical environment (e.g. triple bottom line reporting), and the accounting process makes transparent both direct and indirect subsidies received, as well as direct and indirect costs externalized.	12 (17)	25 (19)
Environ-mental Integrity	Atmosphere	Greenhouse Gases	The emission of GHG is contained.	69 (6)	70 (5)
		Air Quality	The emission of air pollutants is prevented and ozone depleting substances are eliminated.	74 (7)	82 (7)
	Water	Water Withdrawal		68.5 (13)	58 (12)

(continued on next page)

Annex 1 (*continued*)

Dimension	Theme	Subtheme	Sub-theme objective	Median (sd) Goal achievement EC	Median (sd) Goal achievement UG
			Withdrawal of ground and surface water and/or use does not impair the functioning of natural water cycles and ecosystems and human, plant and animal communities.		
		Water Quality	The release of water pollutants is prevented and water quality is restored.	66 (8)	68 (9)
	Land	Soil Quality	Soil characteristics provide the best conditions for plant growth and soil health, while chemical and biological soil contamination is prevented.	65 (7)	65 (5)
		Land Degradation	No land is lost through soil degradation and desertification and degraded land is rehabilitated.	71 (8)	69 (6)
	Biodiversity	Ecosystem Diversity	The diversity, functional integrity and connectivity of natural, semi-natural and agrifood ecosystems are conserved and improved.	50.5 (13)	57 (8)
		Species Diversity	The diversity of wild species living in natural and semi-natural ecosystems, as well as the diversity of domesticated species living in agricultural, forestry and fisheries ecosystems is conserved and improved.	60 (11)	63.5 (9)
		Genetic Diversity	The diversity of populations of wild species, as well as the diversity of varieties, cultivars and breeds of domesticated species, is conserved and improved.	57 (12)	64 (8)
	Materials and Energy	Material Use	Material consumption is minimized and reuse, recycling and recovery rates are maximized.	59 (8)	68 (7)
		Energy Use	Overall energy consumption is minimized and use of sustainable renewable energy is maximized.	70 (6)	78 (6)
		Waste Reduction & Disposal	Waste generation is prevented and is disposed of in a way that does not threaten the health of humans and ecosystems and food loss/waste is minimized.	62 (9)	74 (9)
	Animal Welfare	Animal Health	Animals are kept free from hunger and thirst, injury and disease.	77 (11)	71 (9)
		Freedom from Stress	Animals are kept under species-appropriate conditions and free from discomfort, pain, injury and disease, fear and distress.	77 (13)	74 (9)
Economic Resilience	Investment	Internal Investment	In a continuous, foresighted manner, the enterprise invests into enhancing its sustainability performance.	65 (8)	60 (7)
		Community Investment	Through its investments, the enterprise contributes to sustainable development of a community.	41 (13)	55 (10)
		Long-Ranging Investment	Investments into production facilities, resources, market infrastructure, shares and acquisitions aim at long-term sustainability rather than maximum short-term profit.	56 (10)	61 (9)
		Profitability	Through its investments and business activities, the enterprise has the capacity to generate a positive net income.	50 (8)	55 (8)
	Vulnerability	Stability of Production	Production (quantity and quality) is sufficiently resilient to withstand and be adapted to environmental, social and economic shocks.	55 (6)	56 (6)
		Stability of Supply	Stable business relationships are maintained with a sufficient number of input suppliers and alternative procurement channels are accessible.	68 (9)	75 (9)
		Stability of Market	Stable business relationships are maintained with a sufficient number of buyers, income structure is diversified and alternative marketing channels are accessible.	49 (8)	59 (9)
		Liquidity	Financial liquidity, access to credits and insurance (formal and informal) against economic, environmental and social risk enable the enterprise to withstand shortfalls in payment.	55 (13)	56 (12)
		Risk Management	Strategies are in place to manage and mitigate the internal and external risks (i.e. price, production, market, credit, workforce, social, environmental) that the enterprise could face to withstand their negative impact.	50 (13)	58 (8)
	Product Quality & Information	Food Safety	Food hazards are systematically controlled and any contamination of food with potentially harmful substances is avoided.	55 (10)	62 (14)
		Food Quality	The quality of food products meets the highest nutritional standards applicable to the respective type of product.	75.5 (8)	73 (9)
		Product Information	Products bear complete information that is correct, by no means misleading and accessible for consumers and all members of the food chain.	16 (5)	21.5 (6)
	Local Economy	Value Creation	Enterprises benefit local economies through employment and through payment of local taxes.	43 (8)	44 (10)
		Local Procurement	Enterprises substantially benefit local economies through procurement from local suppliers.	65 (19)	55 (20)
Social Well-Being	Decent Livelihood	Quality of Life	All producers and employees in enterprises of all scales enjoy a livelihood that provides a culturally appropriate and nutritionally adequate diet and allows time for family, rest and culture.	55.5 (6)	59 (7)
		Capacity Development	Through training and education, all primary producers and personnel have opportunities to acquire the skills and knowledge necessary to undertake current and future tasks required by the enterprise, as well as the resources to provide for	29 (21)	39 (22)

