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The Ecological Footprint of Swedish Sugar Consumption

Den svenska sockerkonsumtionens ekologiska fotavtryck

Karin Holmstrand

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Abstract

Climate change, loss of biodiversity and an ongoing population growth are challenging the global food production. Land is a scarce resource that is demanded for many purposes, reason why it is relevant to question how the arable land is used in the food production. Some commodities, including refined sugar, are not essential for the human diet, but are still consumed in higher quantities than are healthy for us. This report aims to investigate the ecological footprint of the sugar consumption in Sweden, focussing on land use. The research questions are:

1) Where does the sugar consumed in Sweden come from – geographically and crop-wise?
2) How much land is required for producing the sugar consumed in Sweden?
3) Does the Swedish consumption require more land than the current Swedish production can provide?
4) What are the environmental and social benefits of the current production, in comparison to those of alternative land uses? Aspects including food security, other food production, organic agriculture, nature conservation for biodiversity and biofuels are considered in three plausible scenarios.

The report is based on a literature review and an analysis of data collected from statistical bureaus and institutions, and it discusses three different scenarios of how the sugar supply can be managed in the future. The results show a present gap between the Swedish sugar production and the Swedish sugar consumption, which can be solved either by importing sugar (scenario 1), by increasing the Swedish sugar beet production (scenario 2) or by adjusting the consumption (scenario 3). The conclusion is that, despite other potential environmental benefits from the first two scenarios, scenario 3 is the only way of reducing the ecological footprint of the Swedish consumption.

Keywords: land use, sustainability, sugar

Sammanfattning

Klimatförändringar, förlust av biologisk mångfald och en pågående befolkningstillväxt utgör ett hot mot den globala livsmedelsproduktionen. Marken är en begränsad resurs som behövs för många syften, till exempel mat- och bränsleproduktion, artrika naturområden och kolsänkor. Av denna anledning är det relevant att ifrågasätta hur jordbruksmarken används i vår livsmedelsproduktion. Några matvaror, som exempelvis vitt socker, innehåller inga för människan nödvändiga näringsämnen. Trots det konsumerar svenskar mer än vad som är hälsosamt. Denna rapport syftar till att utreda den svenska sockerkonsumtionens ekologiska fotavtryck, med fokus på markanvändning. Följande frågor har ställts:

1) Varifrån kommer sockret som konsumeras i Sverige – geografiskt och med avseende på gröda?
2) Vad motsvarar konsumtionen i markanvändning?
3) Är det någon skillnad mellan den svenska produktionen och konsumtionen, med avseende på markanvändning?
4) Vilka miljömässiga och sociala för- och nackdelar finns med den nuvarande sockerförsörjningen, jämfört med andra alternativ? Aspekter som livsmedelssäkerhet, annan matproduktion, ekologiskt jordbruk, bevarade naturmiljöer för biologisk mångfald och biobränsleproduktion beaktas i tre tänkbara scenarier.

Rapporten bygger dels på en litteraturstudie, dels på en analys av data hämtad från statistiska byråer och institutioner, och den resonerar kring tre olika scenarier för hur sockerförsörjningen kan komma att ske i framtiden. Resultatet visar att det finns en lucka mellan vad som produceras och vad som konsumeras, vilket kan mötas antingen genom import (scenario 1), ökad svensk produktion (scenario 2) eller genom att begränsa konsumtionen (scenario 3). Trots eventuella miljövinster i vissa aspekter från scenario 1 och 2, blir slutsatsen att scenario 3 är det enda alternativ som leder till att Sveriges ekologiska fotavtryck minskar.

Nyckelord: markanvändning, hållbarhet, socker

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1 Introduction

The loss of biodiversity and climate change are the two major challenges for our generation. The concern about the unsustainable depletion of limited natural resources is however not new: the topic was widely debated in the wake of the report "Limits to growth", where Meadows et al. presented models suggesting the outrun of some essential resources in the mid or the latter part of 21th century (Meadows, Goldsmith & Meadows, 1972). Twenty years later, the authors published a new report, with a slightly new focus. Whereas the former concern was the lack of sources, the new report was highlighting Earth's decreasing capacity of neutralising waste and emissions (Meadows, Meadows, & Randers, 1992). Meadows et al. (1992) argues that nature has two functions: being a source and providing a sink. Today, it is clear that both functions are under threat.

The Paris Agreement, adopted in 2015, signified a common effort to break the trend of increasing emissions in order to limit the global warming at well below 2 degrees – ideally 1.5 degrees. To meet this target, the emission curve for greenhouse gases needs to fall drastically; worldwide but particularly in the global north. In October 2018, The Intergovernmental Panel on Climate Change (IPCC) published a special report which outlined the various consequences of the 2 degrees-scenario compared to the 1.5-degree scenario. Not least the future of species-rich habitats including the coral reefs fully relies on the more restricted target (Hoegh-Guldberg et al., 2018). The global warming is also expected to have severe consequences for the future food production. Since vast areas which are currently used for agricultural practices will lose their arability due to altered weather patterns, the pressure on the remaining land will harden (ibid.).

The rate of species losses is today of such a magnitude that biologists talk about the risk of a new mass extinction – the sixth that has been recorded throughout Earth's history (Barnosky et al., 2011). In May 2019, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) launched a report on the situation, with the alarming message that one million of Earth's eight million species risk to go extinct within decades (Díaz, Settele & Brondízio, 2019). The consequences are hard to estimate, but it will undoubtedly affect the human civilisation seriously, as the opportunity to food production and the access to substances necessary for producing medicaments are challenged (ibid.). To break the trend of extinction, extensive changes in our way of using natural resources are urgently needed. The main drivers to biodiversity loss include chemicals and climate change, but the most important factor is land conversion leading to depletion of the species' habitats (Díaz, Settele & Brondízio, 2019).

Meanwhile, humanity is continuously facing large inequalities in living standard in different parts of the world. Although the number of people in extreme poverty has diminished significantly the last decades, 8 percent of the global population still live with expenses of less than $1.90 per day (World Poverty Clock, 2019). In the least/developed countries (LDC), almost 70 percent of the population is rural, and the major part earn their living from agriculture (Word Bank, 2019). They are immediately affected by both climatic variations and altered product demand on the global food market. Even though their carbon footprint is small, many of these people are forced into unsustainable agricultural practices leading to soil degradation (Antle & Diagana, 2003) and deforestation (Desbureaux & Brimont, 2015), in order to secure food supply in the short perspective.

