YRKESHÖGSKOLAN NOVIA

The influence of data on Carbon Footprint quantification of agricultural raw materials

From a corporate perspective

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Tiivistelmä

Motivaatio kokonaisvaltaiseen ympäristö- ja hiililaskentaan on yrityksille välttämätöntä ekonomisen resilienssin saavuttamiseksi. CO_2eq hiilijalanjälkimittarin toiminnallisuuden ymmärtäminen on tällöin erityisen olennaista.

Tutkimus valaisee hiilijalanjäljen määritysprosessissa käytetyn datan merkitystä tilanteissa, joissa tuotettu maataloustuote tähtää jatkojalostukseen arvokkaana osana globaalia ruokaketjua. Tutkimuksen tarkoituksena on tuoda esille heikosti hallittujen määritysprosessien eskaloituva negatiivinen vaikutus tilanteissa, joissa ne päätyvät osaksi suurempaa kokonaisuutta tai pitkäaikaista strategiaa.

Mallinnukseen valittiin kolme Suomessa eniten viljeltyä viljalajia; Kaura, ohra ja vehnä, tulosten tinkimättömyyden vahvistamiseksi. Mallinnuksen tarkoitus oli muokata saatavilla olevaa ja usein hyödynnettyä tieteellistä dataa tuoreimmalla tutkimustiedolla ja tämän myötä tarkkailla hiilijalanjälkimittarin käyttäytymistä. Kaikkien kolmen viljan kohdalla näkyi selkeä, lisääntyvä lasku CO_2eq arvoissa mitä pidemmälle tutkimusprosessissa edettiin, eron noustessa enimmillään jo merkittäväksi luokiteltavaan - 28.5 % tulokseen.

Hiilijalanjäljen määritysprosessin todenmukaisuus on erityisen riippuvainen sisällytetyn datan laadusta. Prosessin yksityiskohtien tarkastelulla voi olla merkittävä vaikutus lopputulokseen ja saman toistuessa useamman alkutuotannon raaka-aineen kohdalla, näkyy vaikutus myös lopputuotteen kautta kuluttajavalinnoissa, tuotekehityksessä ja strategisessa suunnittelussa. Määritysprosessin heikko laatu voi täten johtaa jopa pitkäaikaisiin vahinkoihin, niin ekonomiselta kuin ekologiselta kannalta katsottuna, harhaanjohdetun päätöksenteon aiheuttamana.

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Abstract

Motivation towards comprehensive environmental and carbon accounting is a necessity for a corporation to achieve economic resilience. Understanding the functionality of the carbon footprint metric (CO_2eq) is therefore essential.

This study enlightens the influence of data on carbon footprint quantification processes where the produced agricultural commodity is aimed for industrial processing as a valuable part of global food supply chain. The purpose of the study is to bring forth the escalading negative effect a poorly managed carbon footprint quantification process can have when implemented to further processes or long-term strategies.

Three of the main grains cultivated in Finland; Oat, barley and wheat, were chosen for the modelling in order to strengthen the integrity of the results. The purpose was to amend the already available and commonly used scientific data with the most recent information and knowledge in order to see the behavior of resulting carbon footprint estimation. All three grains showed a clear and progressing decrease in CO_2eq when more accurate data was included in the modelling, with the difference being a significant –28.5 % at its best.

The veracity of a CO_2eq quantification process is highly dependent on the quality of the included data. By focusing on the process details the end-result can be substantially changed, and when the same recurs in several raw materials from primary production the influence can be seen through the end-product in customer choices, product development and strategic planning. A low quality of the quantification process can thus create long term damages, both economic and ecological, through possible misguided decision making.

Language: English Key words: Climate Change, Carbon footprint, Grain, Agriculture, Carbon dioxide equivalent

Table of contents

1 Introduction 1
2 Aim of study 2
3 Theoretical background 3
  3.1 The relation between Greenhouse gases and CO_2eq 4
  3.2 Carbon footprint of a product (CFP) 4
  3.3 The contribution of a CFP Standard, ISO 14067 5
    3.3.1 Damage assessment according to standard 6
  3.4 Carbon action plans and GHG projects 7
4 Materials and methods 8
  4.1 Scope 9
    4.1.1 System boundary 9
    4.1.2 Process map 9
    4.1.3 Operational boundaries: Direct and indirect emissions 10
  4.2 Data 11
    4.2.1 Background data 12
    4.2.2 Primary data 12
    4.2.3 Allocation 13
  4.3 Study items and scenarios 14
5 Results 16
  5.1 Oat, Impact assessment and CO_2eq value 16
  5.2 Barley, Impact assessment and CO_2eq value 19
  5.3 Wheat, Impact assessment and CO_2eq value 21
6 Discussion 23
  6.1 Uncertainties 24
  6.2 Further studies or improvements in the field 25
    6.2.1 Completeness and relevance 26
    6.2.2 Transparency and conservativeness 26
    6.2.3 Accuracy, end user responsibility 27
  6.3 A corporate perspective 28
7 Conclusion 29
8 References 30

1 Introduction

In line with and motivated by the Paris agreement, Europe aims to become the world's first climate neutral continent by 2050 (EU, 2018). Furthermore, Finland has taken the ambition to be one of the first countries to reach climate neutral economy already by 2035 and from there onwards - to reach and increase the net negative value of greenhouse gas emissions to whatever extent possible (Valtionneuvosto, 2019). Only by stepping up the game from what we need to do - through what we can do - towards innovative thinking of what we could do - we have a possibility to achieve these goals and even see steps beyond them.

The economic factor in the interactive web of effects related to global climate change mitigation actions plays an important role but is often tragically misunderstood which may result in restrained development, resistance and/or poor decision making. According to Burke, Davis and Diffenbaugh (2018) achieving the goals set by the United Nations and Paris agreement would seemingly and directly reduce the future economic damages caused by the climate change, transferring to trillions of dollars worth of savings. In addition, meeting the goals would also force us to be more economically resilient through change, development and adaptation, creating new socio-economically sustainable pathways for our future.

The success of our national strategic goals is largely dependent on agriculture and industry as these are the main sources of GHG emissions in Finland and are strongly linked with energy (Statistics Finland, 2020). Therefore, the agriculture related industry and corporations have both the responsibility and possibility to notably influence on the carbon flux of their operations. Furthermore, intense interest in environmental actions and accounting is essential for a corporation to achieve economic resilience: implementing action plans to the company strategy serve as an investment to the company's own future through in-house studies and innovative product development; both which are much needed now as the whole world is seeking for solutions to balance between the growing need of food and fight against climate change.

Climate action plans require control which means that the process needs to be measurable. The CO_2eq serves as an efficient tool for carbon accounting but understanding the functionality of this carbon footprint metric and the scale of the emissions in the quantification process is essential. (Pandey *et al.*, 2010; Peng *et al.*, 2015; Storås, 2021). This study enlightens the influence of data on a carbon footprint quantification process where the produced agricultural commodity is aimed for industrial processing as a valuable part of the global food supply chain and the results of the analysis might effect decision making aimed to reduce the climate impact of products.

2 Aim of study

The goal is to highlight the importance of holistic analyses of the Carbon Footprint (CF) based on agricultural raw materials by focusing on the details in the calculation process and database values. A highly respected, profoundly structured and scientifically acknowledged database is chosen to serve as the process baseline. The information provided by the database is studied in accordance with the greenhouse gas inventory principles: relevancy, completeness, consistency, accuracy, transparency and conservativeness, with the aim to refine this background data to better represent the reality the system boundary of the study has established. (ISO 14064:2, 2019)

The purpose is to make further changes to the background data with the most recent information and knowledge in order to see the behavior of the carbon footprint metric (CO_2eq) and set out possible future goals for further improvements of the real-time data and of the carbon footprint calculation process. The changes are categorized into three different models (scenarios) according to their differentiating features. The comparison between the models developed in this study is essential for understanding the functionality of the carbon footprint metric (CO_2eq) and the importance of tracing the arguments behind published values before automatically including them in further studies or assessments.

To verify the trend, calculations are laid out for production of three different grains: Oat, barley and wheat, all with three different scenarios. The study aims to find out if the CO_2eq values retrieved from a model based on data from a common database deviate from values replaced with collected field data, and if the deviance is stable and correlative with all three grains and scenarios. The hypothesis is that there is a clear, constant and correlative deviance between the models, which would suggest that the reliability and significance of CO_2eq calculations are largely dependent on the pedantic professionalism of the party conducting the quantification process. In such case, the corporative decisions and possible strategic climate action plans using CO_2eq quantifications as means to evaluate activities are at risk in taking a wrong turn if the quantification process is not met with sufficient emphasis.

