Decision Support System for Minimizing Food Waste in Agri-food Supply Chains

Madalena Medo
madalena.medo@tecnico.ulisboa.pt
Instituto Superior Técnico, Lisboa, Portugal
January 2021

ABSTRACT

About one third of all food produced for human consumption worldwide is lost or wasted throughout the supply chain before it is delivered to the final customer. This situation compromises the creation of a more sustainable agri-food sector. In this context, this work was developed with the goal of helping companies and supply chains be more sustainable and efficient. With this purpose, this work breaks down into four primary axes: (i) the development of a general sustainable agri-food supply chain network (ii) the creation of a measurement system (iii) the development of a tool to measure the performance of the company in terms of the three pillars of sustainability (iv) the validation of the tool. Through a literature review, a detailed analysis of a general sustainable agri-food supply chain will be conducted and a measurement system proposed. This will lead to a tool with the goal of helping companies and supply chains improve their performance considering the three pillars of sustainability. Finally, this tool is applied to the Greenyard company and so its current performance is evaluated in terms of sustainability, as well as its progression. In the end some improvements to the measurement system are given, as well as, some actions to improve the company's KPIs. This way the scientific community will have an innovative way to measure in quantitative terms the sustainability of an agri-food supply chain.

Keywords: Agri-food Supply Chain; Sustainability; Decision Tool; Performance Measurement System

1 Introduction

The amount of food, wasted or lost, represents approximately 1.3 billion tons of food every year [1]. This quantity of food occupies 1.4 billion hectares of land, which is almost 30 per cent of the total agricultural land area [2]. When it comes to the energy consumption, the agri-food sector is responsible for 30 per cent of the world's total energy consumption, and those losses represent 38% of this energy [1]. According to FAO (2017), the food produced and not eaten have an estimated carbon footprint of CO_2 equivalent of 3.3 Gtonnes without considering the Greenhouse Gas (GHG) emissions from land use. This waste can be also translated in a blue water footprint, which is the surface and groundwater used for its production, of around 250 km^3. So, if we were able to reduce food losses and waste, the supply of available food would increase, which would improve the food security. Moreover, this volume of food waste and loss, makes the transformation of Agri-Food Supply Chain (AFSC) into a sustainable food system a challenge. Reconfiguring the food supply chains and introducing sustainable technologies would allow to recycle resources more effectively and require less transportation and storage. This development would improve the food sector, while reducing GHG emissions [1]. However, transforming the Supply Chain (SC) into a sustainable one needs to be done carefully to ensure that changes are being made to reduce the amount of food loss and waste. To do so, one of the most important tasks is identify the hotspots where the loss is occurring and try to reduce it or eliminate in a sustainable way.

1.1 Objectives Definition

This work aims to study AFSCs and their sustainable management by measuring its performance in terms of the three pillars of sustainability (economy, society and environment). To achieve the aimed result, the following steps will be applied:

- Propose a sustainable general agri-food supply chain network that is going to be the base of the work and describe every entity and flow that composes it;
- Propose a performance measurement system

for this type of SC;
- Build a tool to measure the performance of any SC in the agri-food industry in terms of sustainability;
- Identify some limitations of the tool and possible future work suggestions.

Afterwards, this tool will be applied to the Greenyard company in order to highlight the tool's capabilities and the steps that the user need to go through in order to apply it. In the end, main conclusions and limitations are drawn and some possible improvements will be suggested to the Greenyard company.

2 Literature Review

The goal of this section is to review the existing literature in order to provide basis of knowledge and possible approaches to the problem presented in the introduction. The aim is to analyze the Agri-food supply chains and identify the challenges posed to make them sustainable and how to measure their sustainability.

2.1 Sustainable agri-food supply chain

In 1987 sustainability was defined as the ability to meet the needs of the current generation without compromising the ability of the future generations to do the same [3]. Afterwards, Elkington (1994) created the *Triple Bottom Line Concept*, a framework that proposed three dimensions to define sustainability: environmental, social and economic. Then, Carter and Rogers [5] proposed other aspects of sustainability: risk management, transparency, strategy, and culture. According to these authors supply chain risk management is the capacity that a firm has to understand and manage its supply chain economic, environmental, and social risks. Transparency comprises reporting to stakeholders, as well as, continuously engage with them and using their feedback and input to both secure buy-in and improve supply chain processes. Strategy and culture defend that to become sustainable enterprises, organizations need more than simply overlay sustainability initiatives over corporate strategies, they also have to incorporate those initiatives in their company cultures and mindsets. After understanding what is sustainability, is then important to explain the meaning of AFSC in order to explain how a Sustainable Agri-Food Supply Chain (SAFSC) can be achieved.

