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Sustainability assessment of palm oil by means of expert interviews and the Analytic Hierarchy Process

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Abstract

Palm oil is one of the most important plant oils worldwide and of particular importance for the food industry. In 2017, palm oil accounted for 35 % of the global plant oil production. The area used for palm oil production increased from 6 million hectares in 1990 to 19 million hectares in 2017. Also, the production volume increased from 11 million tons of oil to 63 million tons. Until 2025, it is estimated that the demand for palm oil will rise to 250 million tons. The strong increase is due to a number of factors: The oil palm has a significant higher yield per hectare compared to other oil seeds, the production of palm oil is relatively cheap, palm oil is highly versatile and has excellent manufacturing characteristics. However, the industrial production of palm oil has serious ecological and social impacts, amongst others, deforestation due to significantly increasing large-scale monoculture plantations, drainage of peat forests, loss of habitats, decrease in biodiversity, increase in greenhouse gas emissions and decline in soil, water and air quality. Moreover, land expropriation of indigenous people, poor working conditions as well as forced and child labor are linked to the industrial palm oil production. Therefore, an increase of sustainability in this industry is of utmost importance. In order to achieve this goal, the assessment of sustainability is considered as an efficient tool. However, research about the sustainability of palm oil is usually focusing on the environmental pillar of sustainability only. For this reason, the present study—which was finished in September 2020—presents results from a comprehensive sustainability assessment of palm oil, considering economic, environmental, and social criteria simultaneously. During qualitative expert interviews, various stakeholders of the supply chain assessed the sustainability criteria of the palm oil production and application using the Analytical Hierarchy Process (AHP), a decision support tool by which it was possible to include qualitative and quantitative criteria as well. The determination of the subjective assessments generates a deep understanding of the stakeholders' opinions. Further action that possibly increase the sustainability of the palm oil industry were identified, leading to reliable recommendations for action in the food industry and in politics.

Keywords: Palm oil, Sustainability, Sustainability Assessment, Decision Support, Analytical Hierarchy Process, AHP

1. Introduction

Sustainability assessments of different agricultural production methods are a useful tool to stimulate the emergence of a more sustainable palm oil sector. Their application in the agricultural and food sector is wide spread to identify deficiencies of sustainability (Sala, Ciuffo & Nijkamp, 2015). Due to a steady rising demand in palm oil and increased impact on eco systems numerous methods to evaluate the sustainability of palm oil production exist but the majority of them focuses on the ecological dimension of sustainability but neglects the social and economic dimension of it. An exception is the wholistic study of Lim & Biswas (2015), which included ecological, social and economic dimensions of sustainability to evaluate palm oil production in Malaysia.

Bartzas & Komnitsas (2019) emphasize that most methods to evaluate sustainability need a complex set of indicators, which are only useful, if they are derived from reliable data. To collect reliable data is often time and cost intensive. Furthermore, the application of complex methods often lacks acceptance: „the acceptance of these tools at value chain level is still limited, one reason being the partial suitability of tools as a concrete decision-making method for lead agents. A stakeholder-based approach can help to overcome these limitations" (von Geibler, Kristof & Bienge, 2010, 2208). The Roundtable on Sustainable Palm Oil (RSPO) developed a voluntary standard as a guideline for sustainable palm oil production (RSPO, 2019a). Despite the widespread use of this standard, there is doubt about its effectiveness due to many limitations of the standard (Beherendt, 2017; Laurance et al., 2010; Lim & Biswas, 2019; Ruysschaert & Salles, 2014).

2. Research objective and research questions

There is a lack of holistic sustainability assessment methods, which are easy to use and allow the incorporation of stakeholders. The aim of this study is to close this gap, by demonstrating how to include several stakeholders of the supply chain into the assessment of palm oil production by applying an evaluation method based on the Analytic Hierarchic Process (AHP). This approach will reveal the relative importance of a variety of sustainability criteria from the stakeholders' perspective. It will also identify the preferred alternative of palm oil production. The main research questions are:

Q1: How do different stakeholders of the palm oil supply chain evaluate the *importance of selected sustainability criteria*?

Q2: How do different stakeholders of the palm oil supply chain evaluate the sustainability of non-certified palm oil, RSPO-certified palm oil and European canola oil?

3. Palm Oil

3.1 Global Production and Market of Palm Oil

In the past decades global palm oil production has increased significantly. From 11 million tons in 1990, global production increased to 63 million tons in 2017, which corresponds to a 7% annual growth (FAO, 2019). In the same time span global area under cultivation increased from 6 million hectares to 19 million hectares. The main drivers behind this growth are three factors: continuous population growth, increased demand of palm oil as energy source and an increased number of consumer goods using palm oil (Corley 2009).

