Environmental effects of coffee, tea and cocoa

– data collection for a consumer guide for plant-based foods

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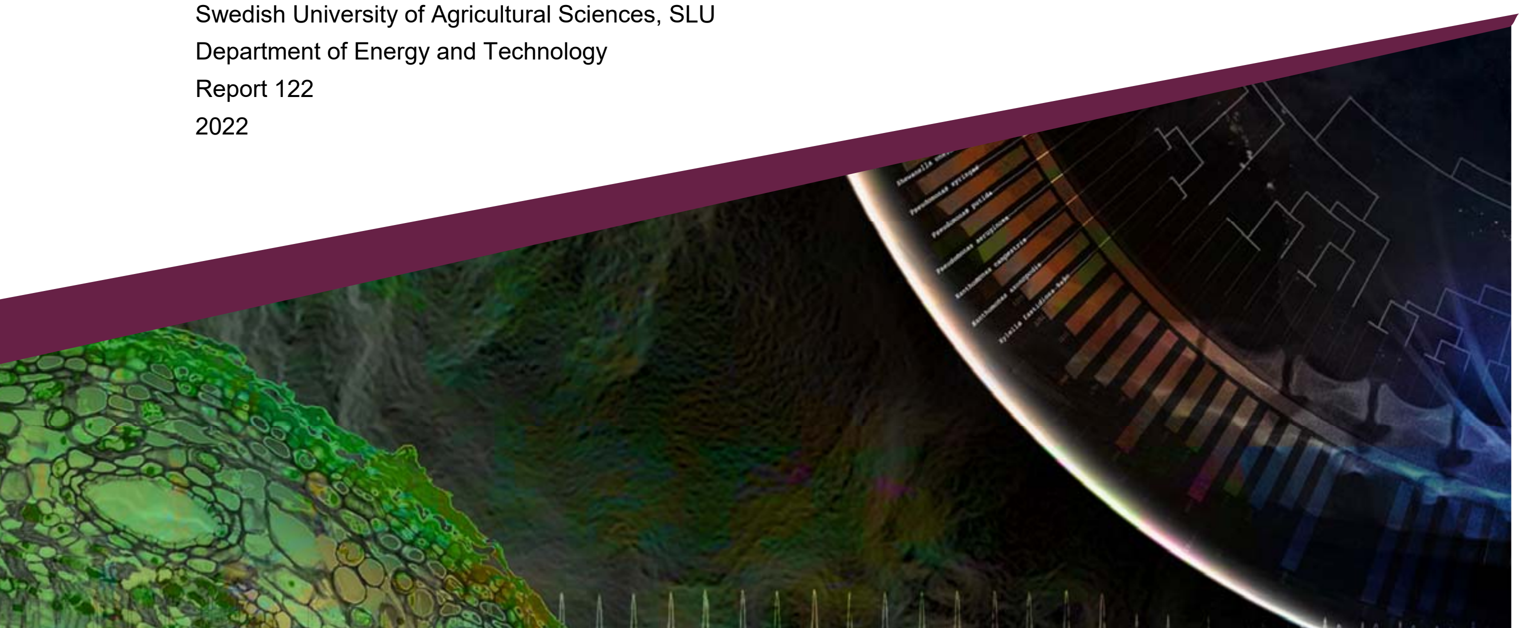

Environmental impact of coffee, tea and cocoa – data collection for a consumer guide for plant-based foods

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The previous version contained a minor error in figure 2 (page 43).

Summary

In 2020, WWF launched a consumer guide on plant-based products targeting Swedish consumers. The development of the guide is described in a journal paper (Karlsson Potter & Röös, 2021) and the environmental impact of different plant based foods was published in a report (Karlsson Potter, Lundmark, & Röös, 2020). This report was prepared for WWF Sweden to provide scientific background information for complementing the consumer guide with information on coffee, tea and cocoa. This report includes quantitative estimations for several environmental categories (climate, land use, biodiversity and water use) of coffee (per L), tea (per L) and cocoa powder (per kg), building on the previously established methodology for the consumer guide. In addition, scenarios of consumption of coffee, tea and cocoa drink with milk/plant-based drinks and waste at household level, are presented.

Tea, coffee and cacao beans have a lot in common. They are tropical perennial crops traditionally grown in the shade among other species, i.e. in agroforestry systems. Today, the production in intensive monocultures has negative impact on biodiversity. Re-introducing agroforestry practices may be part of the solution to improve biodiversity in these landscapes. Climate change will likely, due to changes in temperature, extreme weather events and increases in pests and disease, alter the areas where these crops can be grown in the future. A relatively high ratio of the global land used for coffee, tea and cocoa is certified according to sustainability standards, compared to other crops. Although research on the implications of voluntary standards on different outcomes is inconclusive, the literature supports that certifications have a role in incentivizing more sustainable farming.

Coffee, tea and cocoa all contain caffeine and have a high content of bioactive compounds such as antioxidants, and they have all been associated with positive health outcomes. While there is a strong coffee culture in Sweden and coffee contributes substantially to the environmental impact of our diet, tea is a less consumed beverage. Cocoa powder is consumed as a beverage, but substantial amounts of our cocoa consumption is in the form of chocolate.

Roasted ground coffee on the Swedish market had a climate impact of 4.0 kg CO_2e per kg powder, while the climate impact of instant coffee powder was 11.5 kg CO_2e per kg. Per litre, including the energy use for making the coffee, the total climate impact was estimated to 0.25 kg CO_2e per L brewed coffee and 0.16 kg CO_2e per L for instant coffee. Less green coffee beans are needed to produce the same amount of ready to drink coffee from instant coffee than from brewed coffee. Tea had a climate impact of approximately 6.3 kg CO_2 e per kg dry leaves corresponding to an impact of 0.064 CO_2e per L ready to drink tea. In the assessment of climate impact per cup, tea had the lowest impact with 0.013 kg CO_2e, followed by black instant coffee (0.024 kg CO_2e), black coffee (0.038 kg CO_2e), and cocoa drink made with milk (0.33 kg CO_2e). The climate impact of 1kg cocoa powder on the Swedish market was estimated to 2.8 kg CO_2e. Adding milk to coffee or tea increases the climate impact substantially.

The literature describes a high proportion of the total climate impact of coffee from the consumer stage due to the electricity used by the coffee machine. However, with the Nordic low-carbon energy mix, the brewing and heating of water and milk contributes to only a minor part of the climate impact of coffee. As in previous research, coffee also had a higher land use, water use and biodiversity impact than tea per L beverage.

Another factor of interest at the consumer stage is the waste of prepared coffee. Waste of prepared coffee contributes to climate impact through the additional production costs and electricity for preparation, even though the latter was small in our calculations. The waste of coffee and tea at household level is extensive and measures to reduce the amount of wasted coffee and tea could reduce the environmental impact of Swedish hot drink consumption.

For the final evaluation of coffee and tea for the consumer guide, the boundary for the fruit and vegetable group was used. The functional unit for coffee and tea was 1 L prepared beverage without any added milk or sweetener. In the guide, the final evaluation of conventionally grown coffee is that it is 'yellow' ('Consume sometimes'), and for organic produce, 'light green' ('Please consume). The evaluation of conventionally grown tea is that it is 'light green', and for organic produce, 'dark green' ('Preferably consume this'). For cocoa, the functional unit is 1 kg of cocoa powder and the boundary was taken from the protein group. The final evaluation of conventionally grown cocoa is that it is 'orange' ('Be careful'), and for organically produced cocoa, 'light green'.

Keywords: coffee, tea, cocoa, environmental impact, climate, land use, biodiversity, water use, certifications, consumption

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Abbreviations

AWARE	Water scarcity impact measurement
CO_2e	Greenhouse gas emissions in carbon dioxide equivalents
LCA	Life cycle assessment
PDF	Potentially Disappeared Fraction
RA	Rainforest Alliance
Org.	Organic

1. Introduction

In 2018, WWF Sweden initiated the development of a consumer guide on plant-based products targeting Swedish consumers. The development of the guide is described in a journal paper (Karlsson Potter & Röös, 2021) and the complete compilation of the environmental impact of different plant based foods was published in a report (Karlsson Potter et al., 2020). The initial guide includes four food groups; 1) Protein sources, including nuts and seeds, 2) Carbohydrate sources, 3) Fruit and berries, and 4) Vegetables and mushrooms, and was launched in October in 2020. In 2022, WWF Sweden decided to add information on hot drinks to the guide. This report was prepared for WWF Sweden to provide scientific background information for complementing the consumer guide with information on coffee, tea and cocoa.

There are two main objectives of this report:

1. Present quantitative estimations of the environmental effects related to climate, land use, biodiversity and water use of coffee (per L), tea (per L) and cocoa powder (per kg), building on the previously established methodology for the consumer guide.
2. Increase the understanding of the environmental impact of coffee, tea and cocoa beverage consumption at the consumer stage by presenting scenarios of consumption with milk/plant-based drinks and waste at household level.

2. Background

In this chapter a short background on the production, consumption, health and environmental impact of coffee (section 2.1), tea (section 2.2) and cocoa (section 2.3) is given. Section 2.4 contains a short summary of how global trade of coffee, tea and cocoa drives local environmental impacts. Certification schemes are discussed in section 2.5. In the final section, agroforestry in the production of coffee, tea and cocoa is briefly reviewed (section 2.6).

2.1. Coffee

2.1.1. Coffee production

The steps in the value chain for coffee are coffee bean cultivation, processing (drying, roasting, grinding), packaging, trade and marketing. There are more than 10 million coffee farms in the world and 95% of these are smallholder farms producing 80% of the world´s coffee (Bozzola, 2021). The two most cultivated coffee varieties are Arabica (*Coffea Arabica*) and Robusta (*Coffea Canephora*). Arabica has a larger share of the world's coffee market and is considered a more premium product. Demand for Robusta, which often ends up in instant coffee and caffeinated products, is increasing (Bozzola, 2021). Regions with the best suitability for growing Arabica coffee in terms of climate and soils include Central and South America, in particular Brazil, Central and West Africa, and parts of South and Southeast Asia (Grüter et al., 2022). The major producing countries in 2019 were Brazil, Vietnam and Colombia (Bozzola, 2021). While Arabica can be grown at higher altitudes, Robusta is easier to grow in a warmer climate, and is more resistant to drought and pests (Bozzola, 2021).

The coffee cherry contains two beans, or one bean referred to as a pea. There are two major ways of processing the coffee bean: a dry or a wet process. In the dry process the whole beans are dried before the skin is removed. In the wet process, the outer layers of skin and pulp is removed from the cherry and the beans are dried thereafter. The outer skin (parchment) is removed mechanically from the beans before they are sorted and packed. Most coffee beans are shipped as raw green beans to roasteries in the country of consumption. This is also the case for Sweden, where only a small part of the import is in the form of roasted or ground coffee (European Coffee Federation, 2019). Most of the green coffee beans imported to Sweden come from Brazil, Honduras, Peru and Kenya (Statistics Sweden, 2022). Some of the coffee roasted in Sweden is exported, for example to Denmark and Finland (European Coffee Federation, 2019). In instant coffee production, the roasted, ground and brewed coffee is spray-dried at high temperatures or freeze-dried at low temperatures and low pressure (Bozzola, 2021). Instant coffee is commonly not produced in Sweden.