(*continued on next page*)

Annex 1 (*continued*)

Dimension	Theme	Subtheme	Sub-theme objective	Median (sd) Goal achievement EC	Median (sd) Goal achievement UG
			further training and education for themselves and members of their families.		
		Fair Access to Means of Production	Primary producers have access to the means of production, including equipment, capital and knowledge.	68 (14)	71 (11)
	Fair Trading Practices	Responsible Buyers	The enterprise ensures that a fair price is established through negotiations with suppliers that allow them to earn and pay their own employees a living wage, and cover their costs of production, as well as maintain a high level of sustainability in their practices. Negotiations and contracts (verbal or written) are transparent, based on equal power, terminated only for just cause, and terms are mutually agreed upon.	32 (9)	37 (9)
		Rights of Suppliers	The enterprises negotiating a fair price explicitly recognize and support in good faith suppliers' rights to freedom of association and collective bargaining for all contracts and agreements.	28 (13)	17.5 (14)
	Labour Rights	Employment Relations	Enterprises maintain legally-binding transparent contracts with all employees that are accessible and cover the terms of work and employment is compliant with national laws on labour and social security.	50 (9)	52 (10)
		Forced Labour	The enterprise accepts no forced, bonded or involuntary labour, neither in its own operations nor those of business partners.	25 (9)	25 (10)
		Child Labour	The enterprise accepts no child labour that has a potential to harm the physical or mental health or hinder the education of minors, neither in its own operations nor those of business partners.	47 (8)	47 (22)
		Freedom of Association and Right to Bargaining	All persons in the enterprise can freely execute the rights to: negotiate the terms of their employment individually or as a group; form or adhere to an association defending workers' rights; and collectively bargain, without retribution.	26 (11)	32.5 (14)
	Equity	Non Discrimination	A strict equity and non-discrimination policy is pursued towards all stakeholders; non-discrimination and equal opportunities are explicitly mentioned in enterprise hiring policies, employee or personnel policies (whether written or verbal or code of conduct) and adequate means for implementation and evaluation are in place.	44 (8)	43 (8)
		Gender Equality	There is no gender disparity concerning hiring, remuneration, access to resources, education and career opportunities.	39 (12)	27 (14)
		Support to Vulnerable People	Vulnerable groups, such as young or elderly employees, women, the disabled, minorities and socially disadvantaged are proactively supported.	25 (12)	25 (12)
	Human Safety & Health	Workplace Safety and Health Provisions	The enterprise ensures that the workplace is safe, has met all appropriate regulations, and caters to the satisfaction of human needs in the provision of sanitary facilities, safe and ergonomic work environment, clean water, healthy food, and clean accommodation (if offered).	60 (9)	60 (14)
		Public Health	The enterprise ensures that operations and business activities do not limit the healthy and safe lifestyles of the local community and contributes to community health resources and services.	60 (9)	66.5 (12)
	Cultural Diversity	Indigenous Knowledge	Intellectual property rights related to traditional and cultural knowledge are protected and recognized.	66 (17)	95 (9)
		Food Sovereignty	The enterprise contributes to, and benefits from, exercising the right to choice and ownership of their production means, specifically in the preservation and use of traditional, heirloom and locally adapted varieties or breeds.	52 (10)	61 (9)

Annex 2

Mean (standard deviation) goal achievements within five Environmental Integrity Themes of the SAFA Guidelines for high and low environmental performers in the Ecuadorian and Ugandan sample. Statistical analysis using a Kruskal-Wallis Test.