It has progressively become clear that land is a limited resource. The global population grows and is expected to reach 9.8 billion people in 2050 (United Nations, 2017). Furthermore, billions of people in developing countries are striving for an increased living standard. Meeting these needs requires an effective food system, where not only more, but also better distributed, food is a component. Rockström et al. argues that no more than 15 percent of the global land area should be converted to cropland, if the planetary boundaries are to be respected (Rockström et al., 2009). Meanwhile, climate change has opened a debate about biofuels as a possible substitute to fossil fuels. The conflict between food and fuels was particularly debated during the world agricultural commodity prices crisis in 2007-2008. One hypothesis was that the extended ethanol production was the main driver to the price volatility (Zhang et al., 2010). The conflict gets an aspect of justice, since biofuels are mainly demanded from richer countries, Sweden included, which are rarely affected by lack of food. Nevertheless, the need of replacing fossil fuels is urgent if the target set in the Paris agreement will be possible to reach. Combating climate change is however also dependent on conservation of existing carbon sinks (Grassi et al., 2017). Deforestation in order to provide more agricultural land is not only a major threat for biodiversity but is equally devastating for the climate. To summarise, land is in high demand for many purposes, whereof food production, biofuels and nature conservation may be the most important to safeguard sustainable development. Moreover, increased diplomatic tensions and trade conflicts have recently actualised the question about food security.

Another challenge for the global food system is the two faces of malnutrition. On the one hand, 11 percent of the global population are suffering from undernutrition (Díaz, Settele & Brondízio, 2019). On the other hand, an increasing number of people in developing, as well as richer, countries are dying from diseases linked to malnutrition and obesity (Hossain, Kawar & El Nahas, 2007). Altogether diet-related diseases cause around 20 percent of all premature death (ibid.). This issue raises the question about what food we should produce. Is the agricultural land used in a responsible way? Several scientific papers have investigated this question, focussing on the ecological footprint of different commodities. In particular meat production has been explored, because of its large land-use linked to fodder production. Hallström et al. suggest that the production of meat consumed in Sweden requires 0.11 hectares per capita and year (Hallström, Röös & Börjesson, 2014), corresponding to 1.1 million hectares for the whole Swedish population. Machovina et al. point out the link between livestock production and tropical deforestation (Machovina, Feeley & Ripple, 2015). Other studies demonstrate the land-use of palm-oil and maize (Fitzherbert et al., 2008; Casse et al., 2004). There are however more products that need to be questioned. Excessive sugar consumption is one of the main factors for the Swedish malnutrition. Having few medical benefits, sugar could easily be a symbol for a less sustainable land-use. A reduced sugar intake could therefore potentially have ecological advantages too, in terms of land savings.

1.1 Sustainability effects of sugar production: ecological aspects

Like all agricultural practices, the sugar production may have both positive and negative effects on the environment, depending on how it is undertaken. Croplands bind carbon from the atmosphere and could therefore be carbon sinks. If it is a sink or not depends however on what the alternative land use is; land types including pasture and forests contain more soil carbon than croplands (De Oliveira Bordonal et al., 2015). Agriculture could also contribute to a better nutrient and water regulation in the soil. Additionally, it provides an important ecosystem for many farmland species. Unfortunately, most of the large-scale farming of today is characterised by its negative implications on the ecological system, rather than the positive. Widespread use of agrochemicals in combination with vast monocultures is a threat to biodiversity (Chamberlain et al., 2000) and risk eutrophication (Fammler et al., 2018). Agricultural practices include many sources of the greenhouse gas emissions, e.g. nitrous oxide from fertilised land (Rochette et al., 2018; Smith, 2017) and carbon dioxide from farming machinery driven by fossil fuels. Intensive soil management reduces the soil biota and biodiversity (Tsiafouli et al., 2015) and heavy machinery may cause soil compaction (Gabarron-Galeote et al., 2019). Land, water and nutrients are finite resources that all crops require, and agricultural practices imply transports, soil preparation, possibly soil treatment and harvesting. Thus, the amount and the nature of resources applied determine the sustainability of cultivation. Despite having sugar as final product, sugarcanes and sugar beets have considerable differences in terms of cropping system and the associated impacts.

Sugar beets are grown in the temperate zones in various types of soils, ideally rich in humus. They require good soil quality with decent nutrient supply, however not too much (Nordic Sugar, 2019). An average yield of sugar beets is 63.8 tonnes per hectare, whereas a typical sugar yield is 10 tonnes per hectare (see Table 1). Precipitation should be around 610 mm to a minimum (Yamane et al., 2016). Production areas in Northern and Central Europe are rarely irrigated (Rûdelsheim & Smets, 2012), apart from sporadic irrigation if the amount of precipitation is insufficient. In fact, drought is currently the major source of yield losses of sugar beets in the UK, whereas these losses are smaller in Sweden where sugar beets are generally cultivated on soils with better water-holding capacity (Pidgeon et al., 2001). Sugar beets are frost sensitive (Rûdelsheim & Smets, 2012), and are therefore almost exclusively grown in the southernmost of Sweden (see Figure 1). The crop is not competitive against weeds, which is the reason why a permanent control of weeds is necessary. Various pests (including *Agriotes spp*., *Onychiurus armatus*, *Aphis fabae* and *Heterodera schachtii*) and diseases (including *Ramularia beticola*, *Uromyces betae*, *Erysiphe betae* and Beet Necrotic Yellow Vein Virus) affect European sugar beets, why the vast majority of farms use pesticides to some extent (Rûdelsheim & Smets, 2012). Practically all seeds are treated to resist different forms of fungus-attacks at the earliest stage of the beet life cycle (Rûdelsheim & Smets, 2012). Until 2013, impregnation of the insecticide imidacloprid was a standard procedure, but since this substance has shown negative effects on pollinators, it was banned in the EU in 2013 (European Commission 485/2013).

On the other hand, sugarcanes are grown in tropical and subtropical areas. The sugar content is 7-18 percent and the average yield of sugarcanes is 70.9 tonnes per hectare. The general sugar yield is 6.7 tonnes per hectare (see Appendix II Table E). Being a C4 plant, it is better adapted to a drier and warmer climate. Sugarcane is also a semi-perennial crop, meaning that it can be planted once and simply harvested annually during four to seven years (Lana & Wurbs, 2017). Nevertheless, the sugarcane requires 2000-2300 mm of precipitation during growth and a temperature which is no lower than 20 degrees. It is easily grown on a range of different soils, although the soil needs to be well-drained (Netafim, 2019). As a result of its large water requirements, irrigation is often mandatory, especially at the establishment of the crop. In areas with temporally scarce water resources, strategies to match the irrigation with the most requiring growth period are crucial (Phillips, 2018). Given the right temperature, solar radiation and soil drainage, the yield of sugarcane is directly correlated to the access to water (Holden & McGuire, 2014). Pesticides and fertilisers are usually part of the agricultural practice, of which herbicides are the most frequently used agrochemical (Hess et al., 2016; Dutra De Armas et al., 2005). Since weeds compete effectively with sugarcane, weed control, including agro-chemicals, is a necessity (Holden & McGuire, 2014). The use of these chemicals has repeatedly been found having negative impact on water quality (Hess et al., 2016). Because of its limited tolerance to be stored once harvested, the sugarcane is normally transformed into raw sugar not far from where it is grown. The imported product is therefore rarely sugarcanes, but rather raw or refined sugar. Sugarcane is also used in large scale to produce bioethanol.