2.1.2. Coffee consumption in Sweden

While the United States, Germany and France are the major coffee importers, Sweden is among top 10 in coffee consumption per capita (Bozzola, 2021). In 2019, the yearly per capita consumption of coffee was 7.8 kg (Swedish Board of Agriculture, 2020). On average, Swedes drink two cups of coffee per day ranging from zero to five or more (Swedish Food Agency, 2012). A cup of coffee was assumed to be contain 150 mL, which is something in between a traditional small cup with saucer, and a modern café style cup. In Sweden, more coffee is consumed at home and at workplaces than in cafés and restaurants (Landais et al., 2018) and the retail sector has >70% of the coffee market in Sweden (European Coffee Federation, 2019). The most common coffee brewing method in Sweden is using a drip-filter automatic machine. In 2018, instant coffee had about 4% of the retail coffee market in Sweden (European Coffee Federation, 2019). Coffee pods had only 1% share of the market in 2018, (European Coffee Federation, 2019). A European study found low use of decaf coffee and use of chicory coffee substitutes in Sweden (Landais et al., 2018). Other brewing methods described in the literature are espresso, mocca, French press, and different types of pods and capsules as illustrated in Table A1 Appendix I.

2.1.3. Climate impact from different coffee brewing methods

An overview of life cycle assessment (LCA) studies comparing the climate impact of coffee production using different brewing methods is presented in Table A1 in Appendix I. Varying assumptions and different functional units make comparisons difficult. For example, capsules for coffee preparation resulted in the lowest climate impact (de Figueiredo Tavares & Mourad, 2020; Hicks, 2018) or the highest climate impact (Brommer, Stratmann, & Quack, 2011; Cibelli, Cimini, Cerchiara, & Moresi, 2021) depending on study. The drip filter coffee machine, common in Sweden had comparatively low impact in some studies (Brommer et al., 2011; Phrommarat, 2019; Usva, Sinkko, Silvenius, Riipi, & Heusala, 2020). However, drip filter brewing showed a higher climate impact per cup than espresso and instant coffee, due to the larger amount of coffee used in brewing one cup in a filter brewer.

A high impact at consumer stage is often explained by a high climate impacting electricity mix of the country where coffee is brewed. Another factor affecting results is how much coffee that is used in brewing a certain amount of coffee.

The literature comparing the environmental impact of instant coffee to that of other brewing methods is scarce. Humbert et al. (2009) performed an LCA of three preparation methods for a cup of 100 mL coffee: 1) instant (spray-dried) single portion sachet (a "stick" filled with coffee) and water from a kettle, 2) a drip filter machine brewing, and 3) an espresso capsule machine. The authors of this Swiss study concluded that despite more energy demanding steps in production, instant coffee is less energy demanding overall as it requires less energy to prepare at home (Humbert, Loerincik, Rossi, Margni, & Jolliet, 2009). In addition, only 2 g instant coffee was used, while 6.5 g ground coffee was used for preparing an espresso and 13 g ground coffee used for the same amount ready-to drink coffee in a drip filter machine (33% waste of prepared coffee was assumed in this case). Note however that the waste from the instant coffee processing ends up in the factory, while out of the 6.5 g and 13 g of espresso or ground coffee, a substantial amount end up as coffee grounds at the consumer stage. Also when assuming no waste of drip filtered coffee, this brewing method still had a higher climate and water impact per cup as more coffee beans was used in its preparation (Humbert et al., 2009). It is worth noticing that Humbert (2009) has made the assumption that when preparing espresso coffee at home the machine is only on during the preparation of the coffee. In a coffee shop on the other hand, an espresso machine would be on standby throughout the opening hours and there would also likely be more waste of coffee when preparing the espresso in a café than when a capsule machine is used at home.

Another study focused on packaging and provided no details on the impact of different processing steps on overall environmental impact. The functional unit of the LCA was one cup, but the cups were not equal in size (Büsser & Jungbluth, 2009). For instant coffee, 2 g single portion sachet was used in 125 mL water, for espresso 7 g for 30 mL water and for drip filter brewing, 7 g in 125 mL. One cup of espresso had the lowest climate impact due to the small amount of water to be heated, and instant coffee had higher impact than the espresso but lower than coffee prepared in the drip filter machine (Büsser & Jungbluth, 2009). Authors of both these papers acknowledge the fact that the consumer´s behavior such as wasting, keeping the brewer in stand-by mode has a large effect on the results.

2.1.4. Coffee and health

Coffee contains a large number of bioactive compounds (Barrea et al., 2021). One study found that coffee contributes little to energy intake, even when milk or sugar is added (Landais et al., 2018). However, this depends on type of coffee drink and frequency of consumption. The contribution to antioxidant intake may be substantial from coffee, and in a study from Norway, even higher than that from fruit and vegetables (Svilaas et al., 2004). Coffee has been extensively studied in relation to many health outcomes. Poole et al. (2017) summarized 201 meta-analyses of observational research and 17 meta-analyses of randomized controlled trials in an umbrella review (Poole et al., 2017). The authors conclude that beneficial associations for coffee consumption was of highest magnitude (largest effect sizes) for liver conditions. Coffee consumption was also associated with reduced risk of all-cause mortality, cardiovascular mortality, total cancer, type 2 diabetes, metabolic syndrome, gallstones, gout, renal stones, Parkinson´s disease, depression and Alzheimer´s disease (Poole et al., 2017). The harmful effects identified were on pregnancy outcomes for consumption during pregnancy and a not yet understood association with fracture risk in women (Poole et al., 2017).

The European Food Safety Authority has reviewed the safety of caffeine and concludes that 400 mg caffeine per day, which corresponds to five cups of coffee (445 mg/L) can be part of a healthy diet in the general adult population (EFSA Panel on Dietetic Products & Allergies, 2015). For pregnant and breastfeeding women, caffeine intakes should be limited to 200 mg per day (EFSA Panel on Dietetic Products & Allergies, 2015). The same advice is given to pregnant and lactating women in Sweden (Swedish Food Agency, 2019).

There are a number of issues to consider with the available literature on coffee and health. A cup of coffee is by no means an absolute measure of exposure. There is no standard size and studies rarely have data on type of bean, degree of roasting and brewing method that would all affect the content of bioactive compounds. Observational studies do not prove causality between coffee drinking and risk of a particular disease and some of the associations could be due to residual confounding. Coffee consumption could be linked to a disease in question via the association of coffee consumption with smoking, body-mass index, age and alcohol consumption, all of which are also risk factors for disease (Poole et al., 2017). Another possibility is that coffee acts as a surrogate marker for high income, education or plenty of social interactions, which in turn may be preventive factors for some of these diseases. Randomized controlled trials could give us more information on causality but to date, such studies on coffee have only been performed for a limited number of outcomes with short durations. Despite these limitations, it is possible to conclude that coffee consumption at about current levels of intake are safe (EFSA Panel on Dietetic Products & Allergies, 2015) and potentially beneficial to health (Poole et al., 2017). Negative effects of coffee consumption can be seen during pregnancy, while the issue of increased fracture risk in women remains uncertain (Poole et al., 2017).

2.1.5. Coffee and the environment

In a review of environmental impact of a large number of foods, the impact of coffee can be perceived as small as it is presented per cup (Poore & Nemecek, 2018). However, put in perspective, the greenhouse gas emissions per cup is comparable to that of 1 kg of root vegetables. Actually, in an analysis of Swedish food consumption, coffee stood out as one of the foods with a high overall environmental pressure (N_2O emissions, cropland use, nitrogen application and NH_3 emissions) (Moberg et al., 2020). A large share of the overall pressure of our food consumption on phosphorus application, extinction rate and pesticide use, were associated with consumption of beverages and sweets due to the high pressure per kg of coffee and cocoa (Moberg, Säll, Hansson, & Röös, 2021). Also the freshwater use was high per kg coffee, which is a reflection of some coffee plantations being irrigated (Moberg et al., 2020). The high total burden of coffee from the diet in Sweden is largely due to the large amounts of coffee consumed.

Coffee is one of the key crops causing negative biodiversity impact from Nordic food consumption (Ahlgren, Morell, & Hallström, 2022). Coffee has a high biodiversity impact per kg coffee beans (Moberg et al., 2020; Sandström, Kauppi, Scherer, & Kastner, 2017). Coffee, tea and cocoa drink has among the highest extinction rates per kg food (Moberg et al., 2020). The high biodiversity impact of coffee was mainly due to production in regions with high biodiversity potential (Moberg et al., 2020). In a study by Lenzen et al. (2012) which explored the link between threatened species and international trade, coffee and cocoa were major drivers of species loss (Lenzen et al., 2012).

2.1.6. Coffee by-products and waste

Coffee production and preparation generates large amounts of waste, estimated at 23 million tonnes per year (Durán-Aranguren, Robledo, Gomez-Restrepo, Arboleda Valencia, & Tarazona, 2021). When the cherries of the *Coffea* bush are processed to green coffee beans with a dry or semi-dried method, the by-product is coffee husk. Coffee pulp is the by-product of the wet processing of cherries into green coffee beans. Silverskin is a thin layer that is detached from the beans during roasting. The brewing of coffee result in the by-product spent coffee grounds. Durán-Aranguren et al. (2021) describe how the research on the use of coffee husk, coffee pulp, coffee silverskin and spent coffee grounds has increased dramatically since 2017. The core applications of coffee by-products are as bioactive compounds such as food, feed, neutraceuticals and cosmetics, for microbial transformation such as synthesis of enzymes or fermentation to produce bioethanol, environmental applications for example as bioadsorbents for wastewater treatment, as biofertilizers, and as pesticides or biofuels from thermochemical processes (Durán-Aranguren et al., 2021).

The waste of prepared coffee at household level is extensive. The total waste of liquid foods in Sweden was estimated in a household survey where 583 households responded (28% of the 2050 invited) (Swedish Environmental Protection Agency, 2021). Participants estimated the liquid food waste (in dl) during three days in January 2021. Of the food wasted in the sink, 45% was in the category coffee/tea. This corresponds to a total of 84,400 tonnes of coffee/tea or about eight litres coffee/tea per person and year thrown in the sink (Swedish Environmental Protection Agency, 2021).

2.1.7. Coffee production and climate change

As temperatures rise and extreme weather events become more common as a consequence of climate change, the sensitive coffee crop will be seriously affected. The main risks for coffee production in a changing climate is reduction of areas suitable for coffee cultivation, increased water stress, impaired development of flowers and cherries (which means lower yields) and a higher risk of outbreaks of pests and diseases affecting the coffee plants (Bozzola, 2021).

The global future suitability of areas for coffee cultivation was modelled under three emission scenarios to 2050 (Grüter et al., 2022). Coffee is vulnerable to climatic factors such as change in length of dry seasons, mean temperatures and annual precipitation in all producing regions. In the scenarios, the areas with the highest suitability for coffee cultivation will decrease by 50% to 2050 and the moderately suitable areas decrease with 30-40%. Overall, it means a drastic decrease in suitability of coffee growing by 2050 in all of the main coffee producing countries, mainly caused by an increase in mean annual temperature. Suitability is expected to increase only in a few regions south and north of the currently more suitable regions. The study by Gruter et al. (2022) confirms previous data on expected large shifts in climate suitability of coffee cultivation, which implies shifts in production in most coffee producing regions (Ovalle-Rivera, Läderach, Bunn, Obersteiner, & Schroth, 2015).