As the study is looking into the carbon footprint quantification from a corporate perspective, it is necessary for the process to respect the relevant methodology guidelines and report the result accordingly. This will give further emphasis and apprehension on the behavior of the carbon footprint metric (CO_2eq) and an introduction to the way a corporation preferably should conduct the quantification process, possibilities that would arise from the process and the details that needs to be considered for the process to reach a level of reliability and auditability. Thus, the study is focusing the carbon footprint of products method published by the international standardization organization, ISO 14067:2018, as ISO standards are highly and internationally recognized, and SGS audited reports would give a corporation sufficient reliability on their climate change mitigation efforts.

3 Theoretical background

Natural processes, such as cultivation of grains (although directed by human interference), tend to be miscellaneous and therefore a quite challenging subject for carbon footprint quantification. The soil, field environment and yield are under constant change through biological, chemical and physical events from direct and indirect interactions with the surrounding ecosystem. In addition, the cultivation techniques and variability of inputs are a subject of farmers preference and have a huge influence on the climate. (Huang *et al.*, 2011; Wreford *et al.*, 2010; Ylhäinen, 2021)

Climate change brings further challenges to the cultivation process as the grains’ resilience to different stress factors, e.g. extreme and/or unexpected weather; increased variability of pests and/or diseases, is under constant pressure. This does not only affect the yield but also the grains response to atmospheric CO_2. Stress has been found to trigger higher photosynthesis in some varieties of plants especially if CO_2 fertilizing is applied. As resilience, responses are found to be genotype specific which means that the response activity depends on the variety of each grain. (Farkas *et al.*, 2021).

Still, grains remain a largely unstudied sector, many times generalized with one carbon footprint value representing a vast number of varieties and/or regions, in a specific timeframe. The emission factors in these carbon footprint calculations may even have been generalized at a global scale, an average setting of common agricultural practices to serve as a best estimate for the current status of any given region or grain. These, most likely skewed, results might influence on e.g. selections of raw materials at food processing, decisions on actions towards CO_2eq quantification process identified hotspots, or direction of funds for studies for more resilient agricultural practices. It is therefore essential that the building blocks and the functionality of carbon footprint values are understood, critically evaluated and verified.

3.1 The relation between Greenhouse gases and CO_2eq

Earth's radiative balance is affected by a selection of greenhouse gases (GHG) of both natural and human induced (anthropogenic) origin. As the principal anthropogenic GHG, Carbon dioxide (CO_2) serves as the reference gas to which other greenhouse gases are measured, and therefore has the Global Warming Potential (GWP) of 1 (one). The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in causing radiative forcing. (IPCC, 2013).

The carbon dioxide equivalent (CO_2eq) emissions of each GHG are calculated based on the GWP of a given gas for a given timeframe. (IPCC, 2021). For example, the GWP from pulse emissions over a 100-year timeframe (aligned with the Kyoto protocol) *today* for Methane (CH_4) is 28 and for Nitrous Oxide (N_2O) is 265. However, the GWP value will change if the timeframe is changed, as then the effective climate-forcing atmospheric lifetime of a given gas is also different and thus in need for re-evaluation. Furthermore, the GWP values are under constant review by the International Panel of Climate Change (IPCC) and thus subject to updates. (Cucek *et al.*; IPCC, 2013).

3.2 Carbon footprint of a product (CFP)

Carbon Footprint (CF) is a more general term for GHG Footprint which combines the effect of several greenhouse gases caused by a given product, service or activity. It is obtained by summing the carbon dioxide equivalent emissions of each gas related to the process and expressed as kg CO_2eq / unit of product. Carbon Footprint of a product, referred as PCF or CFP, is a widely recognized consumption-based indicator and serves as an efficient metric for one of the nine planetary boundaries - Climate change. For an organization, it is especially beneficial in understanding the wider impacts of product supply chains, "hotspot" identification resulting to carbon/cost savings, brand enhancement and product differentiation. (Cucek *et al.*, 2015; IPCC, 2013; Mayolo, 2021; Rockström & Klum, 2012).

The Carbon Footprint of a product (CFP) is usually quantified with applicable lifecycle assessment (LCA) software, impact assessment method, and relevant (scientifically acknowledged) database serving as background data, but calculations can also be constructed with a simple excel setup. The emission factors for calculations and in the readily available databases needs to be derived from the IPCC Emission Factor Database. Possible useful information (activity data, emission factors and parameters) can also be found in other databases which are constructed to serve different sectors and/or countries, such as energy balances by the International Energy Agency (IEA) or agriculture, forestry and land use database by Food and Agriculture Organization (FAO). The use of databases and all other related information is *always the responsibility of the users*. (EFDB, 2021)

The selection of calculation tools, methods and data resources are made based on the attributes of the product under analysis and the pursued impact assessment factors. Due to the increasing amount of CF evaluation tools and variability of interpretations by human nature, the scientific community has long lacked a consensus on the basic structure and guidelines of CFP assessments, resulting to space and time bound analysis results that are not comparable – and at times not even repeatable. Thus, there has been an increasing need for more detailed, single issue standard development that contributes to more transparent communication and comparison of CFP quantification results. (Peng *et al.*, 2015)

3.3 The contribution of a CFP Standard, ISO 14067

In 2018, the International Standardization organization (ISO) published a new member to the ISO 14000 family of Environmental standards: *The International Standard for Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification* (ISO 14067:2018). The standard is in line with other well-known greenhouse gas standards such as the various standards and guidelines of GHG protocol published by the World Business Council for Sustainable Development (WBSCD) and World Resource Institute (WRI); and PAS2050 developed by the British Standards Institution, but further enhances and determines the basic requirements especially on the methodology and reporting of PCF studies. (Mayolo, 2021; Peng *et al.*, 2015)

The 14067 standard is especially relevant from a corporative perspective as it brings more emphasis to the quantification, discussion and communication of carbon footprint values. It provides more transparency and reliability for the comparison and evaluation of the quantification processes and results, thus enabling a more efficient platform for interactive co-operations between different stakeholders, contributing to the succession of corporate climate action plans. However, there is still a continuous need for more detailed consensus - both with comparative modelling between industries with equal processes and interactivity of subindustries of the same category, but with varied processes and end-products. (ISO 14067:2018; Katajajuuri *et al.*, 2012; Peng *et al.*, 2015)

3.3.1 Damage assessment according to standard

CFP quantification according to ISO 14067:2018 requires impact assessment execution according to climate change factors of IPCC with a timeframe of 100 years. The IPCC damage assessment indicator for climate change is a single-issue method that includes product carbon dioxide uptake, an indicator for land use and transformation, and both fossil and biogenic emissions. The method is quite widely used within most impact assessment methods but can also be available as a selection rather than default. For some scientific purposes a timeframe of 20 – or even 1000 – years can be more applicable. Therefore, carbon footprint reports stating the compliance to the standard ISO 14067 are known to have (*at least*) the basis set for coherent and thus comparative results. There is an ever growing variety of PCF evaluation tools available but when choosing one its functionality on single issue standards, such as the ISO 14067, is a basic requirement and in need for verification. (ISO 14067:2018; Peng *et al.*, 2015; PRé, 2020)

Below the attributes of the IPCC 100a method used in Life Cycle Assessment for estimating the Carbon Footprint (as in this study) are described:

- Land use and transformation is balancing between the release and sequestration of carbon resulting from land modification. In agriculture, such actions are mostly related to conversion of natural ecosystems to croplands or pasture, and/or abandonment of croplands or pasture.

- Carbon dioxide uptake (sequestration) addresses the addition of carbon containing substances to a reservoir, which in this case is the field.

- Fossil emissions derive from the combustion of fuels originating from fossil carbon deposits such as oil, gas and coal, thus directly adding up to the total amount of GHG emissions in the atmosphere.

- Biogenic emissions are a part of the natural carbon cycle with emissions resulting from combustion, harvest, digestion, fermentation, decomposition or processing of biologically based materials, thus ostensibly recycling carbon emissions. However, succeeded carbon recycling requires efficient sustainable sourcing and poor management can even lead to significant, irreversible environmental damages of which e.g. peat bogs are a strong example of.