Governance Theme	Ecuador			Uganda		
	High environmental performers (N = 46)	Low environmental performers (N = 36)	p-value	High environmental performers (N = 64)	Low environmental performers (N = 30)	p-value
Atmosphere	78.00 (3.79)	59.89 (3.99)	< 0.001	81.05 (3.67)	67.93 (3.61)	< 0.001
Biodiversity	68.39 (6.71)	44.56 (8.11)	< 0.001	69.98 (4.08)	52.53 (5.66)	< 0.001
Land	75.37 (4.53)	57.86 (6.11)	< 0.001	72.19 (3.39)	61.37 (3.57)	< 0.001
Materials and Energy	68.52 (4.90)	54.33 (5.19)	< 0.001	77.97 (4.17)	65.47 (4.32)	< 0.001
Water	73.93 (5.50)	55.53 (6.95)	< 0.001	71.53 (6.15)	53.90 (5.86)	< 0.001

Annex 3

Mean (standard deviation) of Environmental Integrity indicator scores with significant difference between high and low environmental performers in both case studies. The weights refer to the relative importance of each indicator to reach Environmental Integrity subthemes. Empty cells indicate no significant difference between high and low environmental performers for specific indicator and case study. Statistical analysis using a Kruskal-Wallis Test.

	Ecuador			Uganda			
Indicator	High environmental performers (N = 46)	Low environmental performers (N = 36)	p-value	High environmental performers (N = 64)	Low environmental performers (N = 30)	p-value	Weight
00399_UseRainwater	0.86 (0.32)	0.27 (0.41)	0.000				0.973
00738_ProductionMaterialsUsageProblematicElements	0.84 (0.37)	0.53 (0.51)	0.003	1.00 (0.00)	0.73 (0.45)	0.000	0.905
00198_DualPurposeBreedsRuminants	0.81 (0.39)	0.31 (0.47)	0.000	0.92 (0.27)	0.10 (0.31)	0.000	0.9
00619_2_DrainedArableLandOnPeatland	0.63 (0.38)	0.15 (0.24)	0.000	0.92 (0.26)	0.09 (0.21)	0.000	0.889
00353_LivestockHealthProphylacticTreatments	0.85 (0.23)	0.55 (0.32)	0.000	0.82 (0.14)	0.63 (0.25)	0.000	0.878
00206_ShareLegumesArableLand	0.52 (0.44)	0.10 (0.23)	0.000	0.90 (0.29)	0.03 (0.18)	0.000	0.869
00215_ArableLandShareTemporaryGrassland_Calculated	0.74 (0.33)	0.28 (0.28)	0.000	0.96 (0.17)	0.20 (0.29)	0.000	0.869
00517_FeedNoFoodGrazingLivestock	0.13 (0.34)	0.00 (0.00)	0.025	0.30 (0.46)	0.03 (0.18)	0.004	0.864
00376_1_InformationWaterAvailability	0.91 (0.28)	0.47 (0.51)	0.000	0.97 (0.18)	0.80 (0.41)	0.007	0.864
00236_1_NumberElementsCropRotation	0.67 (0.48)	0.11 (0.32)	0.000	0.92 (0.27)	0.20 (0.41)	0.000	0.858
00788_OpenBurning	0.99 (0.04)	0.79 (0.33)	0.000	0.98 (0.06)	0.77 (0.31)	0.000	0.855
00740_GrowthRegulation	0.67 (0.40)	0.16 (0.28)	0.000	0.95 (0.19)	0.14 (0.26)	0.000	0.851
00345_IrrigationLowEnergyTechnologyPumps	0.82 (0.17)	0.62 (0.31)	0.000				0.85
00324_1_PFromFertilizers_Calc				0.12 (0.21)	0.25 (0.32)	0.042	0.823
00289_1_HumusFormationCropResidues	0.98 (0.15)	0.78 (0.42)	0.004				0.821
00247_HybridCultivars				0.94 (0.23)	0.77 (0.43)	0.029	0.817
00377_1_PesticidesNumberActiveSubstances	0.89 (0.21)	0.68 (0.25)	0.003				0.8
00204_WoodlandsDeforestation	0.81 (0.32)	0.32 (0.39)	0.000				0.8
00601_PermanentGrasslandConversion				0.92 (0.18)	0.74 (0.33)	0.015	0.795
00404_IrrigationPrecipitationMeasurement	0.80 (0.40)	0.50 (0.51)	0.004				0.793
00519_UseageGMOcrops	0.88 (0.33)	0.58 (0.50)	0.007				0.792
00748_HumusFormationHumusBalance	0.67 (0.49)	0.22 (0.43)	0.017				0.787
00605_1_ManagementRiparianStripes				0.92 (0.27)	0.33 (0.48)	0.000	0.787