Adaptations to climate change will thus be necessary in all regions where coffee is cultivated today. A change of location of Arabica plantations to higher elevations is one possible solution (Bozzola, 2021). Land conversion of previously non-cultivated land may in turn lead to loss of biodiversity and carbon stocks and sinks. Climate change implications on coffee production will vary across regions and predictions on implications come with uncertainty. Smallholder coffee farmers are the most vulnerable and least resilient to climate change because they often rely on one crop and their financial security is low and they are especially sensitive to volatile crop prices (Bozzola, 2021). Strategies for adaptation could include improving soil fertility and develop and introduce crop varieties that are more resistant to pests and drought (Bozzola, 2021).

2.2. Tea

2.2.1. Tea production

While infusions can be made with hot water and dried leaves of different herbs, for example rooibos and mate, the leaves from the tea bush (*Camellia sinensis)* is the focus of this report as it is a common drink in Sweden. It originates from south west China and thrives in a warm humid climate in light acidic soils (Jayasinghe & Kumar, 2021). Tea is usually cultivated in monocultures on large estates or by smallholder farms forming co-operatives. The major tea producing countries are China (40% of world produce), India (23%), Kenya (9%) and Sri Lanka (7%) (Debnath, Haldar, & Purkait, 2021).

The composition and quality of tea, for example the content of polyphenols depends on growth location, season and type of processing (Debnath et al., 2021; Xu, Hu, Wang, Wang, & Knudsen, 2019). According to Xu (2019), the specific steps in processing varies with setting and type of tea product. Black tea is fully fermented, oolong tea is semi-fermented or oxidized partially while green tea is non-fermented and contains more of the antioxidants. The amount of picked fresh leaves for producing 1 kg of dry tea ranges from 4.1 to 4.6 kg in a study from China (Xu et al., 2019).

2.2.2. Tea consumption in Sweden

The countries consuming most tea in total is China, India, Russia and Pakistan (Euromonitor International, 2017). Sweden is not among the countries that consume the most tea per capita; approximately 0.3 kg dry tea per person was consumed in 2019 (Swedish Board of Agriculture, 2020). On average, people in Sweden drink one cup of tea (200 mL) per day (Swedish Food Agency, 2012). The consumption of herbal teas in Sweden is low compared to other European countries (Landais et al., 2018).

2.2.3. Tea and health

The health effects of tea, and specifically green tea in the form of tea extracts, has been extensively studied in experimental studies. Tea leaves contain nutrients like fluoride and bioactive compounds, like flavanols (also known as cathechines) a type of polyphenols (Filippini et al., 2020). Black tea contains caffeine in amounts about half of those in coffee, 220 mg/L, and green tea contains about 150 mg/L (EFSA

Panel on Dietetic Products & Allergies, 2015). The cathechines are absorbed in the body and are shown to have high antioxidant capacity (Filippini et al., 2020).

Hartley et al. (2013) performed a systematic review of randomised controlled trials three months or longer of healthy adults and exposure to green tea, black tea or tea extracts. Of the 11 trials found, none investigated cardiovascular events. However, there was some evidence of reduction in cardiovascular risk factors such as blood lipids and blood pressure for those receiving tea interventions (green, black or extracts) compared to control groups (Hartley et al., 2013).

Green tea preparations have for long been marketed as promoting weight loss. When the evidence was reviewed systematically, the weight loss associated with consuming green tea preparations compared to placebo in randomised controlled trials, was judged to be too small to have a clinical impact (Jurgens et al., 2012). Green tea has also been studied for cancer prevention. When evidence was recently systematically reviewed, the results from different types of trials and epidemiological studies show inconsistent results (Filippini et al., 2020). Filippini et al (2020) were not able to draw conclusions on overall risk of cancer or risk of specific cancer types of consumption of green tea preparations.

These examples show that even though health effects of tea have been studied, and there are potential mechanisms for beneficial effects, it is far from conclusive whether tea drinking is associated with specific health effects. The difficulties of studying tea are similar to those discussed for coffee (section 2.1.4).

2.2.4. Tea and the environment

Tea monocultures in large plantations is a serious threat to biodiversity (Chowdhury et al., 2021) reflected in a tea high biodiversity impact per L tea consumed (Lenzen et al., 2012; Moberg et al., 2020). Tea was not mentioned as one of the foods with a high overall environmental impact in the Swedish diet (Moberg et al., 2020). In this study, tea was included in the same category as coffee and cocoa, which is often the case.

2.2.5. Tea by-products and waste

The industrial tea waste constitutes mainly of stems, buds and discarded leaves. In India alone, annual waste from the tea industry is about 25 million kg, of which only a small part is used for feed or further processing to caffeine extract (Debnath et al., 2021). Debnath et al. (2021) reviewed the literature on tea by-products and found that although use is limited today there are many opportunities. Some examples are extraction of antioxidant and caffeine extracts for use in foods and food supplements, as adsorbents for treatment of polluted wastewater and bioenergy such as biogas (Debnath et al., 2021). Explorative research also investigated tea by-products for producing electrodes, as filler material and for use in fertilizer production.

Household waste of prepared coffee and tea is substantial but there is no reliable estimate on amount of tea only that is wasted in Sweden (Swedish Environmental Protection Agency, 2021) See section 2.1.6 for details.

2.2.6. Tea production and climate change

Jayasighe and Kumar (2021) summarized the literature on the impact of present and future climate on tea yields, tea quality and areas suitable for tea growing. The literature show that tea production is affected by climate change through stressors such as increased temperatures, extreme weather events, pests and diseases (Jayasinghe & Kumar, 2021). Water stress may result in considerable reductions in yield, for example by increasing unproductive buds. While several studies reported on positive effects of rainfall on yields, uneven rainfall and high intensity rainfall may reduce yields due to flooding, erosion and reduced fertility of the top soil of tea plantations. In many tea-producing countries, increased temperatures leads to reduced yields. Studies reported both positive and negative impact of increased temperatures on tea quality. The effects of climate change on tea quality is complex and there are few studies on future scenarios. The authors conclude that areas with a suitable climate for tea growing will likely decrease and new areas may emerge as suitable for tea growing (Jayasinghe & Kumar, 2021). The authors also point out a number of possible mitigation strategies where carbon sequestration potential of tea bushes are taken into account. Adaptation include for example changing to drought- and heat-resistant tea varieties, climate smart and water saving irrigation systems, cover cropping and non-till methods (Jayasinghe & Kumar, 2021).

2.3. Cocoa powder

2.3.1. Cocoa production

Theobroma cacao is a plant originating from South America. It can be grown mainly on latitudes 10 north and 10 south of the equator, in high temperatures and relatively constant rainfall (Badrie, Bekele, Sikora, & Sikora, 2015). In the fruits of this plant, there is 20-60 seeds embedded in pulp and these seeds are called cacao beans. To produce cocoa powder, i.e. powder made after grinding the seeds and removing the cocoa butter, these fatty beans are dried and fermented. Depending on origin and differences in climate, soil and cultivation, quality and taste of the cocoa powder differs. Seven countries dominate the global production of cacao beans (85%) Ivory Coast, Ghana, Ecuador, Cameroon, Nigeria, Indonesia, and Brazil, while most of the processing takes place in regions where cacao beans is not grown such as Europe and USA (Guirlanda, da Silva, & Takahashi, 2021).

2.3.2. Cocoa consumption in Sweden

In 2020, the Netherlands was the largest importer of cacao beans and cocoa paste, USA the largest importer of cocoa powder while Germany was the top importer of cocoa butter (FAOSTAT, 2022). Based on import and export statistics, we judged Ivory Coast, Ghana, Ecuador and Nigeria as most important countries for import of cocoa powder to Sweden.

According to official statistics, the consumption of cocoa powder in Sweden was 0.3 kg per person and year in 2019 (Swedish Board of Agriculture, 2020). In addition to that, cocoa is consumed in the form of chocolate. Per person and year, 2.5 kg cocoa drink powder, ready to drink chocolate beverages and chocolate sauces and 15.5 kg chocolate and confectionary is consumed in Sweden (JSwedish Board of Agriculture, 2020). Besides cocoa powder and other cacao products, these foods also contain different types of fats, sugar and sometimes dairy products.

2.3.3. Cocoa, chocolate and health

Cocoa contains bioactive compounds called flavonoids that may influence cardiovascular health trough antioxidant, antiplatelet and anti-inflammatory pathways (Veronese et al., 2019). Also of interest to research is the influence of cocoa on mood due to the content of trypthofane, a precursor to the neurotransmitter serotonin (Badrie et al., 2015). However, consumed in the form of chocolate, cocoa comes in a high energy package that is often high in added sugars and saturated fats, milk powder and vegetable oils (Badrie et al., 2015).

Tan et al. (2021) systematically reviewed randomised controlled trials on health effects of chocolate and cocoa. They found that consumption of chocolate or cocoa products had a beneficial effect on triglyceride levels, a marker associated with cardiovascular health (Tan et al., 2021). No other associations were found between cocoa and chocolate consumption on the studied outcomes associated with skin, blood pressure, lipid profile, cognitive function, anthropometry, blood glucose, and quality of life. The studies were usually short, 4-6 weeks and the evidence was graded as low to moderate. Epidemiological evidence suggests an association between chocolate consumption and reduced risk of cardiovascular disease, acute myocardial infarction, stroke and diabetes, but the evidence is weak (Veronese et al., 2019).

Beverage made from cocoa powder contains a tenth of the caffeine compared to coffee approximately 42 mg caffeine per L (EFSA Panel on Dietetic Products & Allergies, 2015).

2.3.4. Cocoa and the environment

Water and soil pollution is extensive in high-tech cocoa producing systems, shown in a literature review of cocoa production in Ghana (Wainaina, Minang, Duguma, & Muthee, 2021). There is a high environmental pressure per kg cocoa, which leads to a high impact of these foods in the Swedish diet (Moberg et al., 2020). Cocoa is one of the foods in Nordic consumption that drives species threats where it is grown (Lenzen et al., 2012).

2.3.5. Cocoa by-products and waste

Cocoa mass and cocoa butter are important co-products in cocoa powder production, by-products are husk and shell (Ntiamoah & Afrane, 2008). Due to developments of cocoa processing, production time and aroma has improved and less mucilage (the cocoa pulp) is needed in the fermentation process. This has led to an increase in the by-product cocoa mucilage juice, called cocoa honey which is used by some middle-sized producers to produce and sell juices, jams and liquors on the local market (Guirlanda et al., 2021).

No estimates of cocoa waste at household level were found.

2.3.6. Cocoa production and climate change

Cacao production is affected by the weather phenomena El Niño with extreme events in transition between rainy and dry seasons (Cilas & Bastide, 2020). Climate change is expected to lead to changed conditions in several cacao growing areas and cacao growing in West Africa may be severely affected as needs of water, high humidity and low wind might not be met in the future. Cilas and Bastide (2020) also discuss the potential consequences of spread of pests and diseases due to climate change. To adapt to changes in climate and to the occurrence of pests and disease, it is crucial to develop more resilient cropping systems, develop biological control of pests, and genetic selection of varieties that are pest resistant and tolerate the tougher growing conditions (Cilas & Bastide, 2020).