Today, 1,2% of global agricultural acreage are used for palm oil production, which makes it number three behind soy bean and rapeseed in respect to acreage used (FAO, 2019, Meijaard et al., 2018). The two biggest palm oil producing countries are Indonesia (58% of global production) and Malaysia (29% of global production; Noleppa & Cartsburg, 2016; Palm Oil Analytics, 2016). Far behind are the next countries with Thailand with 4% and Columbia with 2%. The remaining 7% are divided under Nigeria, Ecuador, Honduras, Papa Neu Guinea, Ghana and Guatemala.

Table 1: Global consumption of palm oil by country (2019)

Country	Consumption in 1 000 tons
Indonesia	14 270
India	10 035
China	7 220
EU	7 145
Malaysia	3 675
Pakistan	3 395
Thailand	2 720

Source: Index Mundi, 2019

Table 1 shows palm oil consumption by country. Indonesia is the biggest consumer of palm oil (17%), followed by India with 14% of global consumption. China and EU are both around 10% of global demand. Malaysia and Pakistan consume approx. 5% of global demand. The rest of the world consumers the remaining 44% of palm oil (Index Mundi, 2019).

3.2 Sustainability of Palm Oil Production

There are numerous evaluations of sustainability of palm oil production in literature. The majority are life cycle analyses with a focus on the ecological dimension of sustainability. In most cases palm oil is evaluated as a renewable energy source and not as a food ingredient. Arvidsson, Persson, Fröling & Svanström (2011) and Schmidt (2010, 2015) compare the ecological impact of palm oil with other plant based oils. Choo et al. (2011), Lam, Tan, Lee & Mohamed (2009) and Yee, Tan, Abdullah & Lee (2009) evaluate by use of an LCA the ecological sustainability of palm oil as an energy source. Only one sustainability evaluation with an LCA takes social and economic aspects of palm oil as energy source into consideration (Manik, Leahy & Halog, 2013).

Lim & Biswas (2015) analyzed existing methods to evaluate sustainability of palm oil and voluntary productions standards. Their study shows that a holistic method encompassing all three dimensions of sustainability is missing. Often relevant indicators are not part of the evaluation methods and the indicators used are nor precise and hard to measure. Based on the palm oil production in Malaysia Lim & Biswas (2015, 2018) developed a model called POSA (Palm Oil Sustainability Assessment). In the following the POSA model is shortly described, because it delivers the foundation for the empirical AHP model we used in our study.

POSA is an indicator based, multi criteria model, which is structured in a hierarchical way similar to the AHP. The main objective of sustainability consist in the POSA model of three

„headline performance indicators“ (HPI). HPIs are the highest level of aggregation of indicators and represent basic principles of sustainability. Each HPI consists of one or more “key performance indicators” (KPI). KPIs represent main areas of impact of an HPI, and they can either promote or hinder the fulfillment of one of the sustainability goals. Each KPI consists of “performance measures” (PM), which are located on the lowest level of aggregation. Performance measures are quantitative values, which get transformed into a 5-point scale. The value 1 represents the worst-case scenario, 3 a threshold value and 5 the ideal scenario.

Lim & Biswas (2015) derived their indicators from literature and from interviews with stakeholders and experts. The indicators of the POSA model were used for the AHP model of this study and will be further explained in the next chapter. In 2019 Lim & Biswas evaluated a typical supply chain of palm oil in Malaysia. Lim and Biswas (2019, 267) conclude that POSA is an „evidence-informed decision-making tool for site-specific sustainability assessment”. They evaluated this specific supply chain with 3,47 of 5 points as not sustainable. There were deficiencies in respect to “smallholder equity”, „average annual income of workers“, „employment for locals“, „GHG emissions“, „percentage of biomass waste recycling and recovery at the mill” and “plantation practices”. Necessary measures to improve the sustainability of this specific supply chain are higher annual income for the workers on the plantations, better employment possibilities for the local population, lower greenhouse gas emissions, a higher share of recycled organic waste in the mill and better working conditions at the plantations.

4. Methods and Measure—The empirical AHP model of this study

The Analytic hierarchy process (AHP) was introduced by Saaty (1995). The core of this decision support system is (1) to structure complex decision situations in the form of a hierarchy containing an overall goal (in this case: the assessment of the sustainability of palm oil), criteria (the holistic assessment of sustainability: ecological, economic, social criteria) and sub-criteria (ecology: climate change, biodiversity, etc.). Alternatives were identified fulfilling the overall goal (palm oil variants and canola oil). (2) The approximation of priorities for criteria, sub-criteria and alternatives is usually done by means of pairwise comparisons if no quantitative information is available. This approach helps to further decrease the complexity of a decision situation. Only two elements have to be compared against each other using a convenient 9-point scale presented by Saaty (1995), Saaty’s fundamental AHP scale, a semantic scale where 1 stands for equal importance, to 5 for higher importance, and 9 for absolute dominance of one element compared to another, with respective in-between values and meanings (Saaty, 1995). If the meaning of the pairwise comparison is reverse (lower importance), reciprocal values are used (1/2, 1/3, … 1/9). (3) Out of this limited information, priorities are approximated. We followed Saaty (1995) and applied the Eigenvector method (principal right eigenvector); however, there are also other approximation methods which might lead to slightly differing outcomes. (4) The AHP can also be used in for group decision making purposes. We aggregated the individual priorities confirming Forman and Peniwati (1998).