00757_ShareGreenCoverPerennialCropLand	0.81 (0.31)	0.61 (0.36)	0.007				0.78
00335_1_RecyclingPaper	0.78 (0.42)	0.47 (0.51)	0.005	0.88 (0.33)	0.70 (0.47)	0.041	0.775
00710_1_HarmfulSubstancesPFertilizer	0.75 (0.41)	0.20 (0.34)	0.000	0.97 (0.14)	0.57 (0.36)	0.000	0.772
00186_RenewableEnergyProductionOnFarm_Calculated	0.61 (0.35)	0.13 (0.23)	0.000	0.69 (0.23)	0.51 (0.20)	0.000	0.77
00332_ElectricityConsumption	0.91 (0.24)	0.55 (0.40)	0.000	0.96 (0.15)	0.55 (0.28)	0.000	0.768
00744_1_PromotionBeneficialOrganisms	0.80 (0.31)	0.65 (0.33)	0.038				0.76
00334_3_RecyclingPlastic	1.00 (0.00)	0.87 (0.32)	0.01				0.752
00334_5_RecyclingGlass	0.98 (0.08)	0.79 (0.35)	0.002	1.00 (0.00)	0.92 (0.11)	0.000	0.752
00378_DistanceManureWater	0.75 (0.44)	0.50 (0.51)	0.025				0.75
00323_1_NFromFertilizers_Calc	0.52 (0.51)	0.22 (0.42)	0.006				0.747
00233_NoUseSynthChemFungicides				0.41 (0.48)	0.08 (0.18)	0.001	0.738
00288_ArableLandErosionControlGreater15Percent	0.20 (0.27)	0.07 (0.18)	0.019	0.45 (0.18)	0.18 (0.28)	0.000	0.729
00234_NoUseSynthChemInsecticides	0.99 (0.04)	0.94 (0.18)	0.02				0.727
00202_AgroForestrySystems_Calculated	0.98 (0.15)	0.83 (0.38)	0.021				0.723
00231_NoUseSynthChemHerbicides				0.98 (0.11)	0.68 (0.25)	0.000	0.715
00380_NutrientsPollutantsSourcesOnFarm	0.46 (0.50)	0.10 (0.29)	0.000				0.71
00299_ArableLandGreenCoverGreater30Percent	0.85 (0.26)	0.50 (0.36)	0.000				0.707
00253_PermanentGrasslandsExtensivelyManaged	0.70 (0.47)	0.39 (0.49)	0.006	0.91 (0.29)	0.50 (0.51)	0.000	0.697
00348_FuelFromRenewableSources	0.98 (0.15)	0.83 (0.38)	0.021				0.693
00298_SoilImprovement	0.56 (0.44)	0.19 (0.32)	0.000				0.693
00334_4_RecyclingMetal	0.85 (0.36)	0.56 (0.50)	0.004	0.92 (0.27)	0.47 (0.51)	0.000	0.692
00739_ReusablePackagingMaterials	0.95 (0.21)	0.79 (0.40)	0.015	0.95 (0.22)	0.82 (0.38)	0.024	0.689
00802_AgroforestryLayers	0.89 (0.31)	0.39 (0.48)	0.000	0.93 (0.24)	0.77 (0.43)	0.032	0.677
00800_LandClearingMethod	0.82 (0.18)	0.39 (0.25)	0.000	0.96 (0.13)	0.34 (0.23)	0.000	0.673
00337_1_FoodWasteDisposal	0.72 (0.46)	0.21 (0.40)	0.000	0.69 (0.47)	0.27 (0.45)	0.000	0.668
00334_RecyclingWasteOil	1.00 (0.00)	0.92 (0.18)	0.004				0.666
00223_RareEndangeredCrops	0.02 (0.06)	0.00 (0.00)	0.039	0.07 (0.21)	0.01 (0.04)	0.046	0.654
00711_EcolComensationValuableLandscapeElements				0.82 (0.22)	0.64 (0.23)	0.000	0.654
00377_75_PesticidesAcuteToxicityInhalation	0.91 (0.28)	0.64 (0.49)	0.002				0.653
00389_IrrigationWaterConsumption_Calculated				1.00 (0.00)	0.63 (0.49)	0.000	0.647
00377_5_PesticidesChronicToxicity	0.74 (0.43)	0.33 (0.43)	0.000				0.641
00765_CorrectWasteDisposal	0.12 (0.18)	0.00 (0.00)	0.014				0.627
00327_WasteDisposalPesticidesVeterinaryMedicines	0.20 (0.40)	0.00 (0.00)	0.005				0.626
00257_2_PesticidesToxicityAquaticOrganisms	1.00 (0.00)	0.79 (0.35)	0.036				0.598
00257_1_PesticidesToxicityBees				0.18 (0.36)	0.03 (0.14)	0.037	0.592
00383_AnnualWaterConsumption_Calculated	0.80 (0.45)	0.14 (0.36)	0.008	0.53 (0.46)	0.20 (0.28)	0.002	0.587
00377_7_PesticidesAcuteToxicity	0.91 (0.28)	0.56 (0.49)	0.000				0.561
00474_1_PesticidesPersistenceWater				0.92 (0.27)	0.53 (0.51)	0.000	0.538
00474_2_PesticidesPersistenceSoil	1.00 (0.01)	0.66 (0.41)	0.005				0.437
00229_1_BiodivAreaShareOfFarmLand_Calc				0.68 (0.47)	0.30 (0.47)	0.000	0.36