(IPPC, 2000 & 2013; PRé, 2020; Schimel & Wigley, 2000)

3.4 Carbon action plans and GHG projects

Product carbon footprints are one basis for efficient carbon action planning, together with organizational GHG inventories. A corporate carbon action plan is an iterative strategy with a certain timeframe, starting point and targets towards carbon neutrality. Development of carbon reduction pathways considers financial constraints or other economic frameworks guiding the decision making. Therefore, revision of the carbon reduction measures and calculation of their financial impact is a constant throughout the many times decades lasting strategy. The generally annual revision is essential to ensure that the measures are on the right path, towards the desired outcome. Attributes effecting the direction tend to change in time which alone creates a need for active revision, along with other possible changes in the processes. (Roosa & Jhaveri, 2009)

Although it is possible for an establishment to compensate its product emissions and therefore ostensibly declare the product to be carbon neutral, carbon offsets can be available "cost-free" through GHG projects. Created offsets can then be included in PCF calculation as emission reductions or, if willing, sold as offsets in global carbon market. However, the emission reductions and removal enhancements need to be recognized, verified and validated before they are released as carbon credits. The complete process, from emission baseline quantification to periodic monitoring until final reporting, is expected to respect the GHG inventory principles of:

- Relevancy: GHG sources, sinks and reservoirs, selection of data and methodology, are appropriate to the project
- Completeness: all relevant emissions, removals, information is included to support the criteria and procedures

- Consistency: GHG related information can be compared throughout the project
- Accuracy: uncertainties are discussed and reduced
- Transparency: sufficient and appropriate information is disclosed for a third party to obtain reasonable confidence
- Conservativeness: conservative assumptions, values and procedures are used to ensure that GHG emission reductions or removal enhancements are not over-estimated

For a corporation to develop a credible inventory the information provided needs to meet the principles, while meeting the decision-making needs of both internal management and external stakeholders. (ISO 14064-2:2019; Mayolo, 2021).

An action plan, inventory or project, can be issued for any corporation or establishment, e.g. from a multinational company with many subsidiaries and associates to a privately owned 20-hectare farm in Finland producing varying quantities of raw materials for local food processors. In fact, an efficient and well-established inventory at farm level can result in substantial environmentally positive versatile causations, when a corporation might not have access to such environmental influence.

4 Materials and methods

The LCA assessment software SimaPro 9.1. (Pré Sustainability, 2020) was used to model and estimate the product carbon footprint for different scenarios for oat, barley and wheat, focusing on the environmental impact category of climate change. SimaPro, widely used in scientific LCA studies, gives access to the details of several readily available databases. Such access would not be easily obtainable without the software. Furthermore, for the consistency and conservativeness of the study, SimaPro has been used to build the baseline database and thus is the best choice for further comparative studies, ruling out uncertainties resulting from differentiating LCA tools. (Blonk, 2019; Blonk(3, 2020; PRé, 2020)

For the estimation the climate change factors of IPCC with a timeframe of 100 years (IPCC 2013 GWP 100a (incl. CO_2 uptake) V1.00) were used, as implemented to SimaPro by Pré Consultants. The method is relevant in assessments carried out according to ISO14067, as explained in chapter 3.3.1 Damage assessment according to standard.

4.1 Scope

4.1.1 System boundary

The functional unit in the analysis is 1 kg of end product (grain) and results are stated as CO_2eq kg per kg of grain (CO_2eq kg / kg) at farm. The system boundary of the study is described in figure 1. as a partial analysis of a full lifecycle of a product, from cradle to gate. The gate is determined *at farm*, thus excluding further distribution to processing, including processes that might take place in the same establishment such as the drying or storing of the grain. Partial analysis covers the lifecycle stages *from the extraction or acquisition of raw materials to the point at which the product leaves the organization* which in this case is the field (Mayolo, 2021). The geographical boundaries are set to cover agricultural production in Finland.

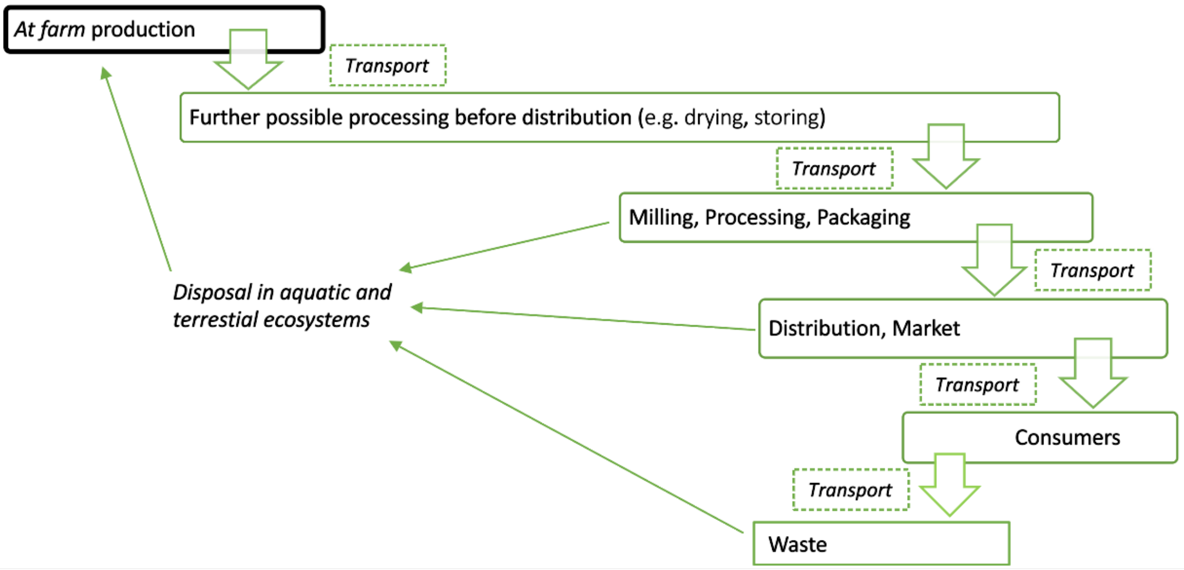


Figure 1. Full product lifecycle of grain aimed for industrial food processing. The Study system boundary of the current study is set to partial analysis, cradle-to-gate, on grain "At farm production", as indicated by the black box. The other parts of the full lifecycle are not considered in this current study. (Altham *et al.*, 2002).

4.1.2 Process map

The analysis consists of all relevant practices needed for the cultivation process of grain at farm (see fig. 2). The data includes transport of inputs and emissions related to the cultivation process; start material and its production (seeds), fertilizer, lime and pesticide application rates and their production (agrichemicals), energy use for field management (energy; ground preparation, harvesting). Irrigation (water), along with some agrichemicals, are present only in the background data (further explained in chapters 4.2 Data, and 4.3 Study items and scenarios).

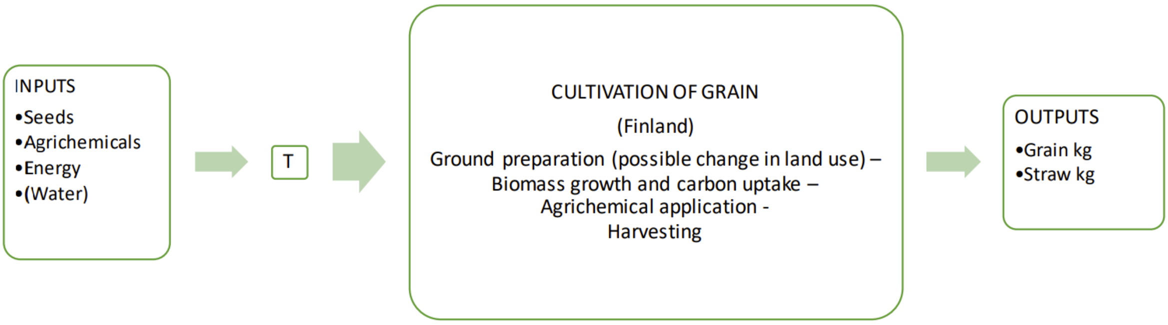


Figure 2. Process map of grain cultivation with inputs, transport of inputs (T), cultivation process and outputs. Water (irrigation) is present in the background data (chapter 4.2) but is not included in the scenarios further explained in chapter 4.3. (Mayolo, 2021)

4.1.3 Operational boundaries: Direct and indirect emissions

In GHG inventories the emissions of a product or process are classified in three categories (scopes): 1) Direct emissions, 2) Indirect emissions from purchased energy and 3) Other indirect emissions (Fig. 3). Reporting scope 1. and 2. emissions is mandatory, but for scope 3. reporting is in some cases optional. Scope 1. direct emissions include all emissions and removals that are in the control or owned by the establishment. Scope 2. emissions derive from imported energy which in this case, as system boundary is set to gate before further processing (e.g. drying), are non-existent. Scope 3. sources are many and diverse that considers the emissions of both input products (upstream emissions) and end-of-life phases of products leaving the farm (downstream emissions), and other sources such as emissions deriving from the lifecycle of machinery and facilities at the farm, man labor or administrative practices.