Many reports have compared the cropping systems of sugar beets and sugarcanes in order to investigate which one is the most resource consuming (Cristóbal et al., 2016; Klenk, Landquist & Ruiz de Imaña, 2012; Renouf & Wegener, 2007; Rein, 2010). However, the results depend highly on the suitability of the site of the field. If the conditions are optimal, the cultivation will require only a few additional resources, including irrigation, fertilisers and agrochemicals, but still provide a profitable yield. However, in the worst-case scenario, the sugar production entails land conversion, which possibly means deforestation, destruction of important ecosystems and loss of carbon sinks. If the quality of the soil is not at an optimal level for the crop, more fertilisers are required, which may increase the carbon footprint as well as endangering the water quality. In the case of pests and diseases, increasing the cultivated area might also increase the consumption of agrochemicals. Land conversion does not always negatively affect the climate; some crops bind carbon dioxide better than others, meaning that the conversion could also give climate benefits (De Oliveira Bordonal et al., 2015). Nevertheless, when forests are turned to agricultural land, carbon is practically always released to the atmosphere.

In general, beet fields are today less likely to cause land conversion from forest to agricultural land, than canes are (Klenk, Landquist & Ruiz de Imaña, 2012). Indeed, most croplands, sugar beet fields included, have caused land conversion when established in the past. For Europe, substantial land conversions took place during the 20^{th} century (Kuemmerle et al., 2016). Sweden has also faced a decline in arable land the since the 1950s (Swedish Board of Agriculture, 2012), which further confirms that land conversion in favour of cropland is not a current issue. Sugar beets are often a part of a crop rotation scheme, whereas canes in greater occurrence are grown as the main crop of the field (Klenk, Landquist & Ruiz de Imaña, 2012). Sugarcanes require tropical or subtropical climate and are consequently restricted to an area traditionally dominated by rainforest. Recent studies have revealed that trade of agricultural products is a major driver to tropical deforestation (Leblois, Damette, & Wolfersberger, 2017).

1.2 Sustainability effects: Social and economic aspects

Growing sugar contributes to the rural economy and employment, regardless if it concerns sugar beets in Sweden or sugarcanes in South America. As earlier mentioned, sugar beets are often used within the crop rotation and since it is a crop with a relatively high value, the beet production could play an important role for making the farm profitable (Nordic Sugar, 2018).

From the year 2016/17 to 2018/19, about 50 percent of the cane sugar which EU imported originated in ACP (African, Caribbean and Pacific) or LDC countries (European Commission, 2019). In many of these countries, the sugarcane production plays a crucial role for the economy, and for the smallholder communities in particular. An altered import quantity could therefore have devastating consequences for the farmers income. An example of this was the outcome of the EU sugar reform, initiated in 2004/2005, which reduced the sugar price in order to stimulate the market (European Commission, 2005). The lower price put many farmers both within Europe and in the import countries in a difficult position, and as a consequence, the production of the following year fell considerably (Figure 1). In sugarcane-producing ACP and LDC countries, the sugar price decreased as well, although it was still higher than the average at the global market (Hess et al., 2016). For this reason, the import remained high. However, the EU quota that restricts domestic production was removed in 2017 – a reform which has led to decreased import from ACP and LDC countries (Fairtrade, 2019). For small-scale farmers, this new situation may have severe consequences. Already living on the edge of poverty, a less accessible European market threatens their chance to earn a living. In order to continue to support these economically exposed countries, duty-free and quota-free EU agreements, including Everything-But-Arms, will remain (European Commission, 2017). Additionally, the union supports efforts to diversify the agricultural production in poor countries that are highly dependent on sugar export (European Commission, 2017).

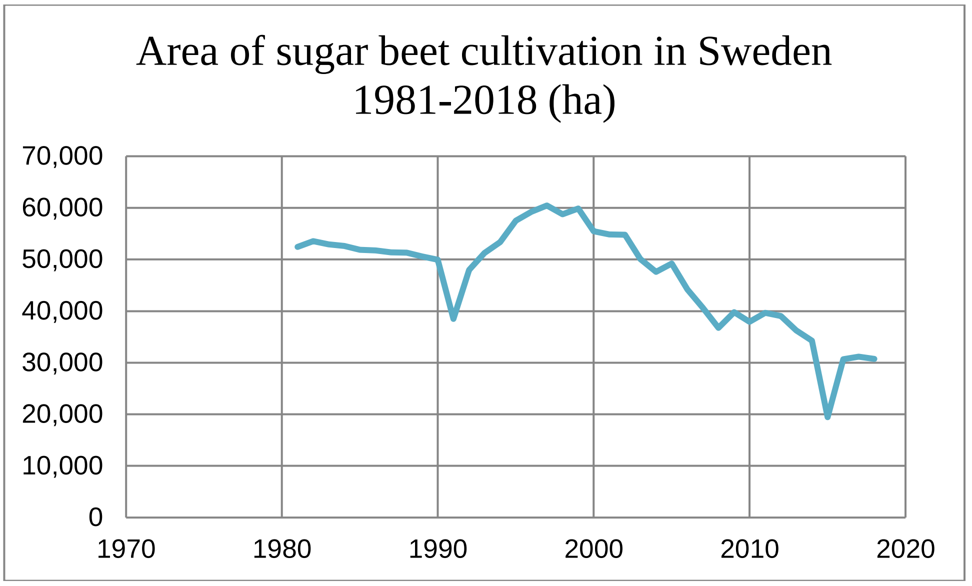

Figure 1: The arable land used for sugar beet cultivation in Sweden from 1981-2018. Based on statistics from Swedish Board of Agriculture.

The purpose of my study is to investigate the ecological footprint of the Swedish sugar consumption, focussing on land-use. Since the ecological impact of the consumption reaches far outside the national borders, I have chosen to have a consumption-based rather than a production-based approach, including both domestic production and import. The report aims to answer following questions:

1) Where does the sugar consumed in Sweden come from – geographically and crop-wise?
2) How much land is required for producing the sugar consumed in Sweden?
3) Does the Swedish consumption require more land than the current Swedish production can provide?
4) Considering different scenarios for the sugar sector in Sweden, what would the environmental and social benefits be? In three plausible scenarios, aspects including food security, other food production, organic agriculture, nature conservation for biodiversity and biofuels are considered.

2 Methodology

In order to answer these questions, a literature search was performed on Google Scholar. Keywords, e.g. “sugarcane”, “sugar beet” and “crop rotation”, were applied and primarily papers from 2010 and onwards were chosen. The relevant literature was then reviewed and compared. Reports financed by the sugar industry were only exceptionally consulted, in case other papers on the topic were not to be found. By collecting data from statistical bureaus and institutions, the required land area was calculated. This, as well as the mapping of sugar production, was visualised in GIS using data adopted from the Swedish Board of Agriculture. This report mainly builds upon 1) a literature review and 2) an analysis of the collected data for the actual situation and for alternative scenarios, including a situation where the sugar consumption is restricted to the WHO recommendations on nutrition.