In our case, the priorities for the (sub-)criteria were combined with quantitative measures for all three alternatives (based on relevant sources from literature; Table 2). The assessment of sustainability falls into the broader topic of natural resources management, where the AHP is widely applied including group decision making, e.g., in land management (Cay and Uyan, 2013), water management (Srdjevic, 2007; Calizaya *et al.*, 2010), bioenergy (Buchholz *et al.*, 2009). In our case, we used expert interviews to assess the sustainability of palm oil.

4.1 Criteria of the AHP Model

We used the criteria of the POSA model from Lim & Biswas (2015, 2018) to develop the present AHP model. The indicators of the POSA model are on a solid theoretical and empirical foundation and the hierarchical structure of the model makes it perfectly suited for the AHP. Table 2 presents the two hierarchy levels of the AHP model.

Table 1: Criteria of the AHP model

Criterion *	Measure	Sources
1 Ecological sustainability		
1.1 Climate change	THG-emissions t CO_2e / t palm oil	Schmidt & De Rosa, 2019; Schmidt, 2010
1.2 Quality of air, water, soil	Acidification SO_2 / t palm oil	Schmidt, 2007; Schmidt, 2010
	Eutrophication NO_3 / t palm oil	Schmidt, 2007; Schmidt, 2010; Saswattecha et al., 2015
1.3 Volume of waste	Recycling biomass [a)]	Queirós et al., 2015; Saswattecha et al., 2015
1.4 Biodiversity	Loss of species [b)]	Schmidt, 2010; Schmidt & De Rosa, 2019
1.5 Use of resources (fossil fuels)	Fossil fuels MJ / ha	Schmidt, 2007; Bernet & Berge, 2019
2 Economic sustainability		
2.1 Productivity	t palm oil / ha	Schmidt, 2007; Morgans et al., 2018
2.2 Profitability	Price / ton (US$)	Pye et al., 2015; Von Geibler, 2013; RSPO, 2019b; IndexMundi, 2020
2.3 Relative poverty	Average income per month (US$)	GTAI, 2020; Lim & Biswas, 2015; BMNT, 2019
2.4 Inclusion of local population and wealth distribution	Possibility of employment etc. [c)]	Bernet & Berge, 2019; BMNT, 2019
3 Social sustainability		
3.1 Fulfillment of basic needs	Access to water, food, housing etc. [c)]	Lim & Biswas, 2019; BMNT, 2019
3.2 Empowerment of local people	Access to information, knowledge etc. [c)]	Bernet & Berge, 2019; BMNT, 2019

[a)] qualitative valuation, open dumping (increase in CH_4) vs. mulching in the plantations
[b)] qualitative valuation, different measurements
[c)] qualitative valuation, rating

* Source: Lim & Biswas (2015, 2018)

The hierarchy level 1 contains the three pillars of the concept of sustainability confirming the Brundtland Report from the World Commission on Environment and Development [WCED] 1987 (Janker & Mann, 2018). Confirming Lim & Biswas (2015, 2018), the hierarchy level 1 therefore contains the three criteria ecological, economic, and social sustainability. Criterion 1 *Environmental sustainability* contains the sub-criteria 1.1 Climate change, 1.2 Quality of soil, water and air, 1.3 Volume of waste, 1.4 Impact on biodiversity and 1.5 Use of resources indicates the amount of fossil fuels used during production and processing. The “climate change” criterion indicates the amount of greenhouse gases released during palm oil production. The quality of soil, water and air is measured by the degree of eutrophication and acidiphication due to palm oil production. The criterion “volume of waste” measures the share of recycled organic residues of the palm oil fruits. Biodiversity includes methods of plantation, land use and loss of species. *Economic sustainability* is operationalized by four sub-criteria. The criterion 2.1 Productivity is measured with oil yield per hectare and 2.2 Profitability is expressed by palm oil price per ton. 2.3 Relative poverty is measured with the average monthly income. 2.4 Inclusion of local population and wealth distribution expresses the possibilities of employment of the local population. *Social sustainability* contains two sub-criteria. First, 3.1 fulfillment of basic needs evaluates the access of plantation workers to clean water, food, housing and sanitation. Second, 3.2 empowerment of local people evaluates access of local population to information and knowledge, fair partnerships, inclusion into decision processes and acceptance of the local population of the activities concerning plantation and processing.