Although it is optional to include scope 3. emissions, it is many times highly recommended. In agriculture, some inputs are considered as important, and should therefore be accounted for. Importance can be estimated e.g. by scaling the possibility of decreasing scope 1. and 2. emissions by using inputs that fall under scope 3. Such can be the case with the manufacture of fertilizer or livestock feed. Leaving out the scope 3. emissions on these inputs contradicts the relevancy, completeness and transparency expected from a GHG inventory. For a full PCF analysis all emissions are mandatory. (GHG, 2021; Mayolo, 2021)

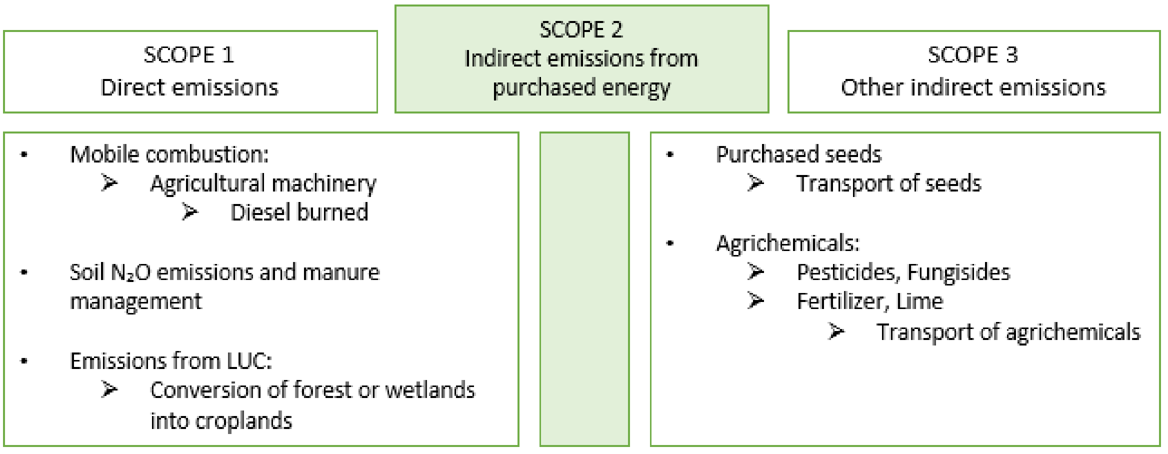


Figure 3. Direct and indirect emissions of grain production in Finland (ref. System boundary, Fig. 1 &2) (GHG, 2021; ISO 14064-1:2018; Mayolo, 2021)

Biogenic emissions resulting from grain production (as described in Figure 2. and 3.) are mainly due to carbon dioxide fluxes to and from the carbon stocks in soil, above- and below-ground biomass and dissolved organic matter (DOM) stocks. Biogenic emissions also cover CO_2 removals by soils and biomass following afforestation (LUC). No biofuel consumption has been linked to average grain production in Finland. (GHG, 2021)

4.2 Data

The dataset used in this study consists of background (secondary) data and site-specific primary data, the background data serving as the basis for the analysis. The background data derives from Agri Footprint 4.1 (Blonk Consultants, 2020) and the primary data was provided by one of the most influential agricultural companies in Finland (Hankkija, 2020) that has a straight contact with the Finnish farms as a first-hand buyer of grains and raw materials, and thus has prime access to the cultivation process data.

4.2.1 Background data

The background (secondary) data served two purposes: As a basis for a comparative model as its original form, and as a part of a newly constructed dataset with primary data implemented to the model. There is a vast variety of databases available, focusing on different fields of study and industries, many which have excellent attributes to agricultural procedures. One of such is Agri-Footprint, developed and maintained by Blonk Consultants.

For grains Agri-footprint uses FAO (Food and Agriculture Organization of the United Nations) and IFA (International Fertilizer Association) statistics in estimations of regional crop yields, manure management and fertilizer usage. Crop yields are derived from FAO statistics using a 5-year average, which - in the most recent version of Agri-footprint available during this study - considers yrs. 2012-2016. The use of energy, water and pesticides are derived from models build by Blonk Consultants and based on IPCC guidelines for National greenhouse gas inventories and several scientific studies of third parties.

The models in the Agri-Footprint database are calculated with a lifecycle impact assessment method, ReCiPé, which *comprises harmonized category indicators at midpoint and endpoint level*. ReCiPé is based on IPCC climate change factors and additionally offers indicators for other planetary boundaries as well. Land use and land-use change (LULUC) is estimated with Direct land-use change assessment tool developed by Blonk Consultants according to PAS2050-1, which accounts for general changes in land use of a given country with a timeframe of 20 years. (Blonk, 2019; Blonk(2,2019)

From all available scientifically acknowledged datasets Agri Footprint was chosen as it is widely used in agricultural applications, such as the publicly available Feed LCA database of the Global Feed LCA Institute (GFLI, 2020). As in this study, both the Agri Footprint data and the results of the study can be used for both feed and food quality fractions, as no difference has been made between the two during the data collection or the assessment itself.

4.2.2 Primary data

The site-specific primary data derives from samples of cultivated and harvested grains sent by farmers to Hankkija nationally accredited laboratory. Each sample has been equipped with background information of the cultivation process such as the season (year), seeds, fertilizers, pesticides, fungicides, yield, cultivation technique and timing. The data applied in the study origins from grains harvested during a three-year period of 2017-2020.

The raw data consisted of *n*=7611 samples. The data cleaning process excluded samples that either lacked sufficient information or the information input was incorrect. One example of the basic requirements for the additional information on each sample was that the amount of fertilizers used had been appropriately reported. In addition, all samples with clear deviance from the norm (excessively low or high values) on any given sector were excluded. The data cleaning process left the final data with *n*=5238 samples: Oat *n*=1991, Barley *n*=1208 and Wheat *n*=2039. (Hankkija, 2020)

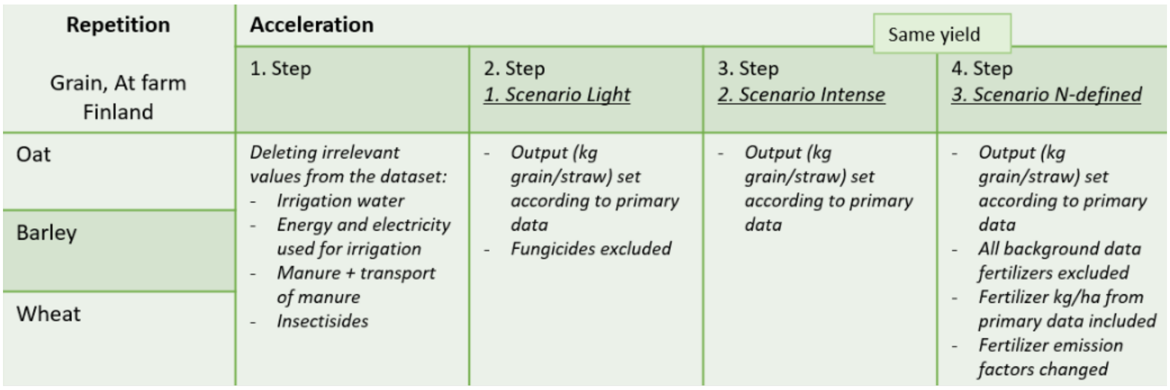
4.2.3 Allocation

Although, among others, the ISO standard 14067 recommends that allocations should be avoided where possible, in cases where there are several outputs in the process economic allocation is a necessity. The grains (Oat, Barley and Wheat) have relatively similar properties and applications, theoretically allowing a wide spectrum of different allocation methods, but economic allocation weights the emissions to the different outputs according to their set value and is therefore highly applicable in PCF analyses. (Mayolo, 2021).

The calculations in the study are done with the economic allocation settings of the background data; Agri-Footprint. The database has derived the values from a scientific publication by *Vellinga et.al.* (2013) which states in relation to crop cultivation a country specific (if available) price average of the most recent five-year period should be used. In addition, "*If country specific prices are not available, the ratio of prices in another country will be used as starting point to calculate off factory prices*". The actual numeric values are not made publicly available. (Blonk, 2019; Vellinga *et.al*, 2013).

4.3 Study items and scenarios

The consistency of the study results is tested by repeating the modelling process with several study items. Therefore, three main grains cultivated in Finland; Oat, barley and wheat, were chosen as study items for the modelling. All three grains were set up with three different scenarios (in addition to the baseline scenario), presented in Figure 4., with the aim to stress the hypothesis that further changing (accelerating) the process would result in growing differences in the PFC values.



Repetition	**Acceleration**		Same yield	
Grain, At farm Finland	1. Step	2. Step *1. Scenario Light*	3. Step *2. Scenario Intense*	4. Step *3. Scenario N-defined*
Oat	*Deleting irrelevant values from the dataset:* - *Irrigation water* - *Energy and electricity used for irrigation* - *Manure + transport of manure* - *Insectisides*	- *Output (kg grain/straw) set according to primary data* - *Fungicides excluded*	- *Output (kg grain/straw) set according to primary data*	- *Output (kg grain/straw) set according to primary data* - *All background data fertilizers excluded* - *Fertilizer kg/ha from primary data included* - *Fertilizer emission factors changed*
Barley				
Wheat				

Figure 4. Study process steps expressing the changes and differences between the modelled scenarios (1, 2 and 3). Same scenarios are repeated with all three grains. The baseline is presented in paragraph 4.1.2 Process map.