The AFSC accommodates a wide range of entities from "farm-to-fork" and so the structure of this type of supply chains can be very complex and for some products it is slightly extended with many entities, which results in many interactions. The goal of the AFSC is to provide the right products (quantity and quality), in the right time and at a competitive cost in order to earn money with it [6].

Hence, it is going to be described how to build an SAFSC. To create a sustainable agri-food system various solutions need to be implemented together, so that there is a chance of feeding the growing population in a sustainable way. In order to be effective, the change needs to be at the system level. So, a food system based on the principles of a Circular Economy (CE) is one that is healthy for people and natural systems [7].

A proper environmental assessment tool is necessary to evaluate to what extent food production affects the environment. The environmental assessment tools can be area based or product based. The area-based indicators are usually used for farm emissions of nutrients, like nitrate that influences the local environment. The product-based indicators assess the emissions from the farm related to the production of inputs, for instance, artificial fertilizer and outputs like slurry exported to other farms. In that way it is easier to avoid shifting environmental problems from one place to another, which reduces its cumulative environmental impacts. Product-based evaluation is called, life cycle assessment [8].

So, circular economy and life cycle assessment are the methodologies that appeared in the articles as the most adequate ones to successfully transform an AFSC into a sustainable one [9] [10] [11] [12].

2.2 Agri-food supply Chain Mapping

A map is a simplified model of the environment to communicate items of information [13]. A SC map is a simplified representation of the members of the SC and their interconnections together with some general information concerning the entire SC. The focus while developing this map could be a particular use or user, or the opposite, covering all aspects of the SC structure. This way, SC mapping can be defined as the group of activities involved in the process of creating and maintaining a SC map. The maps can include organizations, flows, facilities, and/or processes

[14].
The mapping tool aims to address the problem of limited structural Supply Chain Visibility (SCV). There are many definitions of SCV, but almost all are related with the ability to collect and analyze distributed data and formulate recommendations. SCV enables to share real-time information with key customers, suppliers and partners in order to improve SC efficiency [15].
Considering the case of agri-food, the lead time is one of the most important indicators, because when it is decreased there is an improvement in the performance of the demand chains and better competitive capabilities of the actors. This can be justified by the perishable food representing one of the main flows of this type of SC. This food needs to be delivered to the consumer at a considerable level of freshness, otherwise it will be discarded as waste [16].
The Value Stream Mapping tool creates a reliable and systematic map of hotspots to facilitate subsequent food and nutritional loss measurement and reporting. VSM make mitigation approaches possible along the food supply chains [17].

2.3 Measuring the food supply chain

To achieve an adequate measurement of the SC performance and to understand in what extent a SC is meeting the end-user and stakeholders' requirements in terms of sustainability, relevant performance indicators should be used. That's why an effective Performance Measurement System (PMS) should be in place.
According to Neely [18], a PMS is a system that allows informed decisions and actions since it quantifies the efficiency and effectiveness of previous actions across acquisitions, collation, sorting, analysis, interpretation and dissemination of relevant data. A PMS can be also defined as a system that allows firms to control the key performance indicators of products, services and production processes in the appropriate time frame.
PMS gives information to the decision maker about whether they are achieving the goals, if the customers are satisfied or what improvements are needed. In order to do so it is mandatory that the company has access to the right information when asked [19]. That is why choosing the right Key Performance Indicators (KPIs) is essential.
Implementing a PMS in the agri-food supply chain and choosing the right KPIs is a very challenging process because the food industry is an interconnected system made of a wide range of complex relationships due to alliances, horizontal and vertical cooperation and forward and backward integration [20].
The KPIs should be chosen considering organization's business objectives and the fact that they will be used to compare the efficiency and effectiveness of the system with the target value or norm. To establish them it is necessary to have a deep understanding about what is important and needs measurement [19].