2.4. Global trade as a driver of impacts

Tea, coffee and cocoa beans are foods mainly cultivated for export, even if some major tea producing countries also have high domestic consumption. The high biodiversity impact of food production in tropical, biodiverse regions is to a large extent driven by the demand of such foods from industrialized countries (Chaudhary & Kastner, 2016). Global coffee trade for example, threatens species in Mexico, Colombia and Indonesia (Lenzen et al., 2012). The area of land used for production is alone not a good proxy for biodiversity in trade flows as crops such as coffee is occupying only a small land area globally, but have a higher biodiversity impact than might be expected from this land use. Thus from which region a food is imported is commonly more important than the land area used to grow the food (Chaudhary & Kastner, 2016).

Knowledge on major transformations of the landscapes and the driving forces behind those changes are important to understand the sustainability challenges in areas where coffee, tea and cacao are grown. In a review, Harvey et al. (2021) outline the major transformations that takes place simultaneously in coffee growing landscapes in Latin America. One ongoing trend is increased intensification of coffee production, while at the same time there is an increase in the area of coffee grown under the voluntary sustainability standards in this region (Harvey et al., 2021). Another trend is the expansion of coffee fields, resulting in deforestation. Simultaneously, in other places in the region, an increased conversion of coffee fields to other land uses, for example urbanization of previous coffee-growing areas takes place. Regarding the type of coffee grown, traditional Arabica varieties are replaced with varieties resistant to coffee leaf rust and Robusta is introduced in areas where coffee was not previously grown. The drivers of these changes are economic (low and volatile prices, high costs of inputs and labour, market demand and supply), biophysical (climate change, extreme weather events, pests and diseases), social (shortage of labour, migration, conflicts, change in importance of coffee for livelihood) and policy related (for example certification processes and demand for certified coffee, governmental programmes for renovation of plantations affected by pests) (Harvey et al., 2021). Harvey et al. (2021) conclude that these changes may have both socioeconomic and environmental impacts.

Chowdhury et al. (2021) describe how traditional tea agroforestry has been replaced by terrace tea monocultures in for example in China, and that monoculture practices are now dominant worldwide in tea production (Chowdhury et al., 2021). The rapid tea expansion is driven by increased global demand and location of expansion is determined by proximity to roads and urban areas (Chowdhury et al., 2021).

In conclusion, our consumption of coffee, tea and cocoa in Sweden has environmental impacts where these crops are grown. The trade flows are complex and the impacts sometimes difficult to foresee (Lenzen et al., 2012). To evaluate the consequences of our consumption, it is important to know from where a food is sourced (Chaudhary & Kastner, 2016) and to be aware of past and current changes in the agricultural landscape (Harvey et al., 2021).

2.5. Certifications

There are a range of different types of certifications, standards and labels for coffee, tea and cocoa, for example by company specific ones as "C.A.F.E. Practices by" Starbuck´s and "Grown respectfully" Nestlé or by retailers such as "I love Eco" by ICA and "Änglamark" by Coop. The certifications described here are subject to third party audits to ensure adherence to the certification schemes (Hållbar livsmedelskedja, 2020).

2.5.1. Major certifications for coffee, tea and cocoa in Sweden

EU-organic

The leaf, a symbol of EU-organic, can be put on coffee, tea and cocoa that fulfils criteria on organic production according to regulation (EU) 2018/848 of the European Parliament and of the Council on organic production and labelling of organic products (European Commission, no date). The foundation is a production without the use of chemical fertilizers, pesticides, or other artificial compounds.

KRAV

KRAV is a Swedish certification that ensures a product produced without chemical pesticides, packaging without Bisphenol A and plastics such as PVC. All the EU-organic criteria apply, and there are additional rules regarding environmental production and on social responsibility (KRAV, 2022). For coffee and cocoa in particular, KRAV certified products cannot be cultivated on land with ecosystems with high conservation value. For coffee and cocoa production, the verification shall ensure that no cultivation on land with high conservation value has taken place since the start of certification (KRAV, 2022). The most common for coffee, tea and cocoa production is that the additional KRAV rules are verified through another certification for example Fairtrade or Rainforest Alliance.

Fairtrade

The Fairtrade certification includes environmental, social and economic criteria, including a minimum price on coffee to protect coffee farmers against volatile prices on coffee market (Fairtrade, 2020). Only cooperatives and cooperative-like organizations can be Fairtrade certified as a bonus for the crop is paid to a fund to be used by the members for investments to increase productivity and quality. Fairtrade also supports the transformation towards more sustainable production methods and education on climate impact of farming.

Rainforest Alliance

Rainforest Alliance and UTZ merged in 2018 and since Rainforest Alliance launched a new certification program and the Rainforest Alliance seal in 2020, the UTZ label is being phased out (Rainforest Alliance, 2020). The farms and companies that are UTZ certified are transitioning to the Rainforest Alliance 2020 certification program. The program focus on forests and biodiversity, building climate resilience, human rights and livelihoods of farmers and people in rural areas. (Rainforest Alliance, 2020).

2.5.2. Environmental impacts of certification schemes

To be certified, a farm or a product must follow the criteria for a particular certification. The follow-up on how the producers adhere to the standards is done by the certifying agent themselves or by third party audit. Certification, or sustainability standards as they are also called, is a structured system for moving towards improvements and documenting them (Tayleur et al., 2017). More than 10% of the global land used for coffee, tea and cacao production is under certification (Tayleur et al., 2017). Typically, crops grown for exports are certified to a greater extent as domestic demand for certified crops is usually lower.

Research on the 13 most widely adopted standards for agricultural produce was evaluated systematically (Traldi, 2021). One of the major findings was the dominance of research on coffee (75% of the studies) although certified coffee production only make up about 11% of the total global certified agricultural area. Cacao production, on the other hand seems under-researched. Traldi (2021) identified 45 studies on all crops of which 31 studies were on coffee, two on cacao and three on tea. Only 20% of the studies evaluated all the three pillars of sustainability; economic, social and environmental. Studies with a robust research design are few, most studies use what could be called a "quasi experimental" design. This implies that the evidence is generally weak as there is no proper comparison group. Another issue is that the research is mainly focused on evaluating practices, for example planting of trees, rather than outcomes such as avoided deforestation (Traldi, 2021). The most commonly used environmental indicators are the use of best management practices, tree density and tree diversity. Environmentally associated outputs were overall (for all included crops) positively associated with certification schemes, or not associated at all, while the number of negative associations was small. It was not the purpose of the review to compare outcomes across different crops or to compare different certifications.

2.6. Agroforestry in coffee, cocoa and tea production

A full review of different production systems for coffee, cocoa and tea and their implications for sustainability is out of scope of this report. This section provides a brief overview based on recent reviews on agroforestry in coffee, tea and cocoa production. Agroforestry is a system of vegetation, crops and/or animals where woody vegetation is integrated with a purpose, for economic or ecological benefit for example food production (Mahmud, Raj, & Jhariya, 2021). In agroforestry, the type of vegetation varies with time and place, which make these systems diverse and complex. Agroforestry was the dominant way of producing foods (not specific for coffee, tea or cocoa) in the tropics for thousands of years before specialisation of agriculture and introduction of monoculture practices. When it is now re-introduced it is because of the woody vegetation's potential to provide shade and stop soil erosion with positive impact on soil fertility, water availability and biodiversity (Mahmud et al., 2021).

Castle et al. (2021) summarized the research on the impact of agroforestry interventions and found 11 studies from nine countries. When the results from the studies were pooled, a large positive impact on yields appeared (Castle, Miller, Ordonez, Baylis, & Hughes, 2021). However, as the studies are few and the quality evaluated as low due to the use of quasi-experimental methods, the results should be interpreted with caution. Studies differed in type of interventions and in the outcomes, and there was inconsistency in the environmental outcome variables used (Castle et al., 2021). Thus, more and better research is needed to be able to make conclusions on the environmental impact of implementing agroforestry.

De Beenhouwer et al. (2013) reviewed and summarized the literature on impact on biodiversity and ecosystem services from coffee and cacao agroforestry. They showed in a meta-analysis that when natural forest is transformed into coffee and cacao agroforestry, total species richness decline (De Beenhouwer et al., 2013). However, the decline of total species richness is much higher when agroforests are transformed to plantations. The biodiversity impact differed between different species and different regions in the 74 included studies. There were no studies from Africa.

Wainanina et al. (2021) describe different cocoa production systems in Ghana: highly intensified production systems, full sun cacao and agroforestry (shaded cacao). The authors conclude that these systems all play a role in sustainable cacao cultivation but that there are trade-offs to consider. For example, the intensified systems definitely gives the highest cacao bean yields, but the economic value per hectare is highest in the agroforestry because it also provides more of ecosystem services and higher biodiversity (Wainaina et al., 2021).

Chowdhury et al. (2021) found in a literature review that traditional tea agroforestry is associated with higher number of plant species than tea monocultures. Data on tea agroforestry seems more limited than that on coffee, but the authors draw on coffee literature to discuss how tea monocultures can be transformed for increased biodiversity, for example by introducing inter-cropping (Chowdhury et al., 2021).

Agroforestry could also be used as a way to reduce the climate impact. In a literature review, Supriadi et al. (2022) found that agroforestry in cacao production can increase total biomass, absorption of carbon dioxide, and carbon stocks. The size of this carbon sequestration potential depends on the location and how many and what species of trees that are included (Supriadi, Astutik, & Sobari, 2022).

In conclusion, agroforestry is a traditional way of farming coffee, tea and cocoa. Compared to monocultures and full-sun methods of farming, agroforestry seems associated with higher biodiversity (Chowdhury et al., 2021; De Beenhouwer et al., 2013; Wainaina et al., 2021) and in some cases higher yields (Castle et al., 2021). But the results vary with crop (Castle et al., 2021), location and study design.

3. Method

In this chapter, the methods for data collection and the assessment of the impact categories (climate, land use, biodiversity, water use) are described. The main sources of data were the updated database from the studies by Moberg et al. (2019; 2021) on the environmental pressures of Swedish food consumption. The climate impact assessment was based on Moberg et al. (2020) while assessment of land use, biodiversity impact and water use calculated for the purpose of this study. This is further described in sections 3.2.2 and 3.2.4. In section 3.3, the functional units and the system boundaries are described. How the final evaluation of coffee, tea and cocoa was made for the consumer guide is described in section 3.4 while section 3.5 contains the outline of the scenarios on coffee, tea and cocoa beverages. Complementary literature searches were made to explore the data on production of coffee, tea and cacao and ways of preparing these drinks (section 3.1.1).

3.1. Data collection

3.1.1. Literature review

Search

Searches for LCA studies covering hot drinks were made in Google Scholar using the key words “LCA”, “life cycle assessment” and “coffee”, ”tea”, “cocoa” in line with searches for the other foods included in the consumer guide (Karlsson Potter et al., 2020). Due to time restrictions, the search was exploratory in that sense that additional key words were added to find the most relevant literature. For example to refine searches for LCA on coffee, the word “brewing” was added. Studies were included if they provided data on climate impact, land use, water use or water footprint on green coffee beans, ground and roasted coffee, tea leaves or cocoa at the farm gate or at retail gate. In addition, studies assessing environmental impact of the prepared hot drink were included. Type of brewing method was considered, with a focus on drip-filter coffee and instant coffee, tea leaves and tea bags. Both papers published in peer reviewed scientific journals and grey literature was retrieved from the search.