4.2 Alternatives included in the AHP Model

The AHP model contains two alternative palm oil production methods, which will be evaluated in respect to their sustainability. First alternative A1 is conventional, non-certified palm oil, which is the majority of the global palm oil production. The second alternative A2 is RSPO-certified palm oil. Approx. 19% of worldwide produced palm oil is RSPO certified. The third alternative A3 is European canola oil (serves as a reference alternative to palm oil). Rapeseed is one of the major oil plants in Europe with an annual production volume of 20 million tons in 2019. On a national level, the importance of rapeseed broadly varies. For example, after soy bean it is the second most produced oil crop in Austria with a harvest volume of 121.000 tons in 2019 (BMNT, 2019). Canola oil has the technical potential to replace palm oil in numerous food products. The average yield per hectare is 1,5 tons in Europe compared to the global average of 0,7 tons (Noleppa & Cartsburg, 2016, EUROSTAT 2018). Margarine is one of the main end products for palm oil, and in margarine almost any other oil could be used for substitution. For instance, the same simple technical replacement is possible for ice cream, bread, and pastries (Noleppa & Cartsburg, 2016, 44). Table 2 contains all relevant sources that were used to measure the alternatives A1 to A3 in view of the sub-criteria of the AHP-hierarchy.

Figure 1 shows the complete AHP model with the criteria and alternatives derived from literature. To approximate the sustainability of alternatives A1 to A3, eight experts from the food industry, food trade, and palm oil production as well as NGOs evaluated the importance of the criteria and sub-criteria of the AHP-hierarchy. The approximated priorities are then combined with objective measures of the alternatives with respect to all sub-criteria of the AHP-hierarchy (Table 2).

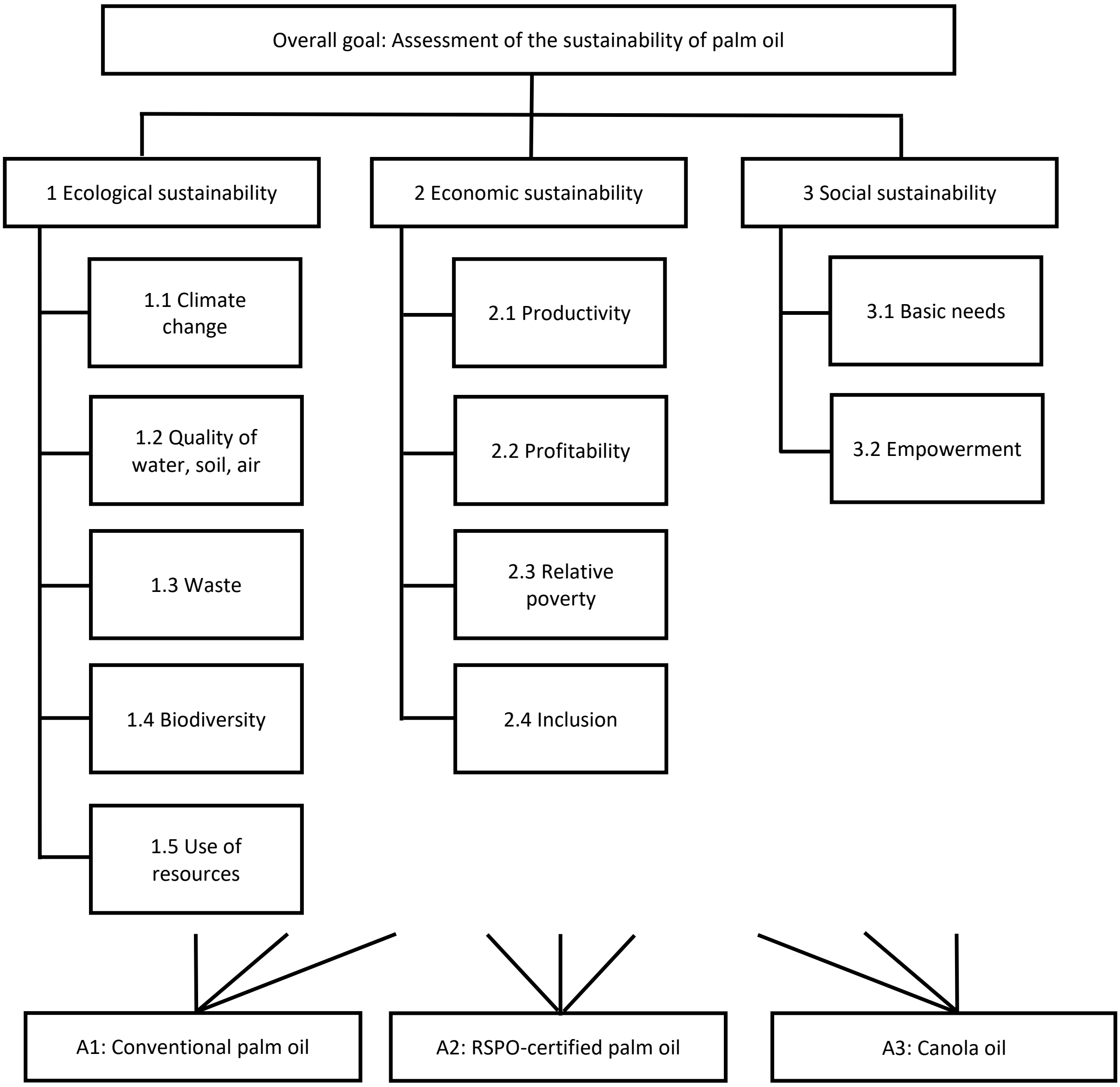


Figure 1. AHP model to approximate sustainability of palm oil

Source: In accordance with Lim & Biswas (2015, 2018)