3 Mapping Agri-food Supply Chain

This section aims to develop a methodology to create SAFSC and then measure how sustainable they are. First, it is important to know all entities and flows involved in a traditional AFSC.

3.1 General Agri-food Supply Chain

A common AFSC starts with the production,which is the **primary producers**' responsibility. Then, the food is delivered to the **processors** where it is going to be transformed until the product is ready for consumption. Afterwards, the food is sent to the **wholesalers** who will handle the food according to the retailer's requirements. Next, it is time for **retailers** to deliver the final product to the end-consumers, who are the ultimate beneficiaries of the SC. The transportation, management and logistics between entities can be helped by **third party logistics (3PL)**. Moreover, this network can also receive a flux of products from the import traders or have an output of products to the export traders.
The entities described are linked by three flow types: the material flow, the financial flow and the information flow. The **material flow** is the physical product movements from input suppliers to the end customers, going through all entities. The **financial flow** is about the credit terms and lending, payment schedules and repayments, savings and insurance arrangements. This flow goes upstream the SC because the entity that receives the product will buy it from the previous one. The **information flow** coordinates the material and financial flows and has the same direction as the product flow because it is about the products that are being transported throughout the SC [6, 21].

3.2 Sustainable Agri-food Supply Chain

To produce the desired product, pollutants and other byproducts are produced along the supply chain. For instance, packaging is used to protect the products from damage, however once they are consumed, the package is no longer desired. That is why, a proper management and awareness of the environmental implications of logistics activities is crucial to significantly reduce the negative impact of those activities. Traditional logistics systems do not usually address environmental problems and are only focused on economic targets. In contrast, an environmentally responsible logistics approach takes into consideration another target to the system: minimizing the total environmental impact.

The **reverse flow** is the process of planning, implementing and monitoring the flow of resources, semi-finished and finished goods and the respective information and financial flows from production until consumption. The ultimate goal is to collect, sort, package and expand items that were used, damaged or obsolete in order to regain their value or to proper dispose the wastes. Reverse logistics flow includes the shipments of packaging waste, recyclable packages, and customer returns.This definition also incorporates all efforts to reduce these reverse flows because it means reducing the total amount of waste in the system. The type of activities carried out during the reverse logistics process depends on the material type and the reason why these materials have entered the process [22].

The tenets of reverse logistics are reduce, substitute, reuse and recycle that are chosen according to the condition in which the material enter the reverse flow. Reverse logistics prioritize source reduction and substitution over reuse and recycling. Source reduction consists on preserving the process while using less resources. Substitution means using more environmentally friendly materials rather than the regular ones which end up as pollutants. Reuse is about employing the same item numerous times in its original form to reduce the amount that is discarded. Recycling gives discarded materials a new life by submitting them to chemical or physical processes [23]. The actions taken in order to incorporate the three tenants in the supply chain are represented in the **recycling entity**. Even though the recycling entity is a separate entity, all the other levels of the SC should be connected to it. The recycling entity includes all external entities and internal efforts to reuse, reduce and recycle the waste food generated by the company. Figure 1 shows the SAFSC composed by all the entities and flows describes above, as well as, the reverse flow and the recycling entity.

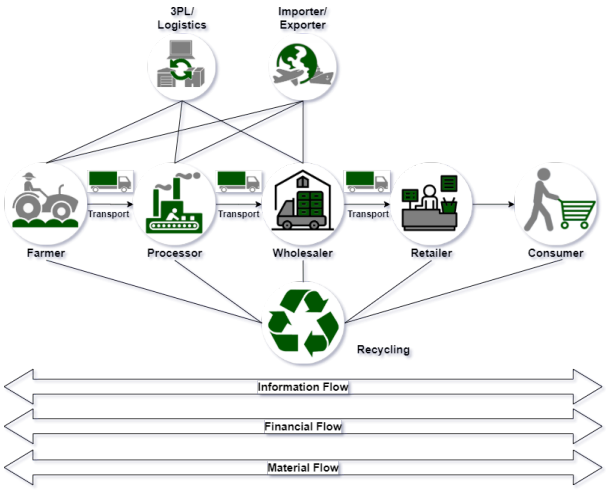

Figure 1: Sustainable Agri-food supply chain network (Adapted: [6, 24])

3.3 A measurement system for an agri-food supply chain

In order to build a tool to measure how sustainable a specific supply chain is, it is important to analyze in detail what to measure inside each entity and understand how we should do it. Some improvements should also be suggested in order to upgrade the sustainable performance of the SC. Next, will be presented a methodology to evaluate the sustainability of an AFSC.