Exclusion criteria

LCAs of cold drinks such as iced coffee, tea or chilled cocoa drinks were excluded as were studies on extracts and essences of coffee, caffeine, tea and cocoa. LCAs of by-products of coffee, tea and cocoa production were also excluded as were LCA studies of social impacts only.

3.1.2. Data on origin, brewing and waste

Data on origin/country of production

To estimate land use, biodiversity impact and water use for products with different geographical origin, the countries with largest import to Sweden were selected. Statistics Sweden "Handel med varor och tjänster" was used for statistics on trade (Statistics Sweden, 2022). Countries that contributed 10% or more to the import were included. For tea and cocoa, some European countries where tea or cocoa is not grown were the major countries of import according to trade statistics. In these cases, data from FAOSTAT was used to find the countries with the highest export of tea, according to the method previously used in the compilation of data for the consumer guide of plant based products (Karlsson Potter et al., 2020).

Data on tea and coffee brewing

Coffee making in a coffee brewer was assumed to require 0.16 kWh electricity per L according to (Usva et al., 2020). Heating water in a kettle was also assumed to use 0.16 kWh per L, which is in line with a test performed in Sweden (Swedish Energy Agency, 2018). Environmental impact from the Nordic electricity mix was 0.09 kg CO_2e per kWh (Sandgren & Nilsson, 2021).

Data on food losss and waste

Losses and waste in primary production (post-harvest and distribution) was accounted for by factors taken from Gustavsson et al. (2011), using the factors for oil crops. Figure 1 describes the amount of green beans used in the making of a) 1 L of brewed coffee, and b) 1 L of prepared instant coffee. It was assumed that around 2.2 kg ground coffee is needed for every kg instant coffee (Humbert et al., 2009). Losses occur at post-harvest, distribution, roasting, processing and brewing. For both processes, there is a 16% weight loss during roasting (personal communication; Eriksson, 2022). For brewed coffee, the main losses occur at the stage for brewing, a process that results in ready to drink coffee and spent coffee grounds. It was assumed that 60 g of roasted coffee is used per L of brewed coffee (European Coffee Brewing Center, NA). Losses during the processing of roasted coffee to instant coffee were 45% (Humbert et al., 2009). Data on food waste in the household was not accounted for when assessing the impact per kg/L but accounted for in the scenarios of different drinks (section 3.5).

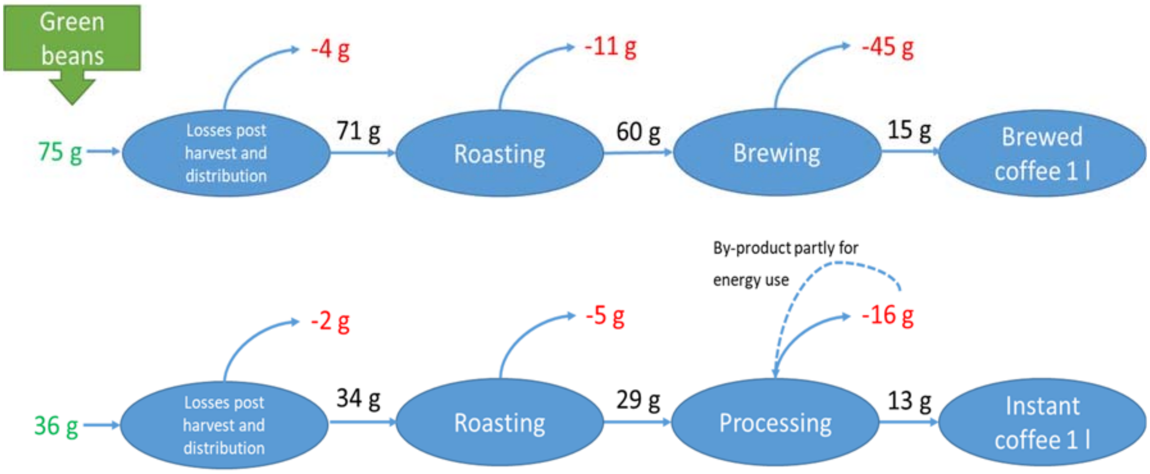

Figure 1. Amount of green beans required to produce 1 L ready to drink of brewed coffee and 1 L ready to drink instant coffee. In the case of instant coffee production the processing of roasted coffee beans into instant coffee powder is more efficient in the sense that more of the bean is extracted and ends up in the coffee drink (compared to regular brewing), that is the main reason behind the lower demand for green coffee beans.

3.2. Calculations of environmental impacts

3.2.1. Climate impact

Climate impact assessment metric GWP_{100} was used to express the climate impact in CO_2-equivalents (CO_2e), i.e. weighting the impacts of different greenhouse gases (carbon dioxide, nitrous oxide and methane) into one common indicator (Masson-Delmotte et al., 2021). Emissions associated with packaging and transportation to retail in Sweden were based on estimates from Moberg et al. (2020). The climate impact from the processing to produce instant coffee was calculated from Nilsson (2010). For instant coffee, it was assumed that natural gas was used as energy source for processing and that the waste product, i.e. the fibre fraction of the coffee, was also used as fuel in the process, which lowered the need for natural gas (Nilsson, 2010). Emissions from energy used during the preparation of the drinks was calculated from assumptions on brewing methods as described in section 3.3.

3.2.2. Land use

Land use of producing coffee, tea and cocoa was estimated using FAOSTAT yield data as described in Karlsson Potter et al. (2020). Yields are highly variable between different types of cultivation such as monoculture and agroforestry. Yields in organic production are often lower than in conventional production (Ponisio et al., 2015). In this study, it was assumed that organic coffee have 92% the yield of conventional coffee and the same was assumed for tea based on (De Ponti, Rijk, &

Van Ittersum, 2012). For cacao, the average for all crops, 80% the yield of conventional was used (De Ponti et al., 2012).

3.2.3. Biodiversity impact

Impacts on biodiversity from land use was estimated following the method by Chaudhary & Brooks (2018). The taxa-aggregated characterization factors for land occupation were used. For conventional production, the factors for 'cropland intensive use' were applied, while 'cropland light use' were applied for organic produce.

3.2.4. Water use

Data on total water use (green, blue and grey) was taken from (Mekonnen & Hoekstra, 2011). The blue water use refers to surface water and groundwater (fresh water) that evaporates as a result of the production of a crop for example by irrigation. Green water is the consumed rain water. Grey water is defined as the water needed to assimilate pollutants and nutrients that leak from the fields (Mekonnen & Hoekstra, 2011). The water scarcity method AWARE was applied by multiplying blue water use with country average factors for agricultural land (Boulay et al., 2018).

3.3. Functional unit and system boundaries

The functional unit (FU) of 1 L of prepared hot drink was selected for coffee and tea. Cocoa was presented with the functional unit 1 kg product at a store in Sweden as cocoa is used for multiple purposes and not only for making chocolate drink.

Environmental impact is also presented per cup of coffee (150 mL) or tea (200 mL) and cocoa drink (200 mL). For coffee brewing, 60 g ground coffee beans was assumed to be used per L water, based on the amount of coffee used in standardized test of coffee brewing machines (European Coffee Brewing Center, NA). This means that for a cup of 150 mL about 9 g roasted and grounded beans are used. This is an approximation, and the amount of coffee used for one cup ranges from about 7 to 11 g depending on type of coffee, how the coffee is ground and taste preference. For tea brewing, 8 g loose tea or five tea bags was assumed to be used per L water. For preparation of cocoa drink, a recipe of two teaspoons of cocoa (8 g), two teaspoons of sugar (8 g) and 200 mL of dairy milk or oat drink was used.

The following steps were included when calculating the climate impact per L of prepared drink: primary production including the production of inputs (e.g. fertilisers), processing, storage, packaging, transport to a store in Sweden, and preparation of the drink. Transport from retail to the consumer was not included. Although information on impact of washing up of cups and disposal of waste related to preparing coffee or tea was included in some of the retrieved studies, this information was not included in the calculations here. The reason for this was for the hot drinks to be presented in a similar way as the other foods in the consumer guide i.e. not including the consumption stage. Water for preparing the hot drinks was not included in the assessment of water use.

3.4. Strategy for producing final estimates for the consumer guide

To rate a product in the consumer guide, i.e. classifying a product with either green star, green, yellow or orange, thresholds were applied for each of the impact categories. Absolute thresholds were used for the dark green category for climate impact and land use, as planetary boundaries for a sustainable food system are suggested for these categories (Willett et al., 2019). For biodiversity impact (Potentially Disappeared Fraction, PDF), total water use, water scarcity (AWARE) and pesticide use, the thresholds were set to show differences between product performance in the different categories (Karlsson Potter & Röös, 2021).

WWF Sweden decided that for biodiversity, a product certified according an organic certification scheme or Rainforest Alliance was classified as ‘one step more sustainable’ (e.g. from yellow to light green).

In the development of the initial guide, separate thresholds were set for protein sources, carbohydrate sources, plant based drinks/cream and fruit and vegetables (Karlsson Potter & Röös, 2021). The ’environmental space’ for each impact category was distributed over the food groups based on how much the food categories contribute to the environmental impact of the food system based on the EAT-*Lancet* report (Willett et al., 2019). Coffee, tea and cocoa are not included in the EAT-*Lancet* report and thus there are no predefined boundaries for such beverages. For coffee and tea, boundaries for the fruit and vegetable group was used, while for cocoa the boundaries were those of protein rich plant based foods. The reasoning behind comparison of coffee and tea with the boundaries applied to fruit and vegetables is that coffee and tea cultivation has similarities with fruit cultivation. The beverages also has a high water content like fruits and vegetables. Cocoa powder contains about 20% protein, why it was compared against the boundaries of the protein group.

There is a general lack of data on pesticide use for different crops, and therefore the impact of pesticide use in food production is hard to assess. In the consumer guide the evaluation of pesticide use of conventionally produced products was therefore based on legislation in the respective production regions, where the EU legislation were assessed to be more restrictive on pesticide use compared to products from outside the EU (Karlsson Potter & Röös, 2021). Organic produce which leaves lower amounts of toxic residues than conventional produce, results in the best outcome in the guide, dark green (Karlsson Potter and Röös, 2021).

The final evaluation of the product for the guide was an average weighted score where impact categories were given one point for a green star ('Preferably consume this'), two for a green rating ('Please consume'), three for a yellow ('Consume sometimes') and four for an orange rating ('Be careful'). Products with a sum <5 points were given green star, 6-8 points green, 9-11 yellow and 12-16 orange as the total score.

3.5. Scenarios of coffee and cocoa drink consumption

To illustrate the environmental impact of coffee, tea and cocoa consumption, a number of scenarios for coffee, tea and cocoa drinking were constructed, including dairy milk or oat drink (as an example of a plant based alternative to dairy milk) and certain levels of waste at the consumer stage. Scenarios for coffee include brewed coffee, instant coffee and espresso coffee drinks with various volumes, with either dairy milk or oat drink (Table 1). Of brewed coffee and tea, 10%, 30% or 50% of the brewed beverage was assumed to be wasted (Table 2). Waste was assumed to be of prepared coffee, tea or cocoa drink, not of the dry products.