4.3 Data collection: Expert interviews

In total, eight interviews with experts from the food sector and a NGO provided the necessary data to approximate the importance of the evaluation criteria of the AHP hierarchy in Figure 1. The experts were selected based on their professional experience with the palm oil industry. The experts (Table 3) are stakeholders and important decision makers in the food supply chain and are periodically confronted with the use of palm oil in their own company / organization (or in the case of NGOs with the palm oil industry in general). Because of the differing viewpoints of the relevant company / organization the assessment of the importance of sustainably criteria by means of the AHP delivered differing results. The heterogeneity will be comprehensively considered in the following results section.

Table 3. Participants in expert interviews

Expert	Organization / company	Function	Field of activity
E1	Organic food company	Head of product management and sales	Food processing
E2	Fair trade organization	Intelligence department and public relations	Food processing
E3	Consumer protection organization	Executive board member	Food consumption
E4	International NGO	CEO	Sustainability
E5	International food retailing company	Senior manager sustainability department	Food retail
E6	International NGO	Program management	Animal welfare, sustainability
E7	International food retailing company	Head of sustainability department	Food retail
E8	Global palm oil producing company	Assistant manager production department	Palm oil production

5. Results and discussion

Based on the AHP hierarchy in Figure 1, each expert applied pairwise comparisons in each hierarchy level to assess the importance of the sustainability criteria. This qualitative approach is necessary, as no information is available concerning the objective assessment of the importance of the sustainability criteria. The priorities are also depending on the relevant company goal and position of the organization within the food supply chain. The overall result where all individual expert judgements are aggregated, is therefore too less meaningful; also, individual approximations should be interpreted.

Table 4. Approximation of priorities of sustainability criteria

criteria	E1		E2		E3		E4		E5		E6		E7		E8		mean		
	w_{i}	$w_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	$\overline{w}_{\mathrm{i}}$	$\overline{w}_{\mathrm{i.i}}$	$rel.\overline{w}_{\mathrm{i.i}}$
1 Ecological sustainability	0.47		0.41		0.33		0.59		0.43		0.43		0.69		0.22		0.448		
1.1 Climate change		0.20		0.41		0.20		0.25		0.33		0.32		0.46		0.16		0.291	0.130
1.2 Quality of water, soil, air		0.20		0.12		0.20		0.14		0.12		0.23		0.21		0.19		0.177	0.079
1.3 Waste		0.20		0.07		0.20		0.14		0.04		0.04		0.06		0.19		0.118	0.053
1.4 Biodiversity		0.20		0.26		0.20		0.33		0.38		0.23		0.15		0.26		0.251	0.112
1.5 Use of resources		0.20		0.14		0.20		0.14		0.13		0.19		0.12		0.19		0.163	0.073
2 Economic sustainability	0.05		0.26		0.33		0.08		0.14		0.14		0.09		0.46		0.195		
2.1 Productivity		0.07		0.07		0.30		0.08		0.17		0.09		0.15		0.24		0.145	0.028
2.2 Profitability		0.04		0.07		0.10		0.04		0.17		0.10		0.09		0.33		0.117	0.023
2.3 Relative poverty		0.44		0.44		0.30		0.44		0.50		0.43		0.35		0.24		0.393	0.076
2.4 Inclusion		0.44		0.42		0.30		0.44		0.17		0.38		0.41		0.19		0.344	0.067
3 Social sustainability	0.47		0.33		0.33		0.33		0.43		0.43		0.22		0.32		0.358		
3.1 Basic needs		0.80		0.75		0.75		0.50		0.88		0.50		0.75		0.50		0.678	0.243
3.2 Empowerment		0.20		0.25		0.25		0.50		0.13		0.50		0.25		0.50		0.322	0.115

w_{i} … local weight (priority) for criterion *i*
$w_{\mathrm{i.i}}$ … weight (priority) for sub-criterion *i.i*
$rel.\overline{w}_{\mathrm{i.i}}$ … relative (global) weight for sub-criterion *i.i*; $rel.\overline{w}_{\mathrm{i.i}} = \overline{w}_{\mathrm{i}} \times \overline{w}_{\mathrm{i.i}}$