Other studies have with similar approaches tried to present possible scenarios for meeting the future need of food (Hallström, Röös, & Börjesson, 2014; Öborn et al., 2013). This study concentrates however only on the Swedish consumption of sugar. It includes both Swedish sugar beet production and the production of imported sugar originating from sugar beets and sugarcanes. Other sugars than sucrose are excluded in order to restrict the proportions of the study.

The data concerning the Swedish production were gathered at statistical bureaus and official institutions, including Statistics Sweden (SCB), the Swedish Board of Agriculture (Jordbruksverket), European Commission database and Food and Agriculture Organization of the United Nations (FAO). The information was compared between the databases, in order to minimise the risk for statistical errors which may cause misleading results when used in further calculations. Yields vary from year to year, why numbers which differ considerably from the surrounding years were avoided.

Since only one sugar factory, located in Örtofta, stands for the processing of all Swedish sugar, a phone interview with the Head of Nordic Sugar, Olof Dahlgren, was undertaken in order to clarify the total Swedish production and to map the pathways for raw sugar with different origins.
The sugar import and export were calculated, using data from Statistics Sweden regarding the trade of foodstuff containing sugar and a table of standard values of sugar content for each product group. The table was generated by the Swedish Board of Agriculture (Swedish Board of Agriculture, 2016). When the production quotas were compared in order to investigate different countries' and regions' share of the overall sugar production, all data concern the year of 2017. When basing all calculations on data from one specific year, there is a risk of failing to catch ongoing trends. For this reason, it was important to choose a year that did not appear to be extreme in comparison to the surrounding years. Being representative according to this criterion, 2017 was chosen. It was also the most recent year for which data were available for all the requested parameters.
The location of the domestic sugar production and of the international production relevant to the Swedish sugar consumption are presented in Figure 2-3. Both maps are produced in QGIS 3.4.4.

In order to analyse the third scenario – a situation where the health guidelines for sugar consumption are respected – recommendations from The National Food Agency (Livsmedelsverket) were used. In addition to this, the World Health Organization (WHO) was consulted (World Health Organization, 2015). With data from Statistics Sweden about the Swedish population and statistics from FAO and U.S. Department of Agriculture (USDA) regarding energy requirements, these recommendations formed a guideline showing what the upper limit of sugar consumption ideally would be from a medical perspective.

The mathematical analysis of all statistical data is displayed in Appendix.
For the evaluation of sustainability effects from sugarcane and sugar beet production, scientific articles were consulted. Websites including Nordic Sugar, Europabio, Fairtrade and Britannica were also visited.

3 Results and discussion

3.1 Production in Sweden and import

The Swedish sugar consumption is composed by domestic beet production and imports – both of pure sugar and of processed food containing sugar – which originate from either sugar beets or sugarcanes. The chart below describes these different origins (Figure 2). One part is produced in Sweden from sugar beets which are later processed in Örtofta sugar factory and refined in Arlöv refinery. About 20 percent of the sugar proceeds to the grocery store for direct purchase, whereas the rest continues into the food industry. The majority of the imported sugar (from sugar beets and sugarcanes) comes in as processed products, while only a small amount of organic sugarcane raw sugar is refined together with the domestically grown beet sugar in Arlöv.

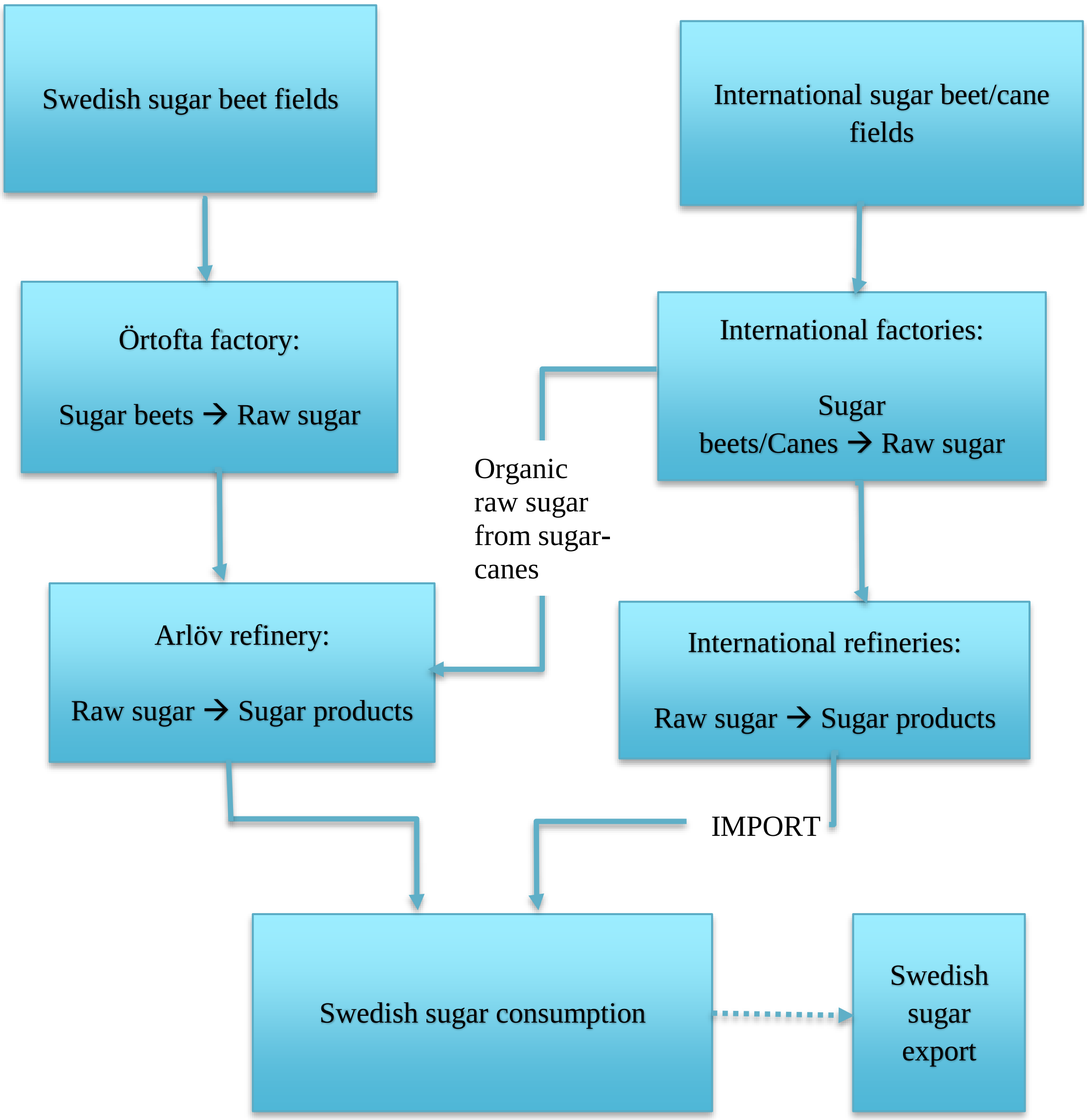

Figure 2: The different pathways of sugar contributing to the Swedish consumption.