The first step in the process was to trace the arguments and references behind the background data in order to ensure the accuracy and relevancy of the process details. This resulted to the exclusion of procedures that were not applicable in estimating an average Finnish grain cultivation process (Figure. 4., Table 1.). In Finland, grains are not irrigated nor sprayed with insecticides, and only a portion of the farms that aim for the grain market have access to manure. Therefore, all related activities, including the related direct and indirect emissions, were excluded from the scenarios 1, 2 and 3, as seen as *Step 1.* in Figure 4.

Table 1. Excluded processes from the background data for basis of scenario 1, 2 & 3 in order to more closely represent the cultivation of grains in Finland.

Process name in database	Comment
Water,unspecified natural origin, FI	Irrigation water based on yield and "blue water footprint" (Mekonnen & Hoekstra, 2010)
Manure (pig), at farm/RER Economic	Swine manure applied for soil maintenance. Based on FAO data on manure management (2012-2016) and methodology described in appendix 4 of Vellinga et al. (2013)
Manure (poultry), at farm/RER Economic	Poultry manure applied for soil maintenance. Based on FAO data on manure management (2012-2016) and methodology described in appendix 4 of Vellinga et al. (2013)
Transport, truck 10-20 t, EURO4, 80%LF, empty return/GLO Economic	Transport of manure (30 km)
Insecticide, at plant/RER Economic	Insecticide use derived from Pesticide model
Insecticide emissions, at farm/RER	Emissions of insecticide active ingredients used within a specific region
Energy, from diesel burned in machinery/RER Economic	Total fuel demand for irrigating arable crops. Derived from "Energy model for crop cultivation"
Electricity mix, AC, consumption mix, at consumer, < 1kV FI S System -Copied from ELCD	Total electricity used for irrigating arable crops. Derived from "Energy model for crop cultivation"

In addition to the general exclusions presented on Table 1., further changes were made to distinguish the differences between the scenarios (Figure. 4). These included 1) changes to the yield (output) of grain and proportionately to straw according to the primary data values, 2) exclusion of fungicides in scenario 2., 3) replacement of background data fertilizer values (Table 2.) with the average N kg /ha values from primary data in Scenario 3.

Table 2. Excluded fertilizers from the background data at Scenario 3. N-defined products

Process name in database	Comment
Calcium ammonium nitrate (CAN), (NPK 26.5-0-0-), at plant/RER Economic	Derived from Calc.amm.nitrate consumed in Finland (IFASTAT, 2016-2012) and total NPK use for Oats/Barley/Wheat cultivation (IFA 2011)
NPK compund (NPK 15-15-15) at plant/RER Economic	Derived from NPK compound consumed in Finland (IFASTAT, 2016-2012) and total NPK use for Oats/Barley/Wheat cultivation (IFA 2011)
Potassium chloride (NPK 0-0-60), at plant/RER Economic	Derived from Potassium chloride consumed in Finland (IFASTAT, 2016-2012) and total NPK use for Oats/Barley/Wheat cultivation (IFA 2011)

The fertilizer used in scenario 3. is estimated to derive from one of the leading manufacturers in Finland, Yara. As the exact fertilizer type is not reported in the primary data, the assumption was made based on the market share of Yara in Finland and through expert opinions (Hankkija, 2020) on the most common fertilizer used in the cultivation of the grains under study: Yara Mila Y2, with an emission factor of 3.58 kg CO_2eq / kg N. (Yara, 2021).

5 Results

All results are presented with the background and primary data input for the modelled scenarios discussed in chapter 4.3, and climate impact assessment according to the requirements of ISO14067; with GWP factors of a timeframe of 100 years as estimated on the IPCC 5th assessment report. Biogenic emissions, carbon dioxide (CO_2) uptake and land use/transformation are reported, as required by the ISO14067 standard, but do not have effect on the product carbon footprint result. In case the biogenic emissions would be resulting from direct human activity (e.g. biodiesel), should the emissions be accounted for and reported separately. All biogenic emissions in the study are a result of a natural process. (IPCC, 2013; ISO14067, 2018; Mayolo, 2021)

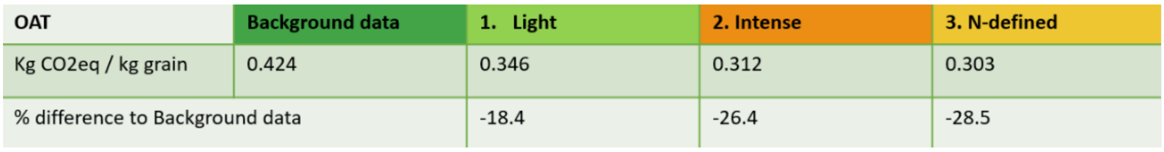
5.1 Oat, Impact assessment and CO_2eq value

From the *n* = 1991 samples of oat provided by the primary data Scenario 1. *Light* is represented with *n* =1465 samples, when as Scenario 2. *Intense* and Scenario 3. *N-defined* are left with *n* = 526. The yields and fertilizer usage are an average of the samplings per scenario, presented in table 4.

Table 4. Data input on oat (at farm/FI) according to the different scenarios (ref. chapter 4.3)

Input	**Scenario 1. Light**	**Scenario 2. Intense**	**Scenario 3. N-defined**
total fertilizer cons. N kg/ha	Background data	Background data	98
Herbicide	Background data	Background data	Background data
Fungicide	Excluded	Background data	Background data
Output			
Grain yield (kg/ha)	4076	4590	4590

The carbon footprint of oat, as presented in Figures 5. and 6., derived from background data resulted to 0.424 kg CO_2eq / kg of oat. With Scenario 1. (*Light*) there was –18.4 % reduced climate impact with a result of 0.346 kg CO_2eq / kg of oat. Scenario 2. (*Intense*) extended the gap with –26.4 % less impact compared to the background data value, and –9.8 % less impact compared to Scenario 1. with 0.312 kg CO_2eq / kg of oat. Scenario 3. (*N-defined)* gave a result of 0.303 kg CO_2eq / kg of oat, which meant a –28.5 % deduction from the background data value, -12.4 % from Scenario 1. and –2.9 % from Scenario 2.



OAT	**Background data**	**1. Light**	**2. Intense**	**3. N-defined**
Kg CO2eq / kg grain	0.424	0.346	0.312	0.303
% difference to Background data		-18.4	-26.4	-28.5

Figure 5. Results on oat product carbon footprint (kg CO_2eq / kg of oat) based on different scenarios (ref. chapter 4.3) and their differences compared to the background data (ref. chapter 4.2)

The biogenic emissions (*Fig*. 6) respectively resulted to (Background data) 0.00626, (Scen. 1.) 0.00526, (Scen. 2) 0.00469, and (Scen. 3.) 0.00158 kg CO_2eq / kg of oat. Carbon dioxide uptake valued to (Background data) -0.000354, (Scen. 1.) -0.00294, (Scen. 2.) -0.000264 and (Scen. 3.) -0.0002 kg CO_2eq /kg of oat. No land-use or land transformation has been assigned to oat.