As we can see from Table 4, overall ecological ($\overline{w}_{\mathrm{i}}$= 0.448) and social ($\overline{w}_{\mathrm{i}}$= 0.358) sustainability criteria are considered to be of much higher importance compared to economic sustainability criteria ($\overline{w}_{\mathrm{i}}$= 0.195). However, this estimation clearly depends on relevant strategic goals of the of the expert's organization. For one expert, all elements are of equal importance. Confirming E3 (consumer protection), all criteria must be equally fulfilled. A comparable approximation can be found with E2 (fair trade organization)—even though ecology is slightly more important for E2 compared to economy and social sustainability. These viewpoints might reflect the estimation on the basis of organization with other than economic benefits (consumer protection and fair trade conditions). For Expert E8, the economic sustainability is essential (w_{i}= 0.46). This result, too, is not really surprising as the approximation was done confirming the strategic position of the only palm oil producing company within our sample. Another exceptional result comes from E7 (food retailer) where environmental sustainability is absolutely dominating within the AHP hierarchy (w_{i}= 0.69). All these evaluations are a clear contradiction to the evaluations of the other experts, where the economic sustainability is evaluated to be much less important (w_{i}= 0.05 to 0.14), environmental criteria a of high priority (w_{i}= 0.41 to 0.59), and social sustainability is important as well (w_{i}= 0.33 to 0.47). The heterogeneity in these results clearly show that aggregated approximations are not too reasonable as soon as it comes to non-tangible, objective elements where evaluations might be significantly affected by the relevant overall company goal and strategies. As mentioned before, it was not surprising at all, that the only palm oil producing company has a completely differing position compared to all other judgements. Therefore, it is wise to additionally cluster the expert assessments. Confirming Table 4, E2 and E3 are building one group as well as E1, E4-E7 build another. E8 is exceptional and will not be aggregated with the other experts' assessments.

Table 5. Clustered approximation of priorities of sustainability criteria

criteria	Cluster 1: E2-3			Cluster 2: E1,4-7			E8		
	$\overline{w}_{\mathrm{i}}$	$\overline{w}_{\mathrm{i.i}}$	$rel.\overline{w}_{\mathrm{i.i}}$	$\overline{w}_{\mathrm{i}}$	$\overline{w}_{\mathrm{i.i}}$	$rel.\overline{w}_{\mathrm{i.i}}$	w_{i}	$w_{\mathrm{i.i}}$	$rel.w_{\mathrm{i.i}}$
1 Ecological sustainability	0.37			0.52			0.22		
1.1 Climate change		0.31	0.11		0.31	0.16		0.16	0.04
1.2 Quality of water, soil, air		0.16	0.06		0.18	0.09		0.19	0.04
1.3 Waste		0.14	0.05		0.09	0.05		0.19	0.04
1.4 Biodiversity		0.23	0.09		0.26	0.13		0.26	0.06
1.5 Use of resources		0.17	0.06		0.16	0.08		0.19	0.04
2 Economic sustainability	0.30			0.10			0.46		
2.1 Productivity		0.18	0.05		0.11	0.01		0.24	0.11
2.2 Profitability		0.09	0.03		0.09	0.01		0.33	0.15
2.3 Relative poverty		0.37	0.11		0.43	0.04		0.24	0.11
2.4 Inclusion		0.36	0.11		0.37	0.04		0.19	0.09
3 Social sustainability	0.33			0.38			0.32		
3.1 Basic needs		0.75	0.25		0.69	0.26		0.50	0.16
3.2 Empowerment		0.25	0.08		0.32	0.12		0.50	0.16

w_{i} … local weight (priority) for criterion *i*
$w_{\mathrm{i.i}}$ … weight (priority) for sub-criterion *i.i*
$rel.\overline{w}_{\mathrm{i.i}}$ … relative (global) weight for sub-criterion *i.i*; $rel.\overline{w}_{\mathrm{i.i}} = \overline{w}_{\mathrm{i}} \times \overline{w}_{\mathrm{i.i}}$

The sub-criteria and their relative weight $rel.w_{\mathrm{i.i}}$ also shows the different priorities between the clusters. The relative weights $rel.w_{\mathrm{i.i}}$ are also depending on the number of sub-criteria, the metric size of the weights should therefore only be compared with care. Climate change is, for instance, the most important sub-criterion in the ecological sustainability section of Cluster 1 and 2, whilst biodiversity is evaluated to be slightly more important for E8. For

Cluster 2, climate change is dominating ecological sub-criteria, while in Cluster 1 the importance between the sustainability criteria is by far more balanced.

Overall, the highest priority was assessed for the social criterion "basic needs" (Cluster 1 and 2); for E8, both social criteria are of equal importance. All other weights can be taken from Table 5. Finally, the weights are combined with the quantitative data of the three alternatives (Table 6).