In this section, the initial focus is on Swedish production, before moving on to the imports. We proceed afterwards to a comparison between production and consumption. Finally, we end up by discussing three different scenarios of managing the future sugar supply.

3.1.1 Swedish sugar beet production

The Swedish sugar production comprises sugar beet production, primarily located in southern Sweden. Figure 3 displays the location of sugar cultivation areas at municipality level. It is notable that the majority of the national sugar beet cultivation takes place in few municipalities. Being a rather demanding crop, sugar beets are only cultivated on land where the yields are sufficient to make the production profitable. Table 1 contains data describing the Swedish production in 2017.

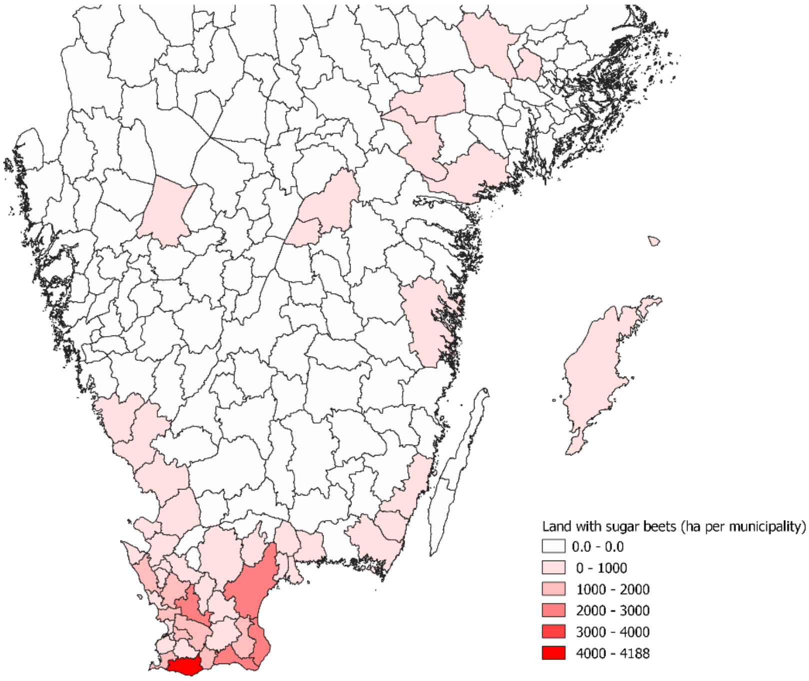

Figure 3: Map of the sugar beet producing municipalities in Sweden. Colours indicate the number of hectares in each municipality used for sugar beet land.

Table 1: Data describing the Swedish beet sugar production in 2017 and the destiny of the sugar after leaving the factory (own calculations based on data from sources).

Arable land[1]	30 800 hectares
Sugar beets per hectare (fresh weight)	63.8 tonnes per hectare
Sugar per hectare	9.96 tonnes per hectare
Sugar beet production[2]	1 964 000 tonnes
Sugar production[1]	306 906 tonnes
Sugar, direct market (20 %)[3]	61 381 tonnes
Sugar, food processing industry (80 %)[4]	245 525 tonnes

1. European Commission
2. The National Board of Agriculture
3. Nordic Sugar: Sugar, direct market: 0.20*306906=61 381 tonnes
4. Sugar, processing industry: 0.80*306906=245 525 tonnes
5. Sugar beets per hectare: 1964000/30800 = 63.8 tonnes/ha

3.1.2 Sugar from the EU and international producers

Although Sweden is a relatively big sugar beet producer, an important part of the internally consumed sugar originates from imports. Pure raw and refined sugar is imported, but the major part of sugar enters Sweden by the trade of processed food. Other EU countries are often the main exporter of these goods – although they are not always responsible for producing the sugar within the products. In order to map the Swedish consumption, it is therefore crucial to take a closer look at the EU production and import.

In 2017-2018, the EU produced 21 million tonnes of sugar, whereof only an insignificant part originated from sugarcane grown in French overseas departments. Other 1.3 million tonnes of sugar were imported to the EU, mainly sugarcane sugar from 18 countries, whereof half are ACP or LDC. On the other hand, the EU exported 3.3 million tonnes. By assuming that all EU imported sugar was from sugarcane, and all exported sugar was beet sugar, this means that 7 percent of the EU sugar was cane sugar (Table 2).

Table 2: Sugar statistics in the EU (own calculations based on data from European Commission).

	Amount (millions of tonnes)	Part cane sugar (%)
EU production[1]	21.0	0
EU import[1]	1.3	100
EU export[1]	3.3	0
EU sugar market, post trade[2-3]	19.2	7

1. European Commission, Sugar Trade Statistics 2019
2. Sugar in EU post trade: 21316841+1308000-3347000=19277841 tonnes
3. Part cane sugar in EU, post trade: 1308000/19277841=0.06785=7 %

Turning back to Sweden, about 70,000 tonnes of sugar are the net outcome from trade to the food processing industry (Swedish Board of Agriculture, 2016). In 2017, the import of sugar through processed foodstuff was approximately 229 000 tonnes, whereas the export via processed goods was about 151 000 tonnes, which would result in a net income from trade of 78 000 tonnes. This does not perfectly reflect the former number, but the application of average numbers, or minor fluctuations from year to year, are likely to be the reason for the difference. By including the direct trade of raw sugar and white sugar, the total sugar import was 291 000 tonnes, whereas the export was 227 000 tonnes (Table 3).

Since all values are an average of the products included in the group, the data are not exact which may undoubtedly lead to an inaccurate value for the import and the export. However, the potential error should be of the same extent for import as for export. Since the net trade amount was the main focus here, this inexactness should be of little importance.

In order to state the importance of cane sugar for Swedish consumption, a further analysis of the import – and not only the net result from trade – is needed. The sugar import via processed products was consequently about 229 000 tonnes. The ten most important categories for this import (representing 70 % of all) were soft drinks, dairy products, wine gum, bread, non-alcoholic beverages, chocolate, other sugar confectionaries, sauces, syrup and pastry (Swedish Board of Agriculture, 2018. See Appendix I, Table B).

To investigate where these products came from, the top five exporters for each category were examined. For soft drinks, dairy products, sugar confectionaries, bread and pastry, non-alcoholic beverages and chocolate, the main exporters were all EU countries. For sauces, four EU countries and USA were top five. For syrup, Paraguay was one of the top five, but the rest were EU countries (Swedish Board of Agriculture, 2018).