Annex 4
Mean (standard deviation) scores for high and low environmental performers for each indicator in the social and economic dimension that show co-benefits or trade-offs with the environmental dimension.

Indicator	Indicator question	Response scale / unit	Ecuador		Uganda	
			HEP	LEP	HEP	LEP
Dimension: Social Well-Being						
Commitment against discrimination	Has the farm committed itself to prevent discrimination against women, minorities and vulnerable groups?	Binary (Yes, No)	0.57 (0.50)	0.31 (0.47)		
Distance manure heap to waters	Is the shortest distance between the "worst" of the storage facilities for livestock wastes or silage and the nearest water resource (well, open drain, sewer, river) more than 30 m?	Binary (Yes, No)	0.75 (0.43)	0.5 (0.50)		
Environmental involvement outside the farm: Costs	Is the farm involved in environmental protection (not paid for), besides its own land? If yes, how many days per year are taken for such projects?	Numeric (days)	0.20 (0.32)	0.07 (0.21)		
Feed No Food: grazing livestock	What proportion of the feed given to grazing livestock would be suitable for human consumption (For maize silage take standard yields for grain maize)?	Percentage (% of feed)	1.00 (0.00)	0.79 (0.34)		
Growth regulation	Does the farm decline to use synthetic chemical growth regulators?	Binary (Yes, No)			1.00 (0.00)	0.63 (0.49)
Harmful substances P-fertilisers	Can the risk be excluded that the farm used mineral P fertilisers (e.g. superphosphate, rock phosphate) with critical contents of cadmium or uranium in the last five years?	Ordinal (Yes, Partly, No)			0.97 (0.10)	0.68 (0.24)
Household food security	Do all members of the farm household have adequate nutritional meals each day?	Ordinal (Yes, Partly, No)			0.87 (0.25)	0.98 (0.09)
Hybrid cultivars	Does the farm decline to cultivate hybrid cultivars?	Ordinal (Yes, Partly, No)	0.71 (0.45)	0.20 (0.40)	0.68 (0.46)	0.26 (0.44)
Livestock health: Proportion of prophylactic treatments	What proportion of the animals (across all livestock categories) was given prophylactic treatments, preventive before any clinical signs of disease, including for purposes of enhanced performance, during the past year?	Percentage (% of animals)	0.91 (0.28)	0.55 (0.49)		
Management of riparian strips	Are the riparian strips extensively managed (minimum width 3 m, no cultivation, no fertilisers, no pesticides)?	Binary (Yes, No)	0.69 (0.46)	0.38 (0.49)	0.90 (0.29)	0.5 (0.50)
Mechanization: Feeding roughage	To what extent does mechanization reduce the physical workload when feeding roughage?	Ordinal (Small, Medium, High)			0.06 (0.25)	0.25 (0.35)
No use of synth. Chem. fungicides	What proportion of the agricultural area does not receive synthetic chemical fungicide applications?	Percentage (% of agric. area)	0.98 (0.08)	0.79 (0.35)	1.00 (0.00)	0.92 (0.11)
No use of synth. Chem. herbicides	What proportion of the agricultural area does not receive synthetic chemical herbicide applications?	Percentage (% of agric. area)	0.75 (0.40)	0.20 (0.33)	0.97 (0.13)	0.57 (0.36)
No use of synth. Chem. insecticides	What proportion of the agricultural area does not receive synthetic chemical insecticide applications?	Percentage (% of agric. area)	0.91 (0.23)	0.55 (0.40)	0.96 (0.15)	0.54 (0.28)
Number of jobs created/ removed	How many new (= additional) jobs have been created at your farm in the past 5 years, or how many jobs have been removed?	Ordinal (Cut, Neither, Created)			0.57 (0.26)	0.73 (0.28)