First, it is determined what is going to be measured. In order to do so, the most common hotspots are used or the SC conducts an internal analysis to determine its own hotspots. These hotspots should be sorted into environmental, social or economical.

Environmental hotspots are associated with the performance of the supply chain based on the inputs (e.g., material, energy, water) and outputs (e.g., emissions, effluents, waste) that result from the activities of each entity. The social dimension of sustainability represents the impact that the organization has on the social systems within which it operates. The economic hotspots are related with the flow of capital between the different entities of the SC and the most important economic impacts of the organization in the society [25].

Second, it is important to find adequate KPIs to

measure those hotspots. This step is crucial to make sure the company is achieving its goals. Using the wrong indicator can compromise the successful of the measurement system. When it is available, the targets associated with those KPIs should also be added.

Third, some possible improvements that can help minimizing the hotspots are suggested. It could also be determined the level of decision that each possible improvement is associated: operational, tactical or strategic. Operational decisions are short-term and focus on daily basis activities. SC tactical planning considers a longer time horizon, normally, months or weeks and involves activities like demand forecasting and master production planning. Strategic decisions are typically made over a longer time horizon, years and usually considers structural aspects, like SC design.

The interested SC or the companies that compose it should join the SAFSC framework presented in Figure 1 with the information about the hotspots to create an illustrative image of all entities and their hotspots. This image will not only be a very intuitive way to show the relation between all entities, but also what are the key activities that deserve more attention. Figure 2 is an example of how this can be done.

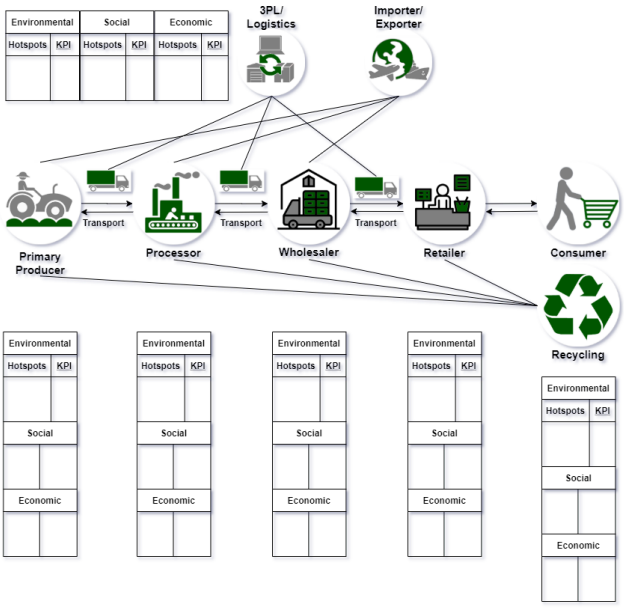

Figure 2: Agri-food supply chain network (Adapted: [6, 24])

In this example, companies can also show all KPIs to their employees so that they can understand what they should improve by comparing themselves to other entities of the SC. This will also show them the impact that the company has on the SC, as well as, on the planet. The Figure 2 shows the general sustainable agri-food framework and above each image there is a table where the hotspots should be added and the KPIs values computed. In the 3PL entity the table is on the left instead of being above.

4 The Eco-Tool Foundations

In this section, a decision supporting tool named Eco-Tool is going to be created, using Microsoft Excel and taking into account all the information gathered previously. First, it will be described the tool's goal and how it is structured. Then, a validation will be performed by applying it to the Greenyard company data. This validation is based on the reports available on the company website. After, the results are analyzed and possible supply chain improvements suggested.

4.1 Eco-Tool's aim and assumptions

The aim of the Eco-Tool is to create a collaborative platform that will enable the assessment on how a certain supply chain is sustainable according to the three pillars of sustainability, through a wide range of KPIs. Such tool involve all entities of an AFSC and aims to be easily adaptable to any real SC. The holistic view of the SC assumed can give an understanding about the current state of the SC and support stakeholders decisions. It will also allow each company to analyze how has been progressing over time as the KPIs are measured for the current and previous years. Hence, if there are entities of the SC that do not want to use the Eco-tool, the ones participating can at least access their performance. Thus, the ultimate goal of the Eco-tool is to access in quantitative terms how the company and the SC is performing and progressing considering the three pillars of sustainability and give possible improvements to help companies and SCs be more sustainable.