How much of the imported sugar is beet sugar and how much is cane sugar? The calculations (see Appendix I, Table D) are based on the assumption that 7 percent of the sugar from EU countries, 50 percent of the sugar coming from the US and 100 percent of the sugar from Paraguay, is cane sugar, whereas the rest originates from sugar beets. Figure 4 displays countries that export sugar to the EU and whether they are sugar beet growing or sugarcane growing regions. Although the production of high-fructose corn syrup plays an important role in the American food industry, it is not included in this study which only concentrates on sugars from sucrose. The result shows that approximately 8 percent of all the sugar from imported processed foodstuff is cane sugar. This means about 23 000 tonnes of the imported sugar to Sweden originates from sugarcane. Table 3 summarises the imports and exports, and the corresponding land use. It is worth noting that the land requirements for net trade is 1800 hectares.

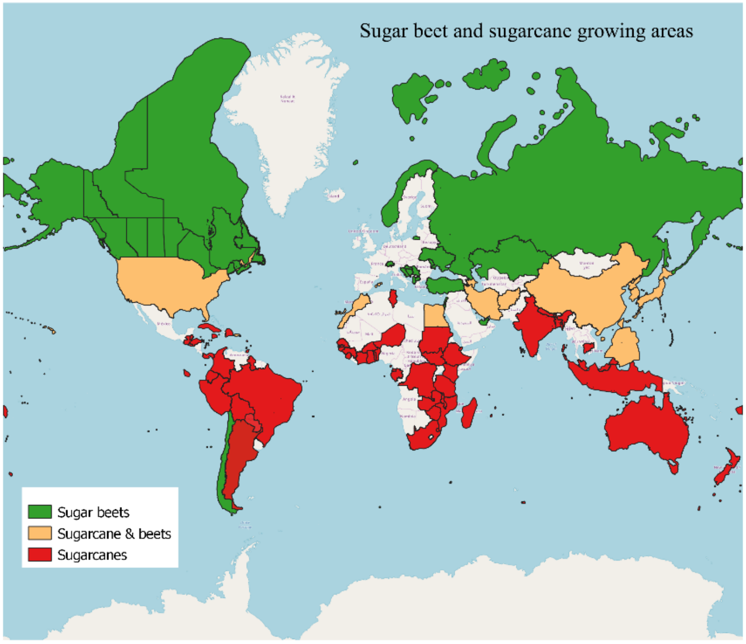

Figure 4: Map showing the countries that export sugar to the EU and whether they are sugar beet or sugarcane growing regions. Source: FAOSTAT and International Sugar Organization.

Table 3: Summary of the amount of sugar and the corresponding land-use related to Swedish sugar import, export and the net trade, i.e. what stays in Sweden after trade with other countries and the corresponding land-use to this amount.

	Amount (1000 tonnes)	Land use (1000 ha)
Beet sugar, Swedish export	227	22.7
Cane sugar, import	23	3.4
Beet sugar, import	268	21.1
Total sugar import	291	24.5
Net trade	64	1.8

3.2 Swedish consumption

A Swedish consumption of 23 000 tonnes of cane sugar corresponds to a land use of 3400 hectares (Table 3). Likewise, the foreign sugar beet production behind Swedish sugar consumption is around 21 100 hectares. Altogether, the Swedish sugar consumption including domestic production and trade results in 371 000 tonnes of sugar, taking up 32 600 hectares of arable land (Table 4). This number is to be compared with the statistics from the Swedish Board of Agriculture, saying that the yearly consumption per capita was 37.5 kg in 2017. Translated into the consumption for the entire population, this means 380 000 tonnes of sugar. The land-use corresponding to this number is 33 600 hectares. Consequently, the land-use derived from the Swedish sugar consumption is likely to be in the interval of 32 600-33 600 hectares (meaning 0.0032-0.0033 hectares per capita). Since the land-use for sugar production in Sweden is 30 800 hectares, there is a gap between the consumption and the production.

Table 4: Summary of the amount and the corresponding land-use related to Swedish sugar consumption, based on the domestic production and sugar net trade. Land use for the whole population and per capita are displayed.

	Amount (1000 tonnes)	Land use, whole population (1000 ha)	Land use, per capita (ha)
Beet sugar, Swedish production	307	30.8	
Sugar from net trade	64	1.8	
Swedish consumption (production+import-export)	371	32.6	0.0032
Swedish consumption (according to Jordbruksverket)	380[1]	33.6	0.0033

Source: 1) Based on own calculations using data from the Swedish Board of Agriculture (see Appendix I, Table E).

Globalisation and increased diplomatic tensions recently have raised questions about food security. With high levels of trading, Sweden is not self-sufficient on many goods. Regarding sugar, the import almost as big as the production (291 000 tonnes compared to 307 000 tonnes). Due to large exports in the current situation (227 000 tonnes), Sweden could also save a substantial part. Nonetheless, if both the imports and the exports were cut off, Sweden would experience a sugar deficiency. In order to make the food supply less vulnerable to international crisis, it is important to safeguard the domestic production.

3.3 Analysis of possible scenarios

There are different methods to adjust the mismatch between Swedish production and consumption. In this section, three scenarios are described, in which the gap is closed by 1. Imports (status quo), 2. Increasing area of sugar beet cultivation in Sweden, or 3. Adjusting the sugar consumption. The adjusted consumption could be motivated by closing the gap only, or by saving agricultural land.

3.3.1 Scenario 1: Import (status quo)

A first solution to fill the gap between production and consumption is to import sugar – which is the case today. From a food security perspective, it is not optimal. In case of a trade blockage due to war or deteriorated political relations, there would be a shortage in the supply, with increasing prices as a possible result. Although the Swedish sugar consumption requires only 1800 additional hectares – compared to the overall need of 32 600 hectares – Sweden relies on foreign resources for satisfying the sugar consumption, which equally is the case for the consumption of many other goods. As explained in the introduction, the existing production of sugar beets and sugarcanes has ecological implications in terms of irrigation, use of agrochemicals, monocultures and land conversion. All these issues remain and could be exacerbated in this situation.

A possible scenario, which is reverse from the aim of increasing food security and sovereignty, is the development of a food market increasingly dominated by large companies. There is undoubtedly a trend pointing in this direction; in Sweden, the number of agricultural companies has declined over the past decades. Comparing data from 1981 and from 2007, farms of various sizes have become fewer – with the only exception of the number of farms larger than 100 hectares, which has almost doubled (Statistics Sweden, 2019). This development is largely driven by a deregulated market which facilitates competition and international trade (Andersson et al., 2017). In case this trend will strengthen in the future, environmental implications could be expected, notably in terms of increasing monocultures and more intensive cropping systems. An agriculture mainly influenced by market forces would only prioritise ecological concerns if its environmental costs were internalised and thereby making unsustainable practices less profitable. If only companies growing sugar crops on the most productive land are sufficiently competitive, the Swedish production is likely to move to other European countries, including Belgium and the Netherlands, where the sugar yields are higher than in Sweden (European Commission, 2019). Likewise, it could promote the sugarcane industry outside Europe, which – due to lower ecological and social standards – can provide products that outperform the Swedish. Possibly, the production of sugar consumed in Sweden would be more efficient in terms of land use, but the result risk to weaken the food sovereignty and create an agricultural sector which is less concerned about environmental qualities.