On-farm point sources of nutrients and pollutants	Can it be excluded that there are direct point source emissions of nutrients and pollutants to the atmosphere and water bodies (incl. Wells and drinking water sources) on the farm and its utilized areas?	Binary (Yes, No)	0.77 (0.42)	0.47 (0.50)	0.87 (0.33)	0.7 (0.46)
Open burning of farm or household wastes and bushes	Does the farm refrain from burning of bushes, crop residues and household/farm wastes?	Ordinal (Yes, Partly, No)	0.73 (0.43)	0.33 (0.43)		
Pesticides: Acute toxicity	Pesticides: Are active substances used, which are classified by the WHO as acute toxic to the health of the users?	Numeric (based on list of pesticides)	0.63 (0.37)	0.14 (0.23)	0.92 (0.26)	0.08 (0.21)
Pesticides: Acute toxicity inhalation	Pesticides: Are active substances used, which are considered acute toxic when inhaled by the users according to the "Globally Harmonized System of Classification (GHS)"?	Numeric (based on list of pesticides)	0.67 (0.40)	0.16 (0.28)	0.95 (0.18)	0.14 (0.26)
Pesticides: Chronic toxicity	Pesticides: Are active substances used, which are considered to have adverse long term effects on the users according to the "PAN List of HHPs" or "PAN Pesticide Database"?	Binary (Yes, No)	0.66 (0.47)	0.11 (0.31)	0.92 (0.27)	0.2 (0.40)
Pesticides: Knowledge about active substances	Are the active substances and the risks associated to their use known to the farm manager?	Ordinal (Yes, Partly, No)			0.00 (0.00)	0.32 (0.30)
Pesticides: Number of active substances	How many active substances of pesticides are used per year?	Numeric (active substances)	0.81 (0.17)	0.38 (0.24)	0.95 (0.13)	0.34 (0.23)
Pesticides: Persistence soil	Pesticides: Are active substances used, which are considered to be very persistent in soil (half-life >180 days) according to the "PAN Pesticide Database"?	Binary (Yes, No)	0.83 (0.37)	0.52 (0.50)	1.00 (0.00)	0.73 (0.44)
Pesticides: Persistence water	Pesticides: Are active substances used, which are considered very persistent in water (half-life >60 days) according to the "PAN Pesticide Database"?	Binary (Yes, No)	0.81 (0.39)	0.30 (0.46)	0.92 (0.27)	0.1 (0.30)
Pesticides: Toxicity aquatic organisms	Pesticides: Are active substances used, which are considered to be toxic to aquatic organisms according to the "PAN Pesticide Database"?	Numeric (based on list of pesticides)	0.51 (0.44)	0.10 (0.22)	0.89 (0.29)	0.03 (0.18)
Pesticides: Toxicity bees	Pesticides: Are active substances used, which are considered toxic to bees according to the "PAN Pesticide Database"?	Numeric (based on list of pesticides)	0.74 (0.33)	0.28 (0.27)	0.95 (0.16)	0.19 (0.29)
Pig keeping: quarantine section for sick pigs	Does the farm have a quarantine space (pens) for sick animals?	Binary (Yes, No)			0.31 (0.47)	0.83 (0.40)
Rare or endangered agricultural crops	How many rare or endangered agricultural crops are grown on the farm?	Numeric (crops)			0.11 (0.21)	0.25 (0.32)
Recycling of plastic waste	What proportion of the plastic waste is delivered to recycling points?	Percentage (% of waste)			0.41 (0.47)	0.07 (0.17)
Recycling of waste oil	What proportion of the used oil is delivered to recycling points?	Percentage (% of waste)	0.97 (0.14)	0.77 (0.42)		
	Does the farm refuse to use seeds dressed with synthetic chemicals?	Binary (Yes, No)	1 (0)			