Moreover, this tool allows the performance comparison between different entities in the same level of the supply chain, as well as, between the different levels. This will give an idea of the impact of each level in the overall supply chain impact.

The Eco-tool was created based on a general AFSC framework, see section 3, so it does not have any specific company or supply chain into consideration. There are three major assumptions in which this tool is based on:

- Each company is only responsible for one level of the SC, which means that a company cannot work as a wholesaler and a retailer

simultaneously.

• There are three companies working inside each SC level;

• The KPIs of each company will measure the most common hotspots of that SC's level.

These assumptions were made so that it is easier for the user to tailor the Eco-Tool to its company requirements. However, they can be reversed.

4.2 Eco-tool's structure

In Figure 3 are represented eight levels of the supply chain and each one is composed by four sheets and there is also the supply chain sheet and the table of contents sheet, so in total the ECO-tool is composed by 34 sheets. Each level of the supply chain can be associated to an icon presented in the general SAFSC of Figure 2. However, there is a difference, there are three 3PL icons, the 3PLA, the 3PLB and 3PLC. The 3PL A is the one responsible for the connection between the primary producer and the processor, the 3PL B links the processor and the wholesaler and the 3PL C connects the wholesaler and the retailer.

In Figure 3, each sheet is represented by a rectangle. The sheets are connected to each other by arrows and they represent the direction of the flow of information. Also, the sheets are grouped by color according to the data computed there. The orange group is composed by the *Entities sheets*, where the KPIs associated to each company of the SC are computed. The green group includes all *Supply Chain Level sheets* whose goal is to compute the overall performance of each level of the supply chain in terms of sustainability. Then, the *Supply Chain sheet* is the only element of the blue group as it is where the tables with the overall performance of each level of the supply chain are inserted.

There are three entity sheets per each *Supply Chain Level sheet*. Each *Entity sheet* represents a company and in each one the KPIs to measure performance of that company in terms of the three pillars of sustainability are computed. Also, in this sheet, the KPIs are systematized in an output table where the company's targets are also added and the evolution over time computed. Then the all output tables are automatically copied to the respective *Supply Chain Level sheet*.

The *Supply Chain Level sheets* have the goal of systematizing the three output tables from the three entities' sheets that compose each level.

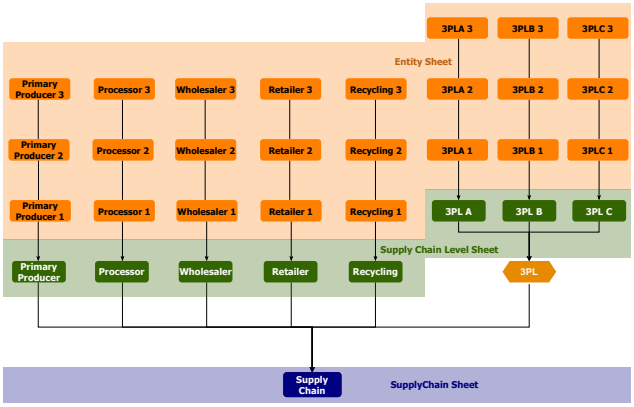

Figure 3: Excel structure

Based on these tables the overall score table is created with the weighted average of each KPI. In order to do so, a weight needs to be assigned to each entity in the SC according to its importance on the supply chain performance. Each company is responsible to find a way to determine this weight.

In the *Supply Chain sheet* all the overall score tables of all supply chain levels are systematized in this sheet. Thus, the user can have an overview of the entire supply chain and its KPIs considering the three pillars of sustainability. It is also possible to analyze the performance of each level individually and understand where the critical points are.

4.3 Eco-Tool's validation

In order to illustrate the usage of the Eco-tool, this tool is going to be applied to the Greenyard company. This was the chosen company since it has a wide range of available data, it is a reference company in the field and its main focus is in agricultural products.