Data on the climate impact of oat drink was taken from (Karlsson Potter et al., 2020) and that of dairy milk from (Moberg et al., 2019). For the cocoa drink, sugar was also added, with climate impact data from (Moberg et al., 2019). In the scenarios, the impact of electricity use was assumed to be 0.144 g CO_2e per 100mL for tea and coffee brewing and heating of milk. Coffee, tea and cocoa was assumed not to add any volume to the beverage.

Table 1. Scenarios of coffee drinks, tea and cocoa beverage made with different amounts of milk or oat drink.

		Volume of total drink, mL	Roasted coffee, instant coffee, tea leaves or cocoa powder, g	Volume of prepared coffee/tea/cocoa beverage, mL	Volume of added milk/plant based drink, mL
1	Black coffee	150	9	150	0
2	White coffee (dairy milk)	150	6	100	50
3	White coffee (oat drink)	150	6	100	50
4	Instant black coffee	150	2	150	0
5	Instant white coffee (dairy milk)	150	1.3	100	50
6	Instant white coffee (oat drink)	150	1.3	100	50
7	Cappuccino (dairy milk)[1]	180	14	60	100
8	Cappuccino (oat drink)[1]	180	14	60	100
9	Medium Latte (dairy milk) [1]	230	7	30	180
10	Medium Latte (oat drink) [1]	230	7	30	180
11	Large Latte (dairy milk) [1]	460	14	60	360
12	Large Latte (oat drink) [1]	460	14	60	360
13	Tea, no addition	200	1.6	200	0
14	Tea with dairy milk	200	1.2	150	50
15	Tea with oat drink	200	1.2	150	50
16	Cocoa beverage (dairy milk)[2]	200	8	0	200
17	Cocoa beverage (oat drink) [1]	200	8	0	200

[1]In cappuccino and latte, some of the added milk/oat drink is whipped to foam, resulting in a larger total volume than volume of coffee + added milk/oat drink

[2]8 g sugar was added in the cocoa beverage

Table 2. Scenarios of coffee and tea with and without milk accounting for 10%, 30% and 50% waste of brewed coffee and tea, milk was assumed not to be wasted.

		Volume of total drink, mL	Coffee/tea, g	Volume of prepared coffee/tea, mL	Volume of added dairy milk/plant based drink, mL
1	Black coffee, 10% wasted	150	9.9	165	0
2	Black coffee, 30% wasted	150	11.7	195	0
3	Black coffee, 50% wasted	150	13.5	225	0
4	White coffee (milk), 10% wasted	150	9.9	110	50
5	White coffee (milk), 30% wasted	150	11.7	133	50
6	White coffee (milk), 50% wasted	150	13.5	150	50
7	Tea, no milk, 10% wasted	200	1.8	220	0
8	Tea, no milk, 30% wasted	200	2.1	260	0
9	Tea, no milk, 50% wasted	200	2.4	300	0
10	Tea with milk, 10% wasted	200	1.3	165	50
11	Tea with milk, 30% wasted	200	1.6	195	50
12	Tea with milk, 50% wasted	200	1.8	225	50

4. Results

In this chapter, results are presented separately for coffee (section 4.1), tea (section 4.2) and cocoa powder (section 4.3). In section 4.4, the ratings of coffee, tea and cocoa powder according to the criteria in the consumer guide for plant based products are presented. Scenarios of different amounts of dairy milk and oat drink, and different amount of waste of coffee and tea are presented in section 4.5.

4.1. Coffee

4.1.1. Climate impact

Climate impact of ground coffee powder on the Swedish market was estimated to 4.0 kg CO_2e per kg (updated value building on Moberg et al. 2019; personal communication Van Rysselberge, 2022) corresponding to 0.25 kg CO_2e per L, and 0.038 kg CO_2e per cup of black coffee beverage.

The climate impact of instant coffee powder was estimated to 11.5 CO_2e per kg. Per L prepared instant coffee ready to drink (including energy use for making the coffee) the total climate impact was 0.16 kg CO_2e per L which corresponds to 0.024 kg CO_2e per cup.

The most comprehensive study from a country with similar coffee consumption patterns and similar electricity mix was one from Finland. In comparison, the climate impact of coffee consumed in Finland was estimated to range from 0.27 to 0.70 kg CO_2e per L coffee depending on the origin of the coffee beans (Usva et al., 2020). A notable difference is that Usva et al. (2020) used questionnaire data from a number of farms supplying coffee to a Finnish roastery, while in our study we use overall national statistics from countries supplying coffee to the Swedish market.

In this study, we present the climate impact of 1 L brewed and 1 kg grounded coffee powder. In the literature, several other functional units are used, making comparisons difficult. Climate impact is sometimes presented per 1 kg (Nab & Maslin, 2020) or one tonne of green beans (Coltro, Mourad, Oliveira, Baddini, &

Kletecke, 2006), or per kg parchment coffee, an intermediate stage in production (Acosta-Alba, Boissy, Chia, & Andrieu, 2020).

Humbert et al. (2009) estimates that 50% of the climate impact of coffee originates from the producer-supplier steps while 50% can be attributed to the consumer stage (shopping, appliances manufacturing, use and waste disposal) in Switzerland. The consumer stage accounted for a lower share (19- 49%) of total climate impact from cradle to grave in Finland, probably due to more renewable energy in the electricity used in Finland (Usva et al., 2020). The variation was high in climate impact from different types of coffee farming in the Finnish study. In our estimate here, approximately 57% of the climate impact from prepared coffee came from the cultivation of green beans (up to farm gate), and the remaining from processing and preparation of the coffee.

4.1.2. Land use

Of the major countries growing coffee for the Swedish market, land use was highest in Kenya and lowest in Brazil (Table 3). The low land use in Brazil reflects its intensive high yielding coffee production. In Kenya, coffee is more likely to be produced in lower-yielding agroforestry systems, which, on the other hand may provide other services. Organic farming was assumed to result in 8% lower yields of green coffee beans (De Ponti et al., 2012).

Table 3. Land use (m^2) per L coffee drink by country of origin in conventional and organic agriculture.

	Land use (m^2) per L	
	Conventional	Organic
Brazil	0.43	0.47
Honduras	0.67	0.73
Kenya	2.3	2.5
Peru	0.88	0.96

4.1.3. Biodiversity impact

Due to land use in countries with high species richness and abundance, coffee cultivation has a considerable negative impact on biodiversity. Among the assessed countries, coffee from Honduras had the highest biodiversity impact (Table 4). As organic farming was assumed to result in lower yields (and hence higher land use), biodiversity impact assessed using the method from Chaudhary and Brooks (2018) was generally higher for organic coffee than for conventional. The negative impact of coffee cultivation on biodiversity is highlighted in several previous studies (Ahlgren et al., 2022; Harvey et al., 2021).

Table 4. Biodiversity impact (PDF, Potentially Disappeared Fraction) per L coffee by country of origin in conventional and organic agriculture.

	Biodiversity impact (10^{-13}*PDF) per L	
	Conventional	Organic
Brazil	1.0	1.1
Honduras	7.7	8.5
Kenya	5.7	6.3
Peru	6.4	6.9

4.1.4. Water use

Water use in coffee production is mostly from green water use, although Brazil and Kenya have some blue water use from irrigation (Table 5). Total water use is highest in Kenya, which is mainly a consequence of low-yielding systems which require more land and hence also green water. Blue water use is also highest in Kenya.

Table 5. Water use m^3 (green, blue, grey and total) and water scarcity by the AWARE method per L coffee, by country of import.

	Green water (m^3 per L)	Blue water (m^3 per L)	Grey water (m^3 per L)	Total water (m^3 per L)	AWARE (m^3eq)
Brazil	0.81	0.014	0.020	0.84	0.033
Honduras	0.98	0	0.069	1.0	0
Kenya	1.8	0.064	0.044	1.9	0.61
Peru	0.91	0	0.045	0.96	0

Usva et al. (2020) reported a water scarcity impact of similar magnitudes in irrigated systems. The highest water use on specific Brazilian farms with irrigation corresponds to an AWARE score of 0.27 m^3eq per L coffee (Usva et al., 2020). This indicates that on specific farms or areas with irrigation, the water use could be considerably higher than in our results that represent country averages.

4.2. Tea

4.2.1. Climate impact

Our estimate of the climate impact of tea was 6.3 kg CO_2e per kg (dry leaves) from cradle to retail, corresponding to 0.064 kg CO_2e per L and 0.013 kg CO_2e per cup prepared beverage (including energy for cooking). This estimate is based on updated data from Moberg et al. (2020) (personal communication Van Rysselberge, 2022), and includes transport and losses in the value chain from Moberg et al. (2019). Moberg et al. (2020) estimated a climate impact of 6.1-6.7 kg CO_2e per kg tea in retail in Sweden, depending on country of origin.

Xu et al. (2019) found that the climate impact ranged from 4.5 to 19.9 kg CO_2e per kg tea leaves in five traditional Chinese tea products in organic production (black tea, green tea and oolong tea). Both the lowest and the highest impact was for green tea. Over the whole life cycle of tea drink, from cradle to grave, the hotspots were the consumption stage, i.e. the boiling of water (in China and the US), production of inputs and processing, and the most influential factor was the sourcing of electricity for these activities (Xu et al., 2019). Azapagic et al. (2016) found that the climate impact was about 12 kg CO_2e per kg tea leaves in Kenya. Also in this study, consumption (in the UK) contributed most to impact of the final tea (85%) due to electricity use when boiling the water, while cultivation and processing accounted for about 10% and transport about 4% (Azapagic, Bore, Cheserek, Kamunya, & Elbehri, 2016). Tea from the famous tea producing region of Darjeeling, had a climate impact of 7.1 to 25.3 kg CO_2e per kg of tea (dry leaves) depending on methods of cultivation, energy sources and transportation mode (Cichorowski, Joa, Hottenroth, & Schmidt, 2015). Cichorowski et al. (2015) found that in the case of Darjeeling tea exported to Germany, about 50% of the impact originated from the consumption stage.

According to Doublet and Jungbluth (2010) tea in tea bags result in slightly higher climate impact per 250 ml cup (about 0.050 kg CO_2e) than loose tea (about 0.045 kg CO_2e) due to the additional climate costs of packaging and distribution. Even for tea bags however, packaging and distribution are small contributions to the climate impact compared to cultivation and processing (Doublet & Jungbluth, 2010).

4.2.2. Land use

Of the major countries growing tea for the Swedish market, land use for tea growing was highest in China and lowest in India and Vietnam (Table 6). Organic farming was assumed to result in 8% lower in yield of tea leaves (De Ponti et al., 2012).

Table 6. Land use (m^2) per L tea by country of origin in conventional and organic farming.

	Land use (m^2) per L	
	Conventional	Organic
Kenya	0.056	0.061
China	0.12	0.13
Sri Lanka	0.084	0.091
India	0.050	0.055
Vietnam	0.050	0.055

4.2.3. Biodiversity impact

Due to land use in countries with high biodiversity, tea has a considerable impact on biodiversity. According to our estimates, tea from Sri Lanka had the highest negative biodiversity impact (Table 7). As organic farming was assumed to result in lower yields (and therefore higher land use), the biodiversity impact is generally higher for organic as conventional produce when biodiversity is assessed with this method.

Table 7. Biodiversity impact (PDF, Potentially Disappeared Fraction) per L tea by country of origin in conventional and organic agriculture.