3.3.2 Scenario 2: Increasing the arable land for sugar beet cultivation in Sweden

A second scenario is to increase the agricultural land used for sugar beet production in Sweden. In 2017, sugar beet fields took up about 31 000 hectares. In 1999, the area was almost the double – 60 000 hectares for sugar beet production (Swedish Board of Agriculture, 2018). The reason for the progressive decline in Swedish production is falling profitability for sugar beet farmers after the EU sugar reform in 2006. Removing the subsidies for sugar beet producers was a step on the way to make the EU market better adapted to the global market (European Commission, 2017) and to avoid production surpluses. However, the end of quotas also meant less profitability for Swedish sugar beet producers and many farmers giving up sugar beet production (Eklöf, Renström & Törnquist, 2012). In some European countries where the sugar sector is particularly vulnerable, including Croatia, Czech Republic, Finland, Greece, Hungary, Italy, Lithuania, Poland, Romania, Slovakia and Spain, voluntary coupled support is provided – although not in Sweden (European Commission, 2017). A scenario where Swedish sugar beet production is aiming for the former production level is therefore reliant on the profitability of the crop. Going back to subsidies within the EU, or at a national level, is a solution. In order to close the gap to the consumption, the Swedish production does not need to reach values like those in 1999; less than 2000 additional hectares would be enough.

This scenario satisfies the food security aspect, but it does not address the question of reducing the land-use. Still some positive effects on the ecological impact at global scale can be expected. The Swedish sugar beet production is less likely to cause land conversion, leading to loss of carbon sinks and of important ecological habitats, than sugarcane production is. Domestic production instead of imported goods means shorter transports and easier for the consumer to evaluate the production conditions, including use of irrigation and agrochemicals. Since sugar beets are usually part of a crop rotation scheme, the risk of soil degradation is higher for sugarcanes than for sugar beets.

In these aspects, an increased area of sugar beet production in Sweden would give environmental benefits. From a social perspective, altered import patterns may negatively affect developing countries whose economies highly depend on the sugar industry (Kihlberg, 2005; Brett, 2005). For ACP and LDC countries, sugar exports could be an important factor to fight poverty (Fairtrade, 2015). At the same time, the sugarcane market is mainly dominated by large companies, whose concern about environmental and social sustainability are strictly limited. Preserving the existing market could therefore prevent the situation to improve. Hence, other ways of supporting sustainable development in the global south, including economic assistance and agricultural techniques, are preferable. Consequently, these countries can primarily focus on securing a domestic food supply.

These sustainability aspects concern the sugarcane production. However, the vast majority of the imported sugar originates from European sugar beets. Since the regulations for sugar beet production are similar within the EU, the difference between importing European sugar beets and producing more Swedish sugar beets is modest.

Overall, the sustainability effects from this scenario seem to be predominately positive. Nevertheless, the same area of agricultural land is needed: clearly, this is not a strategy to reduce the ecological footprint of Sweden.

3.3.3 Scenario 3: Adjusting consumption

In this scenario, the gap is closed by adjusting the consumption to the amount of domestic production. Since Sweden produced approximately 307 000 tonnes sugar in 2017, an adjusted consumption would mean 30.0 kg of sugar per capita during the same year, a reduction of 7.5 kg per person and year (compared to 37.5 kg per capita).

Adjusting the consumption is also an opportunity to save natural resources, why a starting point could be determined by the recommendations from a medical perspective.

According to the nutrition guidelines set up by WHO (World Health Organization, 2015), no more than 10 percent of the daily energy intake should come from "free sugars", in order to prevent diseases linked to malnutrition. Except from health benefits, a decreased intake of sugar could have positive ecological effects, in terms of reduced land use and depletion of natural resources. Table 5 presents the theoretical sugar intake, if the WHO guidelines were respected. Mean height and mean weight for Swedish men and women, at the age of 16 and above, are used, and a moderately active lifestyle (BMR*1.75) is assumed. BMR is the abbreviation for basal metabolic rate, an individual measurement which determines a person's energy requirement. The lifestyle with BMR*1.75 indicates a physical activity requiring 75 percent of the person's BMR (Food and Agriculture Organization, 2004). The land use linked to the guidelines from WHO and the National Food Agency respectively are also displayed (Table 5).

Table 5: Mean values of the height, weight and energy requirements of a Swedish adult (over 16 years old), and the recommended sugars intake according to WHO. This is compared to the recommendations from the National Food Agency. (Calculations found in Appendix III Tables F-I.) Corresponding land use per capita and for the whole Swedish population in 2017.

	Men	Women	Mean men + women	Land use for sugar consumption per capita (m^2)	Land use for sugar consumption, men+women (ha)
WHO:					
Average height[1]	179.4 cm	165.7 cm			
Average weight[1]	82.9 kg	67.1 kg			
Total energy requirements[2]	3150 kcal	2380 kcal			
10 % sugar source, kcal per day	315 kcal	238 kcal			
10 % sugar source, kg per year[3]	29.7 kg	22.4 kg	26.1 kg	26.1	26 700
National Food Agency:					
Recommended sugars intake[4] (per capita and day)	0.075 kg	0.050 kg	0.063 kg		
Recommended sugars intake (per capita and year)	27.4 kg	18.3 kg	22.8 kg	22.8	23 300

Source: 1) Statistics Sweden, 2) FAO, 3) USDA (387 kcal per 100 g sugar), 4) National Food Agency

According to WHO, a healthy sugars intake over a year should be limited to 29.7 kg for men and 22.4 kg for women (mean value 26.1 kg per year). A similar recommendation is given by the National Food Agency, which argues that 50-75 g is a healthy level of daily sugar intake (National Food Agency, 2019). Translated into yearly consumption, this equals 22.8 kg per year on average. The reason to the somewhat higher values of the recommendations from WHO could be the fact that the energy requirements vary widely between young adults and elderly people.

The calculations behind the values in Table 5 are based on a mean value of requirements for all ages in the population (age >16), but the number of people in each age category is not given. Since there are more people at the age of 25-29 than 80-84 years old, a simple average of all ages is likely to give a value which is slightly too high.

Compared to the actual sugar consumption in Sweden today – 37.5 kg per capita and year – it is clear that considerable savings in terms of land-use are possible by adjusting the consumption to the official recommendations. With the more restrictive sugar intake, only 26 700 hectares (first recommendation) or 23 400 hectares (second recommendation) would be needed, given the present Swedish conditions for sugar beet production.