Greenyard does not represent only one level of the supply chain, since they are responsible for picking up the food from framers, for processing it and store it before delivering it to the retailers. Hence, the company incorporates the roles of the 3PL, the processor and the wholesaler. In this context, the data available in the reports concerns the entire company, which means that this data is related to the Greenyard's work as 3PL, processor, wholesaler and recycling. Therefore, the 3PL, processor, wholesaler and recycling KPIs were grouped together in a table. By joining all KPIs, it is assumed that the most common hotspots detected for each level of the supply chain are the hotspots of the entire company. There are common hotspots between the different

levels of the supply chain that are measured by the same KPI. When this situation happens, the hotspots in common will not be repeated. The recycling entity was added since it can be applied to any level of the supply chain.

4.3.1 Outputs of the Eco-tool

The inputs of the tool were gathered through the analysis of the sustainability reports of the years 2018 and 2019, as well as, other articles available in the Greenyard's website referring to those years [26–28]. Based on these values the KPIs for the years of 2018 and 2019 were computed and presented in Table 4 and also some targets were added. These targets were not available for all KPIs. There was data that was already processed, which means that there were no calculations needed to achieve the KPIs and so, even though, the variables were not available, the KPIs were. As the tool is able to incorporate other KPIs and change the variables to compute certain KPI, it was possible to incorporate the changes necessary to tailor the tool to the supply chain data.

Even though the analyse is referred only to one company, the data comprises all subsidiaries throughout the world. Between them there are factors that vary, like culture, eating patterns, political issues, traditions and so on. This means that, this tool will detect hotspots of the entire company, which do not imply that all subsidiaries have these hotspots or that they do not have some others that appear not as weak spots of the entire company.

Although the majority of the KPIs do not have a target defined, in the most part it is known if the company wants to reduce or increase it. When the company is meeting the expectations in the evolution column is represented a green rectangle, when this does do not happen the rectangle is red. However, it is not known if these progressions are significant to have an impact on the efficiency in terms of the three pillars of sustainability since that is what the target is for. There are some rectangles that do not have any contour because, there is not enough information yo know if the progression of these KPIs are in line with the strategic objectives of the company. This is the case of production in risk countries, personnel expenses, costs of sales and operating expenses.

From this, it is possible to evaluate the performance of the company, as shown in Table 4 – column evolution. The information in this column was compared to the values in the "Target" column to see if the company is developing in the right direction. The data showed in Table 4 will be analyzed so as to understand how fairly this data can track the company's performance. The results will be described per pillar of sustainability.

The KPIs computed on the table 4 have the goal of monitoring the most common hotspots of the agri-food industry to understand what is preventing the company from having a sustainable performance. However, there was not enough data to measure them all and so other KPIs were computed to add as much information as possible to the evaluation of the company's performance in terms of sustainability. It is not mandatory that the company has these hotspots. Thus, even though, measuring them will allow the company to detect some of them, probably Greenyard this will not happen with all. In this context, the company should undergo an internal analysis in order to know what are its own hotspots and how to measure them.

Environmental: There has been a clear investment by the company in recyclable packaging and in recycling it since the target of recyclable packaging was surpass. Moreover, the more this KPI increases, the better chances are of increasing the percentage and the amount of recycled packaging. Hence, the company could, for instance, reward the costumers who give back their packaging to the retailer and so Greenyard would be the one responsible for recycling it. About the Emission and the Emission due to transportation KPIs, it was not possible to take any conclusions because they were just measured for one year. Anyway, investing in biodiesel and electric vehicles would have a great impact on the environment. According to Viswanathan and Thomai (2020), the synthesis of biodiesel is predominantly based on seed oils and it can be used to reduce the emissions from the engine since the oxygen present in biodiesel promotes clean combustion. Moreover, the increasing usage of electric vehicles will contribute to an improvement of the air quality [30].

There are some hotspots that are measured with KPIs that on its own are not enough to conclude if the company is having an efficient performance.