	Biodiversity impact (10^{-14}*PDF) per L	
	Conventional	Organic
Kenya	1.4	1.5
China	1.2	1.3
Sri Lanka	21	22
India	1.2	1.2
Vietnam	2.7	2.9

4.2.4. Water use

Water use in tea production is mostly from rainwater, the so called green water, with highest use in Vietnam, Sri Lanka and China (Table 8). Total water use is highest in the same countries. The water scarcity adjusted water use (AWARE) is higher in India and China indicating that fresh water use has a higher impact on water availability in those countries.

Table 8. Water use m^3 (green, blue and grey and total) and water scarcity by the AWARE method per L tea, by country of origin.

	Green water (m^3 per L)	Blue water (m^3 per L)	Grey water (m^3 per L)	Total water (m^3 per L)	AWARE (m^3eq)
Kenya	0.045	0	0.0010	0.046	0
China	0.10	0.009	0.016	0.13	0.40
Sri Lanka	0.11	0	0.015	0.13	0
India	0.052	0.015	0.0039	0.071	0.44
Vietnam	0.14	0.0021	0.0053	0.14	0.040

4.3. Cocoa powder and drink

4.3.1. Climate impact

Climate impact of 1 kg cocoa powder on the Swedish market was estimated to 2.8 kg CO_2e in retail in Sweden based on the updated database from (Moberg et al., 2022) (personal communication Van Rysselberge, 2022). Economic allocation between cocoa powder and other products from the cacao bean such as cocoa butter and cocoa mass affects the results significantly for all impact categories. Comparative data was difficult to find as some studies used 1 kg of cacao beans as functional unit (Neira, 2016; Ntiamoah & Afrane, 2008) and several studies focussed on end products such as chocolate bars (Bianchi, Moreschi, Gallo, Vesce, & Del Borghi, 2021; Recanati, Marveggio, & Dotelli, 2018). When assessing environmental impact of cacao beans in Ecuador, Neira (2016) found that the cultivation of the beans had the highest share of climate impact (about 66%), dominated by the impact of irrigation and fertilization.

4.3.2. Land use

The land used to grow cacao beans for 1 kg cocoa powder was considerably higher in Nigeria than in the other included countries (Table 9). Organic farming was assumed to result in 20% lower in yield of cocoa powder (De Ponti et al., 2012).

Table 9. Land use (m^2) per kg cocoa powder in retail in Sweden by country of import in conventional and organic agriculture.

	Land use (m^2) per L	
	Conventional	Organic
Ivory Coast	42	53
Ghana	39	48
Ecuador	42	52
Nigeria	74	92

4.3.3. Biodiversity impact

As cacao beans are grown in countries with high biodiversity, cocoa has a considerable impact on biodiversity because of land used in those areas (Table 10). As organic farming was assumed to result in lower yields in our method, biodiversity impact is generally higher for organic than for conventional produce.

Table 10. Biodiversity impact (PDF, Potentially Disappeared Fraction) per kg cocoa powder by country of origin in conventional and organic agriculture.

	Biodiversity impact (10^{-11}*PDF) per L	
	Conventional	Organic
Ivory Coast	1.2	1.5
Ghana	0.86	1.1
Ecuador	9.3	12
Nigeria	1.2	1.5

4.3.4. Water use

In the Ivory Coast, less rainwater was used for the production of 1 kg cocoa powder than in the other countries, no country used irrigation according to the data sources used here (Table 11).

Table 11. Water use m3 (green, blue and grey and total) and water scarcity by the AWARE method per kg cocoa powder, by country of origin.

	Green water (m^3 per kg)	Blue water (m^3 per kg)	Grey water (m^3 per kg)	Total water (m^3 per kg)	AWARE (m^3eq)
Ivory Coast	11	0	0.016	11	0
Ghana	21	0	0.015	21	0
Ecuador	27	0	0.11	27	0
Nigeria	18	0	0	18	0

4.4. Final assessment of coffee, tea and cocoa for use in the consumer guide

When rating coffee and tea according to the evaluation method developed for the consumer guide (Karlsson Potter and Röös, 2021), the boundaries for the fruit and vegetable group was used. The functional unit for coffee and tea was 1 L prepared beverage without any added milk or sweetener. The final evaluation of coffee and tea using the boundaries in the consumer guide is presented for the different countries in Table 12. However, because of the uncertainties in the environmental assessment and the relative nature of the boundaries, it is recommended to make an overall judgement per product based on the results from all countries.

The recommendation based on the data compiled in this report is to rate conventionally grown coffee as 'yellow', and organically grown coffee 'light green'. Considering the data for all five countries assessed, the evaluation of conventionally grown tea is that it is 'light green', and for organic tea, 'dark green'. Organic production resulted in the best score ('green star') for pesticide use, while the for biodiversity impact organic production were given one score better than the score that the product resided based on the land use (m^2) and biodiversity impact from land use (estimated in PDF) (Karlsson Potter & Röös, 2021). For Rainforest Alliance (RA) the biodiversity impact was estimated as for organic production, this assessment was made by WWF Sweden.

Table 12. Evaluation of coffee and tea using the boundaries for the fruit and vegetable group. The functional unit is 1 L prepared coffee or tea (without any added milk or sweetener). Org (organic) and RA (Rainforest alliance).

		CLIMATE	BIODIVERSITY	WATER	PESTICIDE USE	FINAL EVALUATION
Coffee	Brazil	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	Honduras	DARK GREEN	ORANGE	LIGHT GREEN	ORANGE	YELLOW
	Kenya	DARK GREEN	YELLOW	LIGHT GREEN	ORANGE	YELLOW
	Peru	DARK GREEN	YELLOW	LIGHT GREEN	ORANGE	YELLOW
Coffee org.	Brazil	DARK GREEN	DARK GREEN	LIGHT GREEN	DARK GREEN	DARK GREEN
	Honduras	DARK GREEN	YELLOW	LIGHT GREEN	DARK GREEN	LIGHT GREEN
	Kenya	DARK GREEN	LIGHT GREEN	LIGHT GREEN	DARK GREEN	LIGHT GREEN
	Peru	DARK GREEN	LIGHT GREEN	LIGHT GREEN	DARK GREEN	LIGHT GREEN
Coffee RA	Brazil	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	Honduras	DARK GREEN	YELLOW	LIGHT GREEN	ORANGE	YELLOW
	Kenya	DARK GREEN	LIGHT GREEN	LIGHT GREEN	ORANGE	YELLOW
	Peru	DARK GREEN	LIGHT GREEN	LIGHT GREEN	ORANGE	YELLOW
Tea	Kenya	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	China	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	Sri Lanka	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	India	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	Vietnam	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
Tea org.	Kenya	DARK GREEN	DARK GREEN	LIGHT GREEN	DARK GREEN	DARK GREEN
	China	DARK GREEN	DARK GREEN	LIGHT GREEN	DARK GREEN	DARK GREEN
	Sri Lanka	DARK GREEN	DARK GREEN	LIGHT GREEN	DARK GREEN	DARK GREEN
	India	DARK GREEN	DARK GREEN	LIGHT GREEN	DARK GREEN	DARK GREEN
	Vietnam	DARK GREEN	DARK GREEN	LIGHT GREEN	DARK GREEN	DARK GREEN
Tea RA	Kenya	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	China	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	Sri Lanka	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	India	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN
	Vietnam	DARK GREEN	DARK GREEN	LIGHT GREEN	ORANGE	LIGHT GREEN

The final evaluation for cocoa powder using the boundaries in the consumer guide per country is presented in Table 13. The functional unit is 1 kg of cocoa powder and the boundary was taken from the protein group of the guide. As for coffee and tea, it is recommended to present an overall impact, based on all the countries. Thus, the evaluation of conventionally produced cocoa powder is that it is 'orange', and for organic produce, 'light green'.

		CLIMATE	BIODIVERSITY	WATER	PESTICIDE USE	FINAL EVALUATION
Cocoa	Ivory Coast	DARK GREEN	ORANGE	YELLOW	ORANGE	ORANGE
	Ghana	DARK GREEN	ORANGE	YELLOW	ORANGE	ORANGE
	Ecuador	DARK GREEN	ORANGE	YELLOW	ORANGE	ORANGE
	Nigeria	DARK GREEN	ORANGE	YELLOW	ORANGE	ORANGE
Cocoa org.	Ivory Coast	DARK GREEN	YELLOW	YELLOW	DARK GREEN	LIGHT GREEN
	Ghana	DARK GREEN	YELLOW	YELLOW	DARK GREEN	LIGHT GREEN
	Ecuador	DARK GREEN	YELLOW	YELLOW	DARK GREEN	LIGHT GREEN
	Nigeria	DARK GREEN	YELLOW	YELLOW	DARK GREEN	LIGHT GREEN
Cocoa RA	Ivory Coast	DARK GREEN	YELLOW	YELLOW	ORANGE	YELLOW
	Ghana	DARK GREEN	YELLOW	YELLOW	ORANGE	YELLOW
	Ecuador	DARK GREEN	YELLOW	YELLOW	ORANGE	YELLOW
	Nigeria	DARK GREEN	YELLOW	YELLOW	ORANGE	YELLOW

Table 13. Evaluation of cocoa powder using the boundaries for the protein group. The functional unit is 1 kg cocoa powder. Org (organic) and RA (Rainforest alliance).

4.5. Scenarios of coffee, tea and cocoa beverage consumption

Climate impact per cup

In the assessment of climate impact per cup, tea has the lowest impact, followed by instant coffee, due to the small amount of coffee beans needed to make one cup (Figure 1). The different scenarios for coffee drinking clearly show the large climate impact of adding milk, or, to a lesser extent, a plant based drink, here exemplified by oat drink. The same applied to tea, but with a smaller effect as tea drinks were assumed to contain less milk or oat drink than coffee drinks. For one cup of cocoa beverage, made with 200 mL dairy milk, the climate impact was 0.31 kg CO_2e, and 0.092 kg CO_2e if the beverage was based on oat drink (Figure 1). The impact of sugar in the cocoa beverage is small.

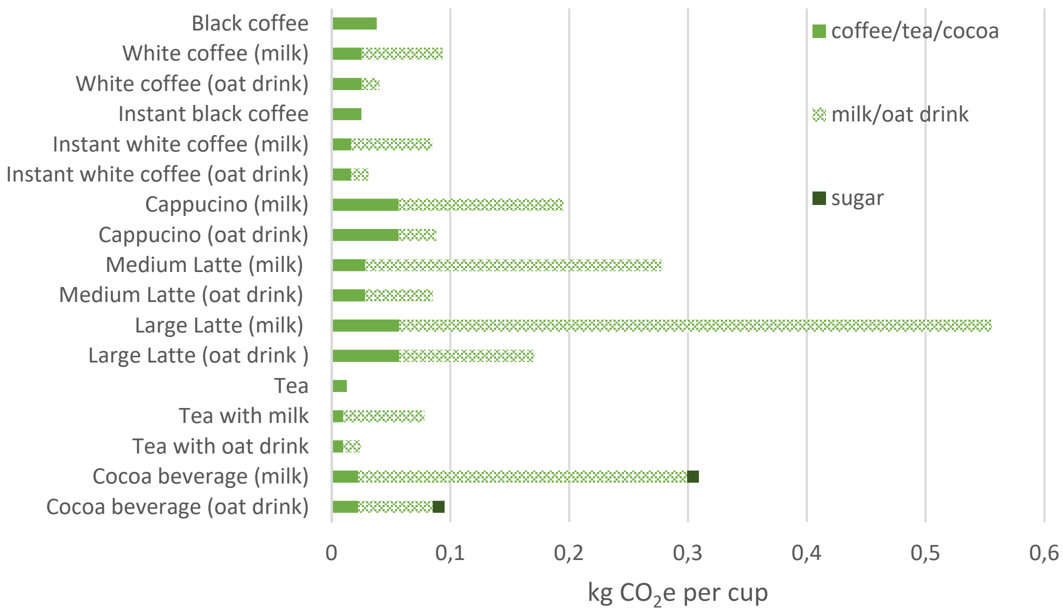

Figure 2. Scenarios of consuming coffee, tea or cocoa beverage made with different amount of milk/oat drink. Sugar is included in the cocoa drink only.