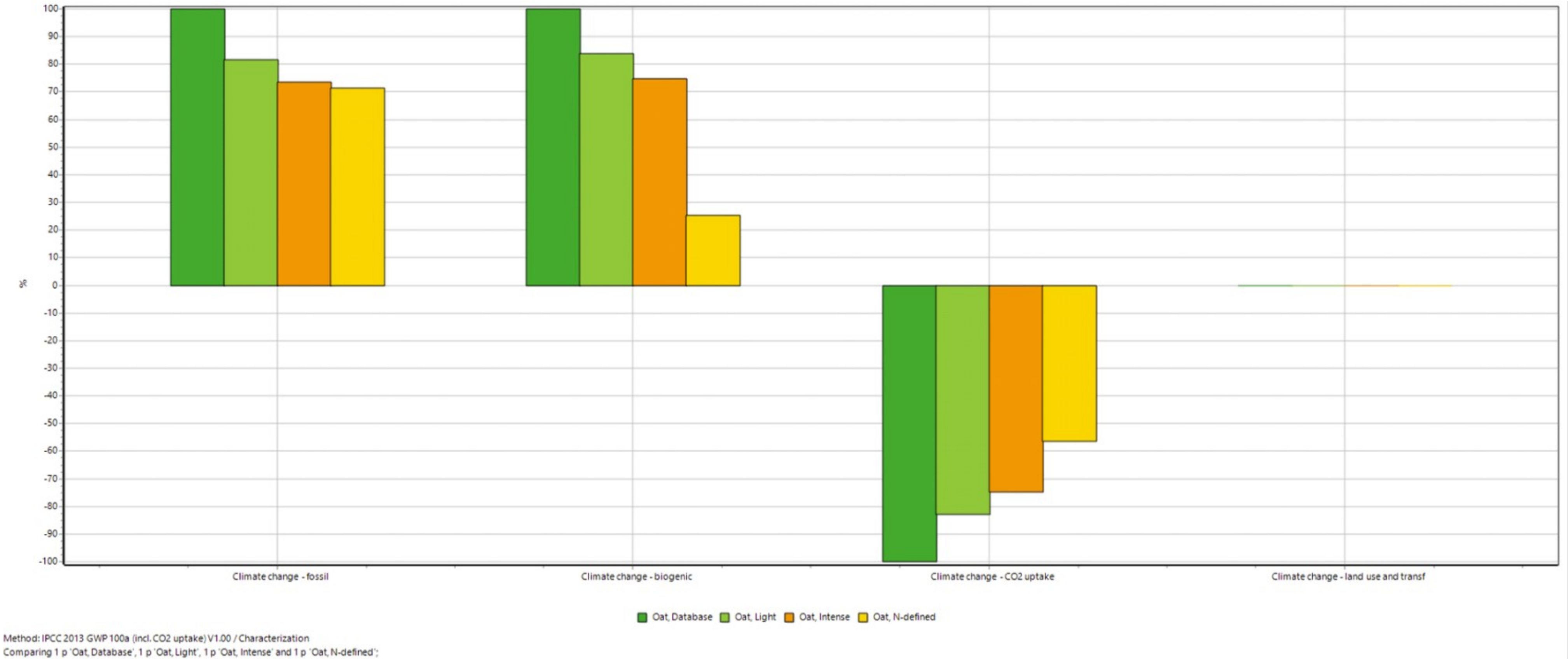


Figure 6. Climate change impact assessment results on wheat (at farm/FI) according to IPCC (2013) GWP 100a with comparison between background data and scenarios 1, 2 and 3.

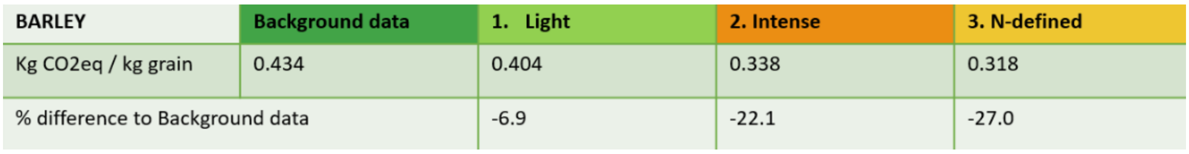
5.2 Barley, Impact assessment and CO_2eq value

From the *n* = 1208 samples of barley provided by the primary data Scenario 1. *Light* is represented with *n* = 518 samples, when as Scenario 2. *Intense* and Scenario 3. *N-defined* are left with *n* = 690. The yields and fertilizer usage are an average of the samplings per scenario, presented in table 5.

Table 5. Data input on barley (at farm/FI) according to the different scenarios (ref. chapter 4.3)

Input	**Scenario 1. Light**	**Scenario 2. Intense**	**Scenario 3. N-defined**
total fertilizer cons. N kg/ha	Background data	Background data	98,3
Herbicide	Background data	Background data	Background data
Fungicide	Excluded	Background data	Background data
Output			
Grain yield (kg/ha)	3746	4598	4598

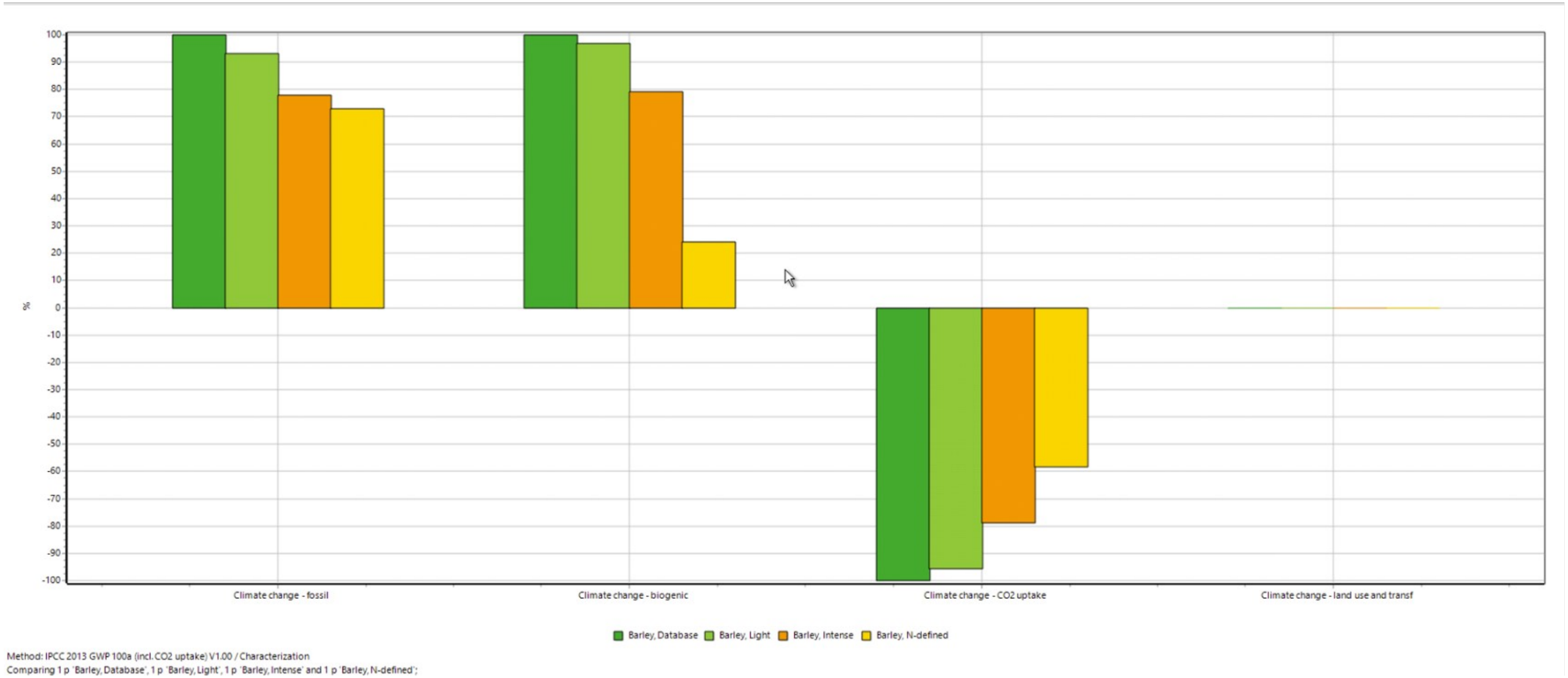
The carbon footprint of barley, as presented in Figures 7. and 8. (Fossil), derived from background data resulted to 0,434 kg CO_2eq / kg of barley. With Scenario 1. (*Light*) there was –6,9 % less climate impact with a result of 0,404 kg CO_2eq / kg of barley. Scenario 2. (*Intense*) extended the gap with –22,1 % less impact compared to the background data value and –16,3 % less impact compared to Scenario 1., with 0,338 kg CO_2eq / kg of barley. Scenario 3. (*N-defined)* gave a result of 0,317 kg CO_2eq / kg of barley, which meant a –27 % deduction from the background data value, -21,5 % from Scenario 1. and –6,2 % from Scenario 2.



BARLEY	Background data	1. Light	2. Intense	3. N-defined
Kg CO2eq / kg grain	0.434	0.404	0.338	0.318
% difference to Background data		-6.9	-22.1	-27.0

Figure 7. Results on barley product carbon footprint (kg CO2eq / kg of barley) based on different scenarios (ref. chapter 4.3) and their differences compared to the background data (ref. chapter 4.2)

The biogenic emissions respectively resulted to (Background data) 0.00632, (Scen. 1.) 0.00612, (Scen. 2) 0.005, and (Scen. 3.) 0.00152 kg CO_2eq / kg of barley. Carbon dioxide uptake valued to (Background data) -0.000345, (Scen. 1.) -0.00033, (Scen. 2.) -0.000272 and (Scen. 3.) -0.000201 kg CO_2eq /kg of oat. No land-use or land transformation has been assigned to barley.



Method: IPCC 2013 GWP 100a (incl. CO2 uptake) V1.00 / Characterization
Comparing 1 p 'Barley, Database', 1 p 'Barley, Light', 1 p 'Barley, Intense' and 1 p 'Barley, N-defined';

Figure 8. Climate change impact assessment results on barley (at farm/FI) according to IPCC (2013) GWP 100a with comparison between background data and scenarios 1, 2 and 3.