This is the case of water and energy consumption since it's something that varies much with the

Input	KPI	Value of 2018	Value of 2019	Evolution	Target in 2025	Units
Environmental						
Percentage of recycled packaging materials	PP	34.9	35.2	0.0086		%
Packaging Recycled	PC	27644.64	28035.04	0.01		Ton
Recyclable Packaging	RP	97	98	0.010	0.0038	%
Energy Use	EU	680,556	684,685	0.006		MWh
Water Use	WU	4,584	4,490	-0.021		10^6 m^3
Fuel consumed for food transportation	FCT	59151.636	58518.785	-0.011		MWh
Emissions	E		0.76239		0.0625	Ton CO_2 eq/ Ton waste
Emissions due to transportation	ET		5927.44			Ton CO_2 eq
Percentage of waste sent to the landfills	LF	5	2	-0.6		%
Social						
Suppliers screened for labor practices	SS	-	78		0.125	%
Gender Balance	GB	33	35	0.061		%
Fair Trade	FT	2.8	3	0.071		%
Wages	W	26.532	28.031	0.057		€/employee
Production in Risk Countries	RC	24	24	0.000		%
Training and Education	TE	11	11	0.000		Hours/employee
Accidents	A	340	344	0.012		Accidents
Charity Causes	CC	1636	1648	0.007		Ton
Economic						
Adjusted EBITDA	AE	64,500,000	95,700,000	0.484		€
Adjusted EBITDA - margin	AEm	1.6	2.4	0.500		%
Sales	S	3,910,000	4,060,000	0.038		€
Turnover	TE	3,912,000	4,061,000	0.038		€
Personnel Expenses	PE	415,511,000	406,372,000	-0.022		€
Costs of Sales	CS	3,712,509	3,813,320	0.027		€
Operating Expenses	OE	4,044,893	4,062,470	0.004		€
Sale of Waste	SW	811,000	933,000	0.150		€

Figure 4: Eco-Tool's outputs
(Adapted: [26–28])

production size. Greenyard should measure the water and energy intensity, which is the amount of water and energy per ton of food produced. Furthermore, Greenyard increased the amount of energy used, which did not go as planned, but, as discussed, could have been due to the increase in the production. However, the company could continue to invest in renewable energy and re-think their processes to make them more efficient.
Even though the values of the total energy and water consumption are available, as well as, the total amount of food produced, these KPIs were not computed because they should be calculated for each segment. This is due to the differences in the usage of this resources caused by the different types of food processing. The same happens with the fuel consumed and emission due to food transportation since it depends on the distance travelled. Thus, there should be other KPIs that measure the fuel consumed and ton of CO_{2eq} issued per km travelled.
A reduction in the waste sent to landfills was also verified, which means that there was more waste recycled, re-used and used for energy recover since these are all the waste's destinations chosen by the Greenyard company. This shows that waste destinations are becoming more environmental friendly.
Social: It is not possible to study the progression of the KPI suppliers screened for labor practices because there is only one year of data. However, Greenyard should continuously invest in assessing its suppliers for labor practices since its the company's responsibility to choose a supplier that has the same principles as the company. In this perspective, the company's image is also on the line if these assessments do show non compliance for labor practice.
The amount of feminine workforce and fair-trade volumes have been increasing as expected. For the last indicator, the company should show to the procurement departments the impact of fair-trade contracts not only for both companies (the supplier and Greenyard), but also for its employees.
Even though, the amount spent in wages per employee has been increasing, it does not mean the increment was done in the same proportion throughout the hierarchy. This KPI could be split in two, one referring to the entire company and other referring to the board positions.
It is essential to guarantee the supplier's social compliance, especially in the risk countries. One way could be through monitor the production that is originated from these countries in order to see if the number suppliers is changing.
The number of hours of training per employee is not increasing and these educational initiatives are a good way to motivate employees, increase their quality and motivation, as well as, a more versatile workforce. This can be one of the reasons that led to the increase of the number of accidents. The increase in the number of accidents will have an impact on the number of working hours and can reduce the overall productivity since the other employees can feel unsafe doing the same work.
Even though giving more food to charity causes being a good sign, this can be the result of an increase of the amount of food not sold. Therefore, the food sent to charity causes should be measured as a percentage of the food not sold.
Economic: The adjusted EBITDA are earnings before interest, taxes, depreciation, and amortization plus other adjustments to the metric. Adjusted EBITDA Margin is the Adjusted EBITDA as a percentage of total revenue. Since both these KPIs are increasing, this means that the company is becoming more profitable. In addition, the turnover and sales have also increased, which means that the company is rising its revenue.
The company should monitor the personnel expenses since it reflects the strategy of the

company associated with the selling and acquire of subsidiaries, the structural growth and the seasonal need's variations. The same happens with the cost of sales indicator, which is mainly related with the cost of goods, transport, packaging, warehousing, farming Personnel and temporary workforce. Therefore, every time this KPI is computed, all other costs need to be accessed. The operating expenses include the cost of sales, expenses related to impairment loss, selling, marketing, distribution and administrative. When analyzing this KPI, all the other expenses will also be computed.
Even though the money resulted from selling waste has increased, it is important to understand why this happened, for instance, due to an increase of waste generated or an increase of its value. This KPI shows that the company was able to recover value from the food that was considered to be waste and not have any value.