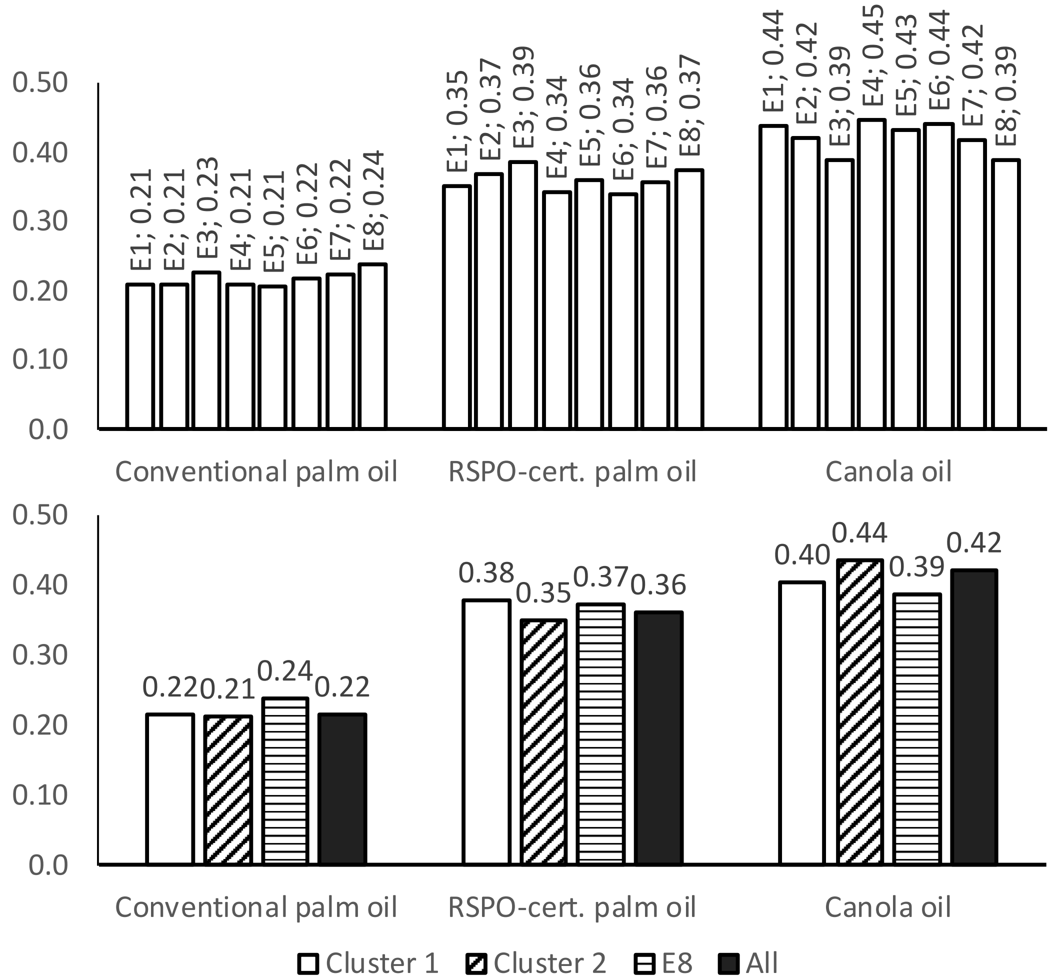
Table 6. Measure and utility estimation of alternatives conventional palm oil (A1), RSPO-certified palm oil (A2), canola oil (A3)

Sub-criterion	Measure				Values for utility approximation			Sum	Priorities		
	A1	A2	A3		A1	A2	A3		w_{A1}	w_{A2}	w_{A3}
1.1 Climate change (THG-emissions t CO_2e / t palm oil)	5.34	3.41	2.22	*r*	0.187	0.293	0.450	0.931	0.201	0.315	0.484
1.2 Air, water, soil quality											
(Acidification SO_2 / t palm oil)	14.8	10.3	20.2	*r*	0.068	0.097	0.050	0.214	0.316	0.453	0.231
(Eutrophication NO_3 / t palm oil)	124	86	140	*r*	0.008	0.012	0.007	0.027	0.301	0.433	0.266
1.3 Waste (recycling biomass) [a)]	1	3	3		1	3	3	7	0.143	0.429	0.429
1.4 Biodiversity (loss of species) [b)]	1	2	3		1	2	3	6	0.167	0.333	0.500
1.5 Use of resources (Fossil fuels MJ / ha)	2.11	2.11	4.116	*r*	0.474	0.474	0.243	1.191	0.398	0.398	0.204
2.1 Productivity (t / ha)	3.75	5	1.5		3.75	5	1.5	10.25	0.366	0.488	0.146
2.2 Profitability (Price / ton in US$)	700	800	900		700	800	900	2400	0.292	0.333	0.375
2.3 Relative poorness (Average income per month in US$)	15	40	7		15	40	7	62	0.242	0.645	0.113
2.4 Inclusion (Possibility of employment etc.) [c)]	1	2	3		1	2	3	6	0.167	0.333	0.500
3.1 Basic needs (Access to water, food, housing etc.) [c)]	1	2	3		1	2	3	6	0.167	0.333	0.500
3.2 Empowerment (Access to information, knowledge etc.) [c)]	1	2	3		1	2	3	6	0.167	0.333	0.500