Household waste of coffee and tea

Scenarios of coffee and tea consumption including household waste is illustrated in Figure 3. The assumptions were waste of 10%, 30% and 50% of the brewed coffee or tea, and no waste of dairy milk. Because of the low climate impact per cup of tea, the effect of different waste levels is small relative to the impact per cup of coffee, even if the waste is 50%. For black coffee, the climate impact of one cup is higher if an additional 50% is brewed, than for a cup of coffee with dairy milk, with no coffee wasted.

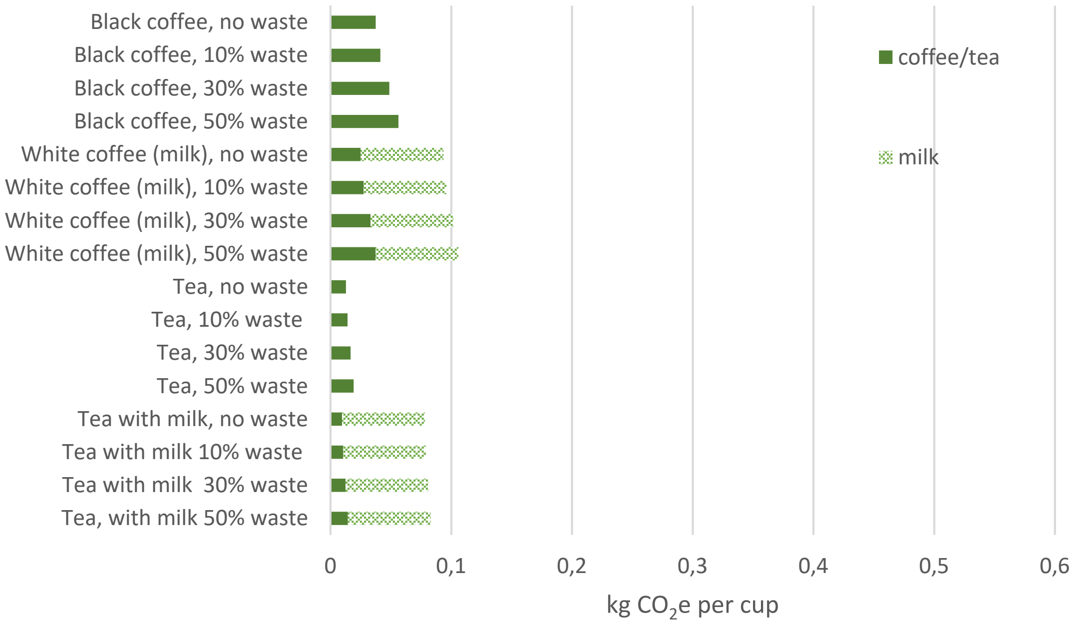

Figure 3. Scenarios of coffee and tea with and without dairy milk accounting for 10%, 30% and 50% waste of brewed coffee and tea, milk was assumed not to be wasted.

5. Discussion and concluding remarks

In this report, the environmental impact of coffee, tea and cocoa was assessed. There are several LCA assessments available, especially for coffee, but also for tea and cocoa. Functional units vary and some studies present data for a specific geographical area. Here we used data aimed a representing products on the Swedish market to the extent possible with data from Moberg et al., (2019; 2020) and ecoinvent. Import statistics on green coffee beans show the major coffee producing countries relevant for Sweden. For tea and cocoa powder, the trade statistics did not show the major producing countries, but rather the trade hubs for these products. Statistics on major export and import countries of tea and cocoa was therefore used, but the relevance of these countries for Sweden could not be confirmed.

Certification systems aim at incentivising production systems that reduce the negative impacts on e.g. biodiversity. For coffee, tea and cacao, that can be achieved by e.g. the use of agroforestry systems which have shown positive impacts on biodiversity in comparison with monocultures (Chowdhury et al., 2021; De Beenhouwer et al., 2013). However, the impact of certifications are context dependent and complex to evaluate. The impact of coffee certifications on sustainability outcomes is mainly positive or non-existent, rarely negative (Traldi, 2021). The impact of certification on cocoa and tea is much less evaluated. Tayleur et al. (2017) see a great potential for sustainability standards to contribute to biodiversity conservation if their implementation is properly monitored. Certification alone cannot ensure biodiversity conservation, but it may provide a way of incentivising innovations and best practice. Governments, companies, financial institutions and civil society can promote the scaling up of certifications in areas where it has the potential to deliver large positive impact (Tayleur et al., 2017). Some companies in the coffee value chain put sustainability high on the agenda, but globally, sustainability is not mainstream, and climate change and deforestation was under-addressed by many companies (Bager & Lambin, 2020).

The scenarios clearly show that the amount and type of milk or plant based drink results in the largest effect on climate impact on different beverages made from coffee, tea and cocoa powder. In some LCA studies of coffee, the consumption stage usually has a high impact due to high electricity use (Humbert et al., 2009).

We found the electricity use in the preparation of drinks in Sweden to have only minor impact on the climate impact of coffee, tea and cocoa beverage. It is due to the low climate impact of the Nordic electricity mix used in the scenarios. With the Nordic electricity mix, long stand-by times of electrical equipment have a small impact on the estimates.

Wasting coffee or tea increases the climate impact per cup drunk due to the additional impact of producing the wasted coffee or tea. In addition, electricity for preparation is also higher when more drinks than is drunken are prepared, although with a smaller contribution to the overall impact. Wasted prepared coffee and tea make up the largest amount of waste thrown in the sink in Sweden (Swedish Environmental Protection Agency, 2021). Although coffee and tea are in the same category in the study, it is fair to assume that most of the liquid waste consists of coffee, as coffe consumption is higher than tea consumption. Our scenarios show that wasted coffee has a larger climate impact than wasted tea due to higher climate impact of producing coffee. The implications of coffee waste is that the environmental impacts occur, without the sensory, cultural or health benefits of drinking the coffee. In Sweden, where a lot of coffee is consumed at home (Landais et al., 2018), reducing the amount of wasted coffee in households is an important step towards less environmental impact of coffee consumption.

To produce one kg of instant coffee powder, more green coffee beans are needed than to produce one kg of ground coffee for brewing. The higher impact of cultivation of green beans and the additional energy costs for the drying process of instant coffee results in a higher climate impact of instant coffee per kg of powder. However, when preparing coffee a smaller amount of instant coffee is used for making one cup of coffee as the instant coffee powder is dissolved in the water with no waste, while the ground coffee leaves substantial waste in the form of coffee grounds when the coffee is brewed. Therefore, the climate impact of instant coffee is still smaller than that for brewed coffee, per cup.

Data on land use is based on reported agro-statistics and has a lower uncertainty than the figures for biodiversity and water use. There may be several reasons for the relatively higher land use for coffee production in Kenya, and for cocoa production in Nigeria, and it may relate to accuracy of statistics (You, Wood, & Wood-Sichra, 2009). Yield was assumed to be lower in organic production, and estimates vary by crop (De Ponti et al., 2012; Ponisio et al., 2015). The method to assess biodiversity used here is coarse. Although we used different characterisation factors for conventional and organic production (‘cropland intensive use’ for conventional and ‘cropland light use’ for organic), the assumed higher land use from organic production caused organic production to show higher biodiversity impacts than conventional production with this method. This is in contradiction to many studies in the literature that show lower impacts on biodiversity from organic production compared to conventional production (Gomiero, Pimentel, & Paoletti, 2011). However, in the final rating of the products in the consumer guide, WWF Sweden has decided to reward organic production ’one step better scoring’ to account for the biodiversity benefits of organic production.

The same total water use for organic and conventional produce was assumed, even though the numbers for water use (Mekonnen & Hoekstra, 2011) are probably more representative of conventional agriculture (Karlsson Potter et al., 2020). Many different products can be made out of the cacao bean, and allocation is therefore probably a larger issue for cocoa powder than for coffee or tea. There are uncertainties in the figures for allocation to different cocoa products. For coffee and tea, allocation was usually not considered as their by-products have low economic value.

Because of high uncertainties, the grading of coffee, tea and cocoa powder in ‘dark green’, ‘green’, ‘yellow’ and ‘orange’ for the consumer guide is based on an overall assessment of the performance across countries.

6. Appendix

Table A1. Overview of LCA studies comparing climate impact, carbon footprint (CO_2e per functional unit) from different brewing methods. Some of the studies also included other outcomes.

Country of consumption and study	**Methods included**	**Functional unit**	**Results in brief**
Germany (Brommer et al., 2011)	French press and drip filter machine, filter pad machine, fully automatic coffee machine, capsule machine	2000 cups à 125 mL	French press and drip filter machine had the lowest impact, automatic machines higher due to high power consumption
Switzerland (Büsser & Jungbluth, 2009)	Drip filter machine, espresso and instant coffee	1 cup (not equal in size)	Espresso results in the lowest impact due to the small amount of water heated per cup (7g coffee per 30 g water). Instant coffee, 2 g one-portion stick had a lower climate impact than a 125 cup of drip filter-coffee (7 g coffee)
Italy (Cibelli et al., 2021)	Moka, espresso- pod- and capsule machines	40 mL	Lowest impact from Moka, highest from pod- and capsule machines
Italy (de Figueiredo Tavares & Mourad, 2020)	Traditional espresso, French press, AeroPress, filtered coffee systems in coffee shops, manual filtration, single-serve automatic machines with pods or capsules	50 mL	Lowest impact from single-serve soft pod with paper sachet using an automatic machine

USA (Hicks, 2018)	Drip filter, French press and pod-style brewing	0.275 L (size of one pod style coffee)	The plastic coffee pod had the lowest impact. The major impact was due to the amount of ground coffee used per cup (74 g/L for drip-filter, and 43 g/L for pod-style) and the electricity use.
Europe (Humbert et al., 2009)	Spray dried soluble coffee (instant) capsule espresso machine, drip filter machine	100 mL	Spray dried soluble coffee had lower carbon footprint than capsule espresso coffee or drip filter coffee due to less electricity use.
Thailand (Phrommarat, 2019)	Drip filter machine, drip filter manually and Moka	One cup (13.5 g ground coffee in 150 mL water)	Electric drip filter and manual, pour-over dripper had lower impact than Moka brewing due to less electricity use
Finland (Usva et al., 2020)	Office coffee machine, drip filter machine (home) and French press	1 L coffee/ 140 ml cup	Brewing at home with drip filter machine or French press had lower impact than office machines, mainly because office machines used more coffee per cup, especially for coffee drinks with milk.

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