(*continued on next page*)

Annex 4 (*continued*)

Indicator	Indicator question	Response scale / unit	Ecuador		Uganda	
			HEP	LEP	HEP	LEP
Use of chem. Synth. seed dressings				0.80 (0.40)	0.82 (0.38)	0.23 (0.43)
Use of GMO-crops	Is there a risk that GMO crops are grown at the farm?	Binary (Yes, No)	0.97 (0.14)	0.83 (0.37)		
Waste disposal: pesticides and veterinary medicines	Are all waste materials from plant protection products and veterinary medicines disposed properly?	Binary (Yes, No)	0.91 (0.28)	0.47 (0.50)	0.96 (0.17)	0.8 (0.40)
Workers: Regular breaks	Are all employees free to take regular breaks?	Binary (Yes, No)			1.00 (0.00)	0.93 (0.25)
Workers: Use of protective gear	Does the farmer ensure that workers have appropriate protection during their application of pesticides and other hazardous materials?	Ordinal (Yes, Partly, No)	0.65 (0.48)	0.30 (0.46)	0.84 (0.36)	0.2 (0.40)
Workers: Weekly working hours	What are the average working hours per week of all employees (including seasonal workers, family members as well as the farm manager)?	Numeric (hours)			0.81 (0.32)	0.55 (0.44)
Dimension: Economic Resilience						
Agricultural area: Erosion control >15%	Are sufficient measures taken on agricultural areas (excluding permanent grassland) with sloping gradients higher than 15% (up to 30%) to prevent erosion (e.g. contour ploughing)?	Ordinal (Yes, Partly, No)	0.79 (0.31)	0.65 (0.33)		
Agricultural area: Green cover >30%	Care is taken on agricultural areas with sloping gradients higher than 30% to ensure a good, continuous green cover (under sown crops, catch crops etc.)?	Ordinal (Yes, Partly, No)	0.81 (0.30)	0.61 (0.36)		
Agro-forestry systems	What proportion of the farm's agricultural area is devoted to agro-forestry systems?	Percentage (% of agric. area)	0.61 (0.34)	0.13 (0.23)	0.68 (0.23)	0.50 (0.19)
Animal welfare standards slaughter	Does the farm manager know the welfare standards of the slaughterhouse?	Binary (Yes, No)			0.23 (0.43)	0.66 (0.48)
Arable land: Share of temporary grasslands	What proportion of the arable land is devoted to temporary grassland (grass-clover, ley, alfalfa etc.)?	Percentage (% of arable land)			0.18 (0.36)	0.03 (0.14)
Areas for biodiversity promotion	What proportion of the agricultural area are ecological compensation areas / areas to promote biodiversity?	Percentage (% of agric. area)	0.82 (0.17)	0.61 (0.31)		
Condition of farm infrastructure	What is the general condition of the farm infrastructure (buildings, installations, machinery and vehicles necessary to maintain proper functioning of the farm)?	Ordinal (Good, Medium, Poor)	0.63 (0.30)	0.77 (0.27)	0.62 (0.37)	0.81 (0.28)
Dependency on main customer	What proportion of sales profit, in terms of income, does the most important buyer generate?	Percentage (% of sales)			0.41 (0.25)	0.57 (0.24)
Diversification of income	How many other sources of income (related to agriculture and which contribute more than 10% of farmer's income) exist on the farm besides farming?	Numeric (income sources)			0.19 (0.34)	0.45 (0.43)
Diversification of sales	To how many customers does the farm sell its products?	Numeric (customers)			0.67 (0.24)	0.88 (0.14)
Dual-purpose breeds: Ruminants	What proportion of the ruminants are dual-purpose breeds?	Percentage (% of ruminants)	0.99 (0.01)	0.66 (0.41)		
Farm Net Income	Over the past five years, was the farm able to generate a positive net income (which also includes a living wage for the farmer and his family)?	Ordinal (Yes, Partly, No)			0.44 (0.41)	0.74 (0.27)
Food Waste Disposal	Was there any produced food intended for human consumption disposed of over the past five years?	Ordinal (Yes, Partly, No)			0.93 (0.22)	0.76 (0.43)
Humus Formation: Humus balance	Is a humus balance calculated and is the humus balance positive, balanced or negative on average? (In case of small holder farms, check whether the farmer focuses on practices that improve humus balance)	Ordinal (No, Negative, Balanced/ Positive)	0.55 (0.43)	0.18 (0.32)		
Irrigation: Low energy technology and pumps	Does the farm use low-energy irrigation technology and pumps, drip irrigation and micro irrigation?	Binary (Yes, No)	0.91 (0.28)	0.63 (0.48)		
Liquidity	Is the liquidity of the farm ensured?	Ordinal (Yes, Partly, No)			0.45 (0.38)	0.73 (0.34)
Local procurement: producer level	Proportion of the five most important inputs that are produced locally or domestically, weighted by total expenses	Percentage (% of costs)	0.51 (0.34)	0.35 (0.32)		
Long term investments	Has the farm invested in long-term improvements to infrastructure (buildings, roads) or in the purchase of further productive land in the last 10 years?	Binary (Yes, No)	0.36 (0.48)	0.63 (0.48)	0.28 (0.45)	0.6 (0.49)
Market challenges	Is the farmer aware and informed about future market challenges?	Ordinal (Yes, Partly, No)			0.19 (0.27)	0.35 (0.26)
N from fertilisers	How much N from fertilisers (in kg) does the farm apply on its agricultural area per hectare per year?	Numeric (N)	1.00 (0.00)	0.87 (0.31)		
On-farm renewable energy production	What proportion of the electricity consumed is generated by the farm's own installations that are run with renewable sources?	Percentage (% of energy)	0.97 (0.14)	0.83 (0.37)		
Oral information sustainability improvements	Is the farm manager able to describe planned sustainability improvements in detail?	Ordinal (Yes, Few, No)	0.26 (0.31)	0.04 (0.14)		
P from fertilisers	How much P from fertilisers (in kg P2O5) does the farm apply on its agricultural area per hectare per year?	Numeric (P)			0.81 (0.22)	0.64 (0.23)
Permanent grasslands: Extensively managed	What proportion of the area of permanent grassland is under extensive management?	Percentage (% of perm. grassland)	0.66 (0.49)	0.22 (0.42)		
Political / Policy challenges	Is the farmer aware and informed about future policy changes / political challenges?	Ordinal (Yes, Partly, No)			0.06 (0.16)	0.2 (0.28)
Professional agricultural accounts	Does the farm have a professional agricultural accounting procedure that is also used for the farm management?	Ordinal (Yes, Partly, No)			0.06 (0.16)	0.18 (0.30)
Profit stability	Has the farm's profit been rising, stable or falling in the last 5 years?	Ordinal (Rising, Stable, Falling)	0.45 (0.40)	0.63 (0.35)	0.75 (0.38)	0.89 (0.30)