[a)] qualitative, open dumping (increase in CH_4) vs. mulching in the plantations
[b)] different approximation methods: PDF/m^2/year/kg RBD oil and standard wS100
[c)] qualitative, ranking
i … inverse values (less = higher utility)

The quantitative data can be transformed immediately into AHP priorities w_{A_j} with *j* = 1,2,3 by building the sum of each row and dividing individual values through this sum if higher values represent higher benefit (e.g., productivity in t / ha). In the case of cost attributes (e.g., climate change: THG-emissions t CO_2e), inverse, reciprocal values are applied (*r* in Table 6). Consequently, w_{A_j} is then multiplied with $rel. \bar{w}_{\mathrm{i.i}}$. The overall priorities index p_j for A1 to A3 is approximated by $p_j = \sum rel. \bar{w}_{\mathrm{i.i}} \times w_{Aj}$. The index p_j represents the level of sustainability between conventional palm oil (A1), RSPO-certified palm oil (A2), and canola oil (A3).

Figure 2. Sustainability index p_j for alternatives A1 to A3



Although the heterogeneity of individual assessments of the importance of the sustainability criteria was rather high, the final results between the different experts and also groups of experts is quite comparable. Conventional palm (A1) oil is by far the least sustainable alternative (average sustainability index $\bar{p}_{A1} = 0.216$), followed by RSPO-certified palm oil (A2) ($\bar{p}_{A2} = 0.362$), and canola oil (A3) ($\bar{p}_{A3} = 0.422$). A2 and A3 are not that clearly separated from each other compared to A1. Changes in the importance of specific sustainability criteria might result in changes in the ranking of A2 and A3. However, we proved that by means of a sensitivity analysis. Changes can only be expected if the economic criteria gain significantly importance towards 0.4 at the expense of the environmental criteria. This is, in the context of sustainability, quite unrealistic.

Altogether, the results clearly show how difficult it is to assess non-tangible, qualitative characteristics such as sustainability. We wanted to take a broader look at the concept of "sustainability" and not only focuse on the ecological dimension of sustainability (the majority of studies in the field are life cycle analyses with a focus on this dimension: Arvidsson et al., 2011; Schmidt, 2010, 2015; Yee et al., 2009—to name just a few). However, the individual preferences, goals, visions, and strategies (and comparable factors), and personal attitudes and values will influence the overall outcome of qualitative judgements resulting in a more or less large divergence. Considering this, there might be no objective answer to our research questions: Stakeholder evaluated the *importance of selected* *sustainability criteria differently* (Q1). We integrated all dimensions of sustainability which was missing confirming Lim & Biswas (2015)—based on their analysis of existing voluntary productions standards showed the absence of a holistic method encompassing all three dimensions of sustainability. This was a broader approach compared Lim & Biswas (2019) who only evaluated a typical supply chain of palm oil in Malaysia. But obviously, the priorities are influenced by the above-mentioned factors. Even though the importance of the sustainability criteria was divergent between the experts, the assessment of the *sustainability of the alternatives* brought a rather clear picture (Q2): European canola oil is considered to be the most sustainable alternative, barley followed by RSPO-certified palm oil. The distance to the least sustainable alternative, conventional, non-certified palm oil is large. The stakeholders have a narrow connection to the food supply chain or are even integral part of it. Their opinion and subjective judgements might not completely cover the point of view of their customers (consumers and/or other partners within the food supply chain). Nevertheless, the results deliver quite a clear and—based on the expertise of the interviewed persons—trustworthy picture of the sustainability of palm oil. This outcome is a clear contradiction to the mentioned doubts about the effectiveness of the RSPO-standard and the related sustainability improvements (Beherendt, 2017; Laurance et al., 2010; Lim & Biswas, 2019; Ruysschaert & Salles, 2014): RSPO-certified palm oil was considered to be almost as sustainable as canola oil, which might be surprising to the scientific community and should be addressed in future studies. Needless to mention that our results only reflect hypotheses as we used a qualitative study design with only a limited number of expert interviews. Future studies should therefore focus on a broad application of the AHP to assess the sustainability including larger number of experts, by integrating new findings in view of the *quantitative* assessment of the alternatives, and also by widening the methodological approach towards a better understanding of heterogeneity in group decision making. We followed Saaty (1995) when applying the AHP, however, actual developments in the AHP methodology might be useful in order to cover heterogeneity in group decision processes (e.g., Meixner et al., 2020). In general, literature showed that the application of the AHP is quite appropriate in natural resources management such as land (Cay and Uyan, 2013) or water management (Srdjevic, 2007; Calizaya *et al.*, 2010); a further expansion of the application of the AHP towards the assessment of sustainability within the food supply chain seems to be promising. Future research could take our methodological approach as an adequate groundwork.

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