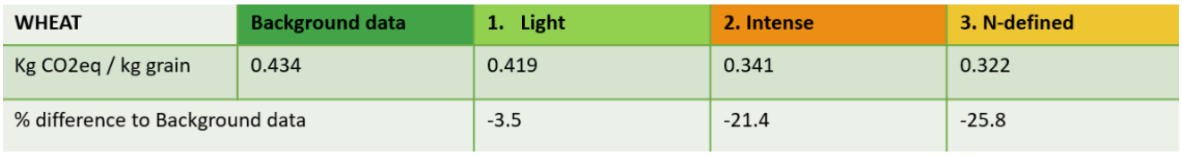
5.3 Wheat, Impact assessment and CO_2eq value

From the *n* = 2039 samples of wheat provided by the primary data Scenario 1. *Light* is represented with *n* = 1042 samples, when as Scenario 2. *Intense* and Scenario 3. *N-defined* are left with *n* = 997. The yields and fertilizer usage are an average of the samplings per scenario, presented in table 6.

Table 6. Data input on wheat (at farm/FI) according to the different scenarios (ref. chapter 4.3)

Input	**Scenario 1. Light**	**Scenario 2. Intense**	**Scenario 3. N-defined**
total fertilizer cons. N kg/ha	Background data	Background data	127,7
Herbicide	Background data	Background data	Background data
Fungicide	Excluded	Background data	Background data
Output			
Grain yield (kg/ha)	3811	4827	4827

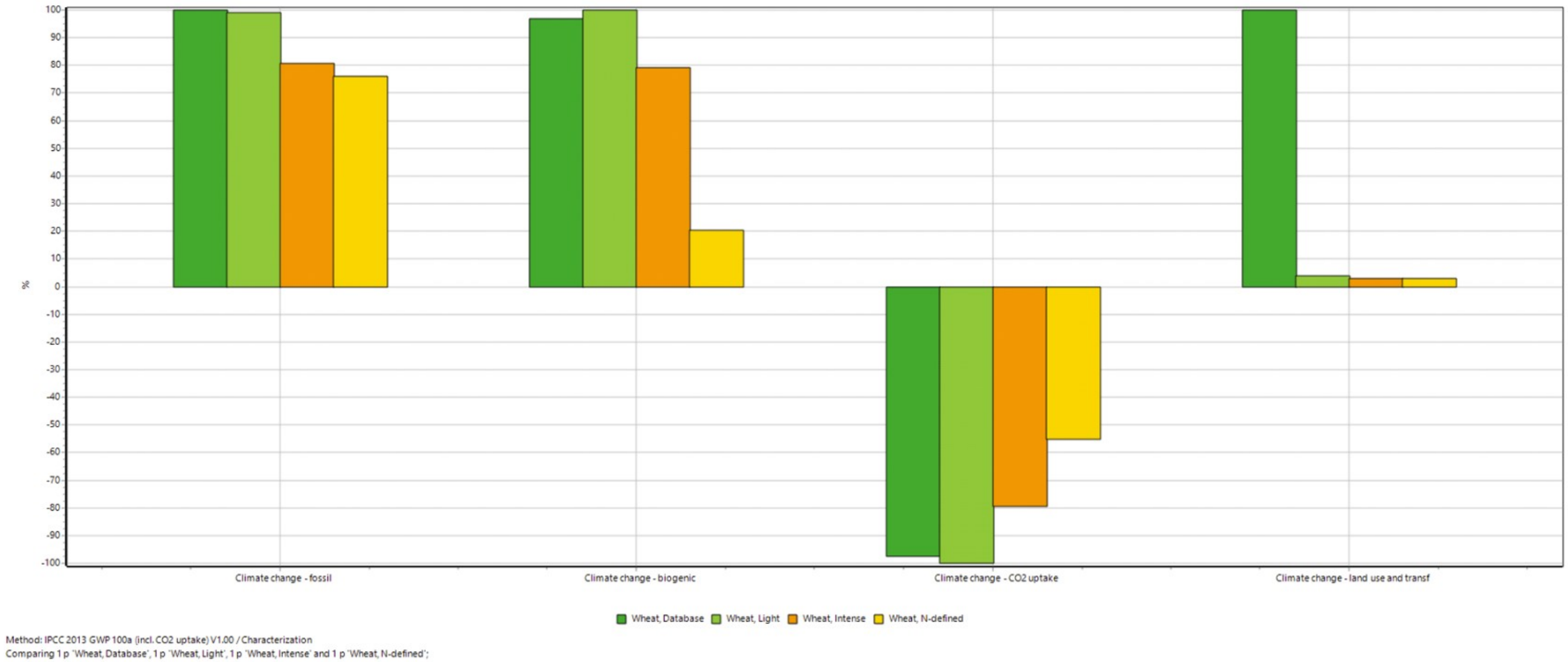
The carbon footprint of wheat, as presented in Figures 9. and 10. (Fossil), derived from background data resulted to 0,434 kg CO_2eq / kg of wheat. With Scenario 1. (*Light*) there was –3,5 % less climate impact with a result of 0,419 kg CO_2eq / kg of wheat. Scenario 2. (*Intense*) extended the gap with –21,4 % less impact compared to the background data value and –18,6 % less impact compared to Scenario 1., with 0,341 kg CO_2eq / kg of wheat. Scenario 3. (*N-defined)* gave a result of 0,322 kg CO_2eq / kg of wheat, which meant a –25,8 % deduction from the bacckground data value, -23,2 % from Scenario 1. and –5,6 % from Scenario 2.



WHEAT	Background data	1. Light	2. Intense	3. N-defined
Kg CO2eq / kg grain	0.434	0.419	0.341	0.322
% difference to Background data		-3.5	-21.4	-25.8

Figure 9. Results on wheat product carbon footprint (kg CO2eq / kg of wheat) based on different scenarios (ref. chapter 4.3) and their differences compared to the background data (ref. chapter 4.2)

The biogenic emissions respectively resulted to (Background data) 0.00608, (Scen. 1.) 0.00628, (Scen. 2) 0.00497, and (Scen. 3.) 0.00128 kg CO_2eq / kg of wheat. Carbon dioxide uptake valued to (Background data) -0.000292, (Scen. 1.) -0.00299, (Scen. 2.) -0.000238 and (Scen. 3.) -0.000165 kg CO_2eq /kg of wheat. Land-use and transformation assigned to (Background data) 0.0117, (Scen. 1.) 0.0121 and, for both Scenarios 2 & 3: 0.096 kg CO_2eq / kg of wheat. (*Fig*. 10)



Method: IPCC 2013 GWP 100a (incl. CO2 uptake) V1.00 / Characterization
Comparing 1 p 'Wheat, Database', 1 p 'Wheat, Light', 1 p 'Wheat, Intense' and 1 p 'Wheat, N-defined';

Fig 10. Climate change impact assessment results on wheat (at farm/FI) according to IPCC (2013) GWP 100a with comparison between background data and scenarios 1, 2 and 3.

6 Discussion

The primary purpose of this study was to highlight the importance of holistic analyses of the Carbon Footprint (CF) based on agricultural raw materials by focusing on the details in the calculation process and database values. The hypothesis was that by amending the background data with focused primary data, a clear and significant deviance will be displayed. The hypothesis was tested by using Finnish oat, barley and wheat as a mean to demonstrate the importance of differences in the interpretations, background information and methods in carbon footprint calculations. The process was carried out in a very simple form, with only a few changes between the scenarios. This was to show how influential even a small change (or error) can be and how it effects the results. As seen in Table 7., the hypothesis was shown to be correct.

Table 7. The variation in CO2eq kg/kg of Finnish grains based on changes in background information

Grain	Database	Scenario 1. Light	Scenario 2. Intense	Scenario 3. N-defined
Oat	0.424	0.346	0.312	0.303
Barley	0.434	0.404	0.338	0.317
Wheat	0.434	0.419	0.341	0.322

All three grains show a significant and progressing decrease in CO_2eq the further process steps are taken. With scenario 3. the difference to the database values is already up to 25,8 - 28,5 %. The slightest difference was between scenarios 2. and 3. where the fertilizer volumes were defined, resulting to a difference of 2,9 % - 6,2 %. Between scenarios 1. and 2. the difference is almost purely due to the change in yield, with the lack of fungicides effecting positively for the climate but negatively to the yield. However, expanding the study to all planetary boundaries the result might look different than what the carbon footprint alone suggests.

We have a perfect example for this in the case of wheat, where the yield in scenario 1. was lower than that of the background data, resulting to higher biogenic emissions (but also higher carbon dioxide uptake) and higher emissions from land-use and transformation (Fig. 10). However, the carbon footprint of scenario 1. remained lower than that of the database

(Table 7.). The more variability we have from different environmental perspectives, the better understanding we obtain of the overall situation.

Some confusion might arise from the land-use and transformation only being applied on the wheat. The data behind LULUC is from Agri-Footprint and complies with PAS2050-1: It accounts for regional land-use changes over the past 20 years and associates the values to the grain(s) that have increased in hectares during the same time period. In other words, the grain that has become more popular to cultivate will bear the losses even if that exact grain has had nothing to do with land use changes. (Blonk, 2019; Blonk(2, 2019; Blonk(3, 2020).