(*continued on next page*)

Annex 4 (*continued*)

Indicator	Indicator question	Response scale / unit	Ecuador		Uganda	
			HEP	LEP	HEP	LEP
Promotion of beneficial organisms	Are beneficial organisms on the farm protected and promoted?	Ordinal (Yes, Partly, No)	0.19 (0.26)	0.06 (0.17)	0.44 (0.18)	0.18 (0.27)
Quality of cooperation with suppliers	What proportion of farm inputs comes from contracted suppliers or stable long-term suppliers?	Percentage (% of inputs)			0.42 (0.45)	0.72 (0.35)
Recycling of paper/ cardboards	What proportion of paper and cardboard is delivered to recycling points?	Percentage (% of waste)	0.45 (0.49)	0.09 (0.28)		
Reusable packaging materials	Does the farm use reusable and multiple-use packaging?	Ordinal (Yes, Partly, No)			0.92 (0.18)	0.73 (0.33)
Secure supply of farm inputs	Have there been any occasions in the last 5 years when necessary farm inputs were not available, and which in turn resulted in production losses?	Binary (Yes, No)			0.95 (0.21)	0.76 (0.43)
Share green cover on perennial crop land	On what proportion of the perennial cropland is a green cover maintained during the whole year?	Percentage (% of perennial cropland)	0.84 (0.26)	0.49 (0.35)		
Share of area for biodiversity promotion on total farm area	Share of areas to promote biodiversity of the total farm area.	Percentage (% of farm area)	0.85 (0.32)	0.27 (0.41)		
Share of legumes on arable land	What proportion of the arable land is devoted to leguminous crops?	Percentage (% of arable land)	0.8 (0.44)	0.14 (0.36)	0.52 (0.46)	0.2 (0.28)
Soil improvement	What proportion of formerly degraded lands (not suitable for farming) has been regenerated over the past 20 years and can again be used for farming?	Percentage (% of formerly degraded areas)	0.87 (0.32)	0.57 (0.50)		
Storage facilities	Are storage facilities and equipment kept clean, pest and water leak proof, with good ventilation, stored off-ground, away from the walls and not together with chemicals?	Ordinal (Yes, Partly, No)			0.56 (0.38)	0.78 (0.28)
Use of clean planting materials	Are seeds and planting materials obtained from external sources controlled/certified to ensure high levels of seed health, cleanness and germination?	Ordinal (Yes, Partly, No)			0.25 (0.40)	0.58 (0.39)
Verbal commitment to sustainability	Is the farm manager committed to the principles of sustainability?	Ordinal (Yes, Partly, No)	0.34 (0.36)	0.06 (0.21)		
Woodlands: Deforestation	Which portion of the farm's current agricultural area has been deforested over the past 20 years?	Percentage (% of agric. area)	0.89 (0.31)	0.38 (0.47)	0.93 (0.24)	0.76 (0.43)
Yield loss	Has the farm been affected by crop failures (> 20% of expected yields) in the past 5 years?	Binary (Yes, No)			0.42 (0.49)	0.73 (0.44)

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