5 Conclusions and Future Work

As stated in the Introduction, it was clear that the world is facing very harmful environmental problems. In this context, research has been developed in how to eliminate or minimize the impact of these problems. The aim of this work was to help companies and SCs becoming more sustainable by creating a tool to measure their sustainability performance. This, among other goals, can help reducing the amount of food waste and lost, and allow companies keep tracking their weak spots and improve them.
The review of the existing literature showed that there was a lack of information for companies who wanted to evaluate their sustainable performance in a quantitative measure and considering an holistic view of the entire SC. This way, the tool created in chapter 4 helped filling this gap.
There were some limitations felt during the construction of this dissertation. During the literature review, it was noticed a lack of articles about mapping food chains and the SAFSCs, especially the sustainable ones. In section 3, a SAFSC was proposed in order to try to fill this gap. This chapter was also based on previous articles to gather the needed information to build the map. The more focused on the agri-food sector the searched information was, the less data was available. For this reason, there should be more data regarding the description of the information flow that connects the different entities.
This lack of data would probably be solved if different AFSCs were described, which include the different entities and flows that compose them. This is very important since the meat SC can be very different from the coffee SC, even though they are both agri-food products. For this reason, the systematization of the hotspots should be done to a more specific type of AFSC, for instance fruits or a specific fruit, instead of any agri-food product.
In the Chapter 4, the Eco-tool was built to measure the performance of the company or/and the entire SC. This tool can be tailored to any company and any SC. That is why, all the VBA code used to program the tool was explained, as well as, the structure of the excel sheets and what is done in each one of them. Given this, all companies of the SC can track their progress by computing the KPIs recurrently to make sure that the measures taken to improve the hotspots are having the supposed effects.
However, there are some setbacks that the companies should take into consideration while using this tool. It depends greatly on the data given by the companies and their collaboration, so transparency is a key factor to the success of the outputs. The companies also needs to be willing to start measuring some variables that have not been measured before, as well as, sharing the KPIs values and their improvements. The tool user need to know how to work with Microsoft Excel and how to program in VBA. This will allow the company to take advantage of all capabilities of this tool.
In this context, a good improvement would be to add to the Eco-tool an natural language processing (NLP) and MATLAB program to create a completely automatic tool to measure the performance of the company in terms of sustainability. The NLP program would be responsible for mapping the SC automatically and the MATLAB program to gather the data needed and insert it in the Excel. It would also be interesting if the tool saved the KPIs over time. This would give the information needed to compute a graphic showing the progression of the company. Furthermore, if these progressions were associated with the improvement actions made by the company, it would be possible to forecast how the company would react to certain changes. This way, the Eco-tool would be able to support even more strategic, tactical and operational decisions.
Afterwards, part of the tool was validated by analyzing the Greenyard company and measuring the most common hotspots of the SC levels that this company is responsible for. To have a better and more precised analysis of the company, the data should had been given per country and per segment since the values available were referring to all subsidiaries throughout the world and all segments (the fresh, prepared and frozen segments). This would also allow the formulation of more oriented improvement suggestions and analyse of the results.
This tool must be more and better tested since

only part of the tool was validated. It should be applied to various SC and companies. This will allow the companies to share their feedback about the features of the tool and detect improvement actions that can be added. As a result, the Eco-tool would go through a series of adjustments until it is according to the companies and SCs specifications and requirements. Moreover, it is essential that these validations occur in direct contact with the various companies in order to receive their feedback to understand how intuitive the tool is, if it was helpful and if it met the expectations. This would also give the idea which are the features that the users give more value and, in contrast, the ones that do not bring any value. This Eco-tool represents an innovative and disruptive tool to measure the sustainability of an AFSC and an important addition to the already existing research in the field. This tool can be used across the company, by all chain decision levels.

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