6.1 Uncertainties

Even though the results of the study show a clear trend it is worth to notice that much of it (but not all) is due to the changes in yield and the timeframe between the background and primary data does not overlap. In a sense it would have been more reasonable for a comparison to ensure that the compared data is linked in time. But, as the aim of the study was to see how the changes in some small details effect the functionality of the carbon footprint, the issue of correct timeframe between the data is somewhat irrelevant - as yield is never a constant value. Furthermore, Agri-footprint data is very commonly used in scientific studies but - due to the time-consuming process of data collection by several stakeholders - the data is already several years old when it reaches the experts at Blonk Consultants. This needs consideration when conducting CFP calculations, comparing results of different studies, or implementing action plans based on CFP reports.

A partial analysis was a reasonable perspective to narrow down the uncertainties of details unknown further downstream in the lifecycle. The next step, as shown in figure 1., would have been to evaluate the transport distance to a possible drying and/or storage facility, and the capacity, energy source and energy consumption of the process. This information was not available in the primary data and it was therefore unnecessary to take further steps downstream, as it would increase the risk of skewing the results. Nevertheless, a full cradle-to-grave analysis with the same emphasis on details would give more imperatively important information on the significance and relevance of possible differences between generalized and elaborated values.

The CO_2eq results presented are not applicable to any further quantification processes, nor should they be used in any decision making. More emphasis needs to be put on the primary data for the results to be refined to usable information for further processing. Moreover, the primary data should preferably be audited by a third party before it can be implemented to further scientific purposes. The study merely, but successfully, demonstrated the need for understanding the behavior of the metric and significance of the details. The values are also highly bound to time and thus do not necessarily represent the current situation.

6.2 Further studies or improvements in the field

Pandey *et al.* (2010) discuss the importance of consistent CO_2eq calculations from an economic perspective, as carbon footprint quantification is increasingly associated with money transactions in form of taxes, carbon offsets, or increase/decrease in consumer choices. However, the results of assessments done by different organizations vary significantly due to lack of consensus among the selection of characteristic properties and boundaries drawn. We are in such a hurry to report the results (Carbon footprint values of a product) that we are forgetting to build a multifunctional track that would help us in our journeys yet to come.

If it is not unanimously decided between the different stakeholders to give the evaluations their upmost best and honest performance, the development areas meant for the carbon footprint value to express are not detected and therefore no steps will be taken to improve the situation for the better. At its worst, the good intentions behind the calculation process could result to severe damages and setbacks in climate change mitigation efforts. This conclusively destroys the fundamental idea behind the very calculations done. The focus should be moved from creating or having the end value of CO_2eq of a given agricultural commodity to the actual holistic comprehension of the process and its structural, transparent reporting.

The study was not so much meant to create yet another result for carbon footprint of different grains, but to demonstrate that without pedantic and professional studies it will be impossible to develop the agricultural sector to face future challenges. Without the small details, the work of many will be invisible and in lack of further incentive. The development of resilient and positively responsive raw materials for future food chains is dependent on more detailed and comprehensive studies. Through such work, with efficient monitoring, it is possible to generate new possibilities and innovations that will carry the economic cost research projects tend to start with.

A view of environmental effects by a grain type is a general view of the situation. Data collection and calculations should be executed with consideration to different varieties. Such point of view would be an efficient pathway for the development of environmentally effective grain varieties. Furthermore, adding a study of different soil types to the matrix with different grain varieties and weather patterns, with respect to the possible CO_2 response activity suggested by Farkas *et al.* (2021), could result to effective precision in the farm cultivation regime regarding both climate change mitigation efforts and yield succession.

6.2.1 Completeness and relevance

More emphasis needs to be put in ensuring that all components related to the process are fully included and the proportions and scales of the emissions –rather than the exact values – are correct. The search for the absolute value might not be in itself feasible. (Storås, 2021). Natural processes tend to change attributes due to surrounding conditions and even the most subtle fluctuations in habitat, which further increases the challenge of determining causalities leading to changes in carbon flows. Therefore, the holistic comprehension requires a certain level of professionalism and expertise in the area of study to ensure the validity of the details. Such knowledge and understanding does not only produce a strongly based estimation of the current situation but should also be able to generate prediction models for strategic planning by applying up to date information from several fields of study to the prevailing scenario.

6.2.2 Transparency and conservativeness

Sufficient, transparent and open reporting of carbon footprint quantification studies would enable their rightful and efficient usage in interactions between subindustries. Guidelines in allocations, methods and other details may vary by industrial category, but clear and comprehensive CFP reporting would help the second party to evaluate the weighting and proportioning of the results; applying the information to another process. Distribution of scientific information is crucial for the success of climate change mitigation efforts and should not be considered, at any point, as secretive marketing schemes.

Further emphasis could be obtained by focusing on the values behind economic allocation. In regional projects the carbon footprint of the main product could be decreased if the value of other outputs is managed to increase, e.g. through circular economy. In any case it would be good to estimate the economic values of a project either to the exact prices in that space and time scenario or by evaluating a price according to the end use value of the products (e.g. protein content) regardless of the actual market price. Monetary values are not always the best way to represent the product quality and utility due to volatile markets that are dependent on various circumstances unrelated to the actual primary production in food production process. By evaluating the outputs through other qualifications, more environmentally efficient practices might be created.

6.2.3 Accuracy, end user responsibility

The study also thoroughly investigated the methodology behind background data and it is clear, that many - if not most - readily available databases or CFP calculation programs will not provide a result based on reality. The background data is needed for the process but needs thorough examination to ensure the process results validity. It is therefore essential for the party conducting the calculations to firstly know the process and secondly have a transparent access to the methodology.

Quantification processes and reports are today incrementally provided and sold almost as "one-click" fast solutions by different organizations. Such reports can pass an audit process, but it is again the responsibility of the concerned party to verify the details of the process. The focus should not be merely obtaining the carbon footprint value but to understand the functionality and direct actions based on verified, meticulously built details. The greenhouse gases do not follow the reports, they are released and sequestrated at their own pace, regardless of a given emission factor. Up to 28.5 % possible difference in emissions suggest that the reality can be substantially disparate from quantification processes that do not have conception of the details.

Agri-Footprint and many related datasets remain an excellent, reliable and scientifically acknowledged database. It would be impossible for any organization to create a completely accurate description of every country and commodity. Data collection and implementation would take even longer, resulting the information to be even further back in time. Common statistics and data collections are a completely accepted and even encouraged source to be used in calculations. It is always the *responsibility of the user* to ensure the validity of the details in the data, references and process.

6.3 A corporate perspective

Even though the carbon footprint values are merely (and hopefully) just one of the many assets used in strategic planning, the consumer-based interest and thus commercial aspect of the footprint seems to increase the emphasis of the value. This further enhances the importance of profoundly and professionally executed quantification studies, as - if the basis is wrong - it might take years to correct, during which time the damages accelerate and multiply. (Cucek *et al.*, 2015; IPCC, 2013)

By directing the action plans towards a more holistic view with consideration to all nine planetary boundaries: 1)freshwater use, 2)ocean acidification, 3)biochemical flows (Nitrogen (N) and Phosphorus (P)), 4)biosphere integrity (biodiversity; extinction of species), 5)land system change, 6)atmospheric aerosol loading, 7)stratospheric ozone depletion, 9)novel entities (chemical pollution), together with the strongly build CO_2eq values for 9)Climate Change, a corporation does not only have a strong answer to the consumers, but is most likely to have an actual, well-guided influence for the future. The carbon footprint alone is a relatively narrow, although important, view of the complete environmental status. (Rockström & Klum, 2012).

7 Conclusion

Consistent and real time aimed carbon footprint accounting is conclusively needed and could be used as a firm directional component in long-term strategies and climate action plans, including product development and marketing. The importance of CO_2eq quantification is dependent on the quality of the quantification process. The study shows that there can be up to 28.5 % difference in the emission factor of a given agricultural raw material depending on the accuracy and relevancy of the details. If the same result is repeated in several raw materials used for one end-product, the actual carbon footprint value can differ substantially from the one resulting from the calculation process.

The purpose of carbon footprint quantification is to estimate as closely as possible the actual amount of greenhouse gas emissions released into the atmosphere by the production of a given product or activity. It is aimed to direct development towards carbon neutrality. The details defined in the quantification process can direct towards productive long-term benefits; succeeded innovations and verified results for the better; or dictate destructive losses – economic and ecological - through possible misguided decision making. Therefore, a well prepared and profoundly studied quantification with a strong foundation can result to the millions of dollars of savings (Burke *et al.*, 2018) in this incipient turning point of agriculture, but a calculation executed without a strategy, sufficient knowledge and holistic comprehension of the whole is like shooting in the dark. Unfortunately, there is no time for a miss.

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