By adjusting the consumption, many positive effects can be distinguished. Firstly, the sustainability effects described in Scenario 2 are the same in this scenario. By reducing the import of conventionally grown sugarcane, the risk of contributing to indirect land conversion is minimised. In developing countries, the land could be used for local food production, and even reduce the pressure to expand crop areas. Regarding sugar beets, it is easier to get an overview of the ecological and the social consequences from domestic production than from another country. Secondly, land savings are possible even in Sweden; whereas 31 000 hectares are used today for sugar beet production, only 26 700 hectares or 23 400 hectares are needed if the consumption is adjusted to the nutritional guidelines. Compared to the land requirements of the current sugar consumption – between 32 600 and 33 600 hectares – the land savings are estimated to be 5900-10200 hectares. This land could instead be utilised for other food production, in order to improve the food security and sovereignty. As one example, legumes could be cultivated in such areas as part of an effort to reduce the high dependence on imported plant-based protein (notably soybean). Energy crops could also be an option, reducing the reliance on fossil fuels. Alternatively, the conventional sugar beet production could be converted to organic, with a consequential reduction in yield. In this case, the area cultivated with sugar beet would be the same, but with a lower sugar consumption and a less environmentally harming cropping operation, creating a more heterogenic landscape and thereby improving the conditions for biodiversity and soil fertility. Thirdly, reducing the white sugar would have health benefits, since an excessive intake is associated with obesity and diseases linked to malnutrition, including type 2 diabetes and many types of cancers (Nordic Council of Ministers, 2014; Guh et al., 2009).

4 Conclusions

The first objective of this report was to investigate the origin of the Swedish sugar consumption geographically and crop-wise. Sugar consumed in Sweden comes from Swedish sugar beet production, sugar beet production in and outside the EU and sugarcane production outside Europe.

Table 6: Summary of the components of Swedish sugar consumption, including quantity and geographical origin.

	Amount (1000 tonnes)	Sugar origin
Domestic production, beet sugar	307	Sweden
Export, beet sugar	227	Sweden
Import, cane sugar	23	Outside Europe
Import, beet sugar	268	Mostly Europe

The second objective was estimating the land use associated with the sugar consumption. Although the domestic sugar beet production in 2017 covered 30 800 hectares, additional land use must be considered: international production of sugar beets corresponded to 21 100 hectare and international production of sugarcanes took up 3410 hectares. Altogether, adjusted for Swedish sugar exports, the consumption is estimated to be between 32 600-33 600 hectares.

The third objective was to explore whether there is a gap between Swedish production and Swedish consumption of sugar. This is the case – actually, the difference is approximately 64 000-73 000 tonnes, which is translated into about 1800-2800 hectares.

The fourth objective was to analyse three possible scenarios which could help to fill this gap. All the three scenarios depicted here are possible strategies for meeting the present mismatch between the domestic sugar production and consumption. However, the scenarios clearly differ in suitability if the aim also is to provide food sovereignty and to reduce the environmental impact of the cropping system. Moving all production to Sweden would meet the former criteria, and possibly also the latter, depending on what type of land conversion it would trigger directly and indirectly. Scenario 3 is however the case where several positive consequences are most likely to occur. By only following the nutritional guidelines for sugar – which by no means implies a zero consumption – around 5900-10200 hectares could be released, either in Sweden or in countries with more environmentally damaging practices. A further reduction of sugar consumption would naturally result in additional land savings. Given that these areas are dedicated to ecologically and socially sustainable practices, including organic production, biofuel development and avoiding negative land conversion, the reduced sugar consumption would have environmental – and not only medical – benefits.

There are few, if any, negative effects from reducing the sugar consumption – provided that social implications for growers, e.g. unemployment, are considered and met in an adequate way. An adjusted consumption is therefore an approach which reduces the ecological footprint of land-use. Since the direct consumption of sugar represents only a minor part of the overall sugar intake today, it is in the industry of processed food the main change must take place. This would equally enhance the traceability of food, which is important for ensuring sustainable production.

By adopting a wider perspective on the overall food consumption and its corresponding land use, sugar production is not individually the largest exploiter of the land resources. Compared to the land use associated with meat production (0.11 hectares per capita), the land use for sugar (0.003 hectares per capita) is of less importance. Nevertheless, reducing sugar production should be considered as part of an effort to minimise the footprint of our food system – especially since white sugar has no essential function in the human diet. Due to global population growth, climate change and a potentially augmented demand for biofuels, the pressure on arable land will harden during the 21th century. Meanwhile, the urgency of conserving natural habitats, including species-rich forests, in order to combating climate change and biodiversity losses, is becoming increasingly clear. In a future characterized by these challenges, combined with a continuous aim to eliminate poverty and starvation, the question about what we eat and how it is produced is central.

5 References

Andersson, L., Bengtsson, J., Dahlén, L., Ekelund Axelsson, L., Eriksson, C., Fedrowitz, K., Fischer, K., Friberg, H., Hallin, S., Hunter, E., Jansson, T., Johnsson, P., Mobjörk, M., Oskarsson, D., Patel, M., Rydhmer, L., Räty, R., Röös, E., Slätmo, E., Stenström, M., Sundberg, C., Svensson, C., Westholm, E., Wikman Svahn, P. (2017). *Agriculture in 2030 – stories of the future*. Uppsala, Swedish University of Agricultural Sciences. https://www.slu.se/globalassets/ew/org/centrb/fr-lantbr/publikationer/agriculture-in-2030---stories-of-the-future_webb.pdf [2019-05-24]

Antle, J. M., & Diagana, B. (2003). Creating Incentives for the Adoption of Sustainable Agricultural Practices in Developing Countries: The Role of Soil Carbon Sequestration. *American Journal of Agricultural Economics*, 85(5), 1178-1184. https://doi.org/10.1111/j.0092-5853.2003.00526.x

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., … Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, 471, 51-57. https://doi.org/10.1038/nature09678

Brett, C. (2005). EU sugar deal 'scandalous detrayal' of poor countries. WWF European Policy Office, November 24. http://www.wwf.eu/?51760/EU-sugar-deal-scandalous-betrayal-of-poor-countries [2019-05-23]

Casse, T., Milhøj, A., Ranaivoson, S., & Randriamanarivo, J. R. (2004). Causes of deforestation in southwestern Madagascar: What do we know? *Forest Policy and Economics*, 6 (1), 33-48. https://doi.org/10.1016/S1389-9341(02)00084-9

Chamberlain, D. E., Fuller, R. J., Bunce, R. G., Duckworth, J. C., & Shrubb, M. (2000). Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. *Journal of applied ecology*, 37(5), 771-788. https://doi.org/10.1046/j.1365-2664.2000.00548.x

Cristóbal, J., Matos, C. T., Aurambout, J. P., Manfredi, S., & Kavalov, B. (2016). Environmental sustainability assessment of bioeconomy value chains. *Biomass and bioenergy*, 89, 159-171. https://www.sciencedirect.com/science/article/pii/S096195341630023X

De Oliveira Bordonal, R., Lal, R., Alves Aguiar, D., De Figueiredo, E. B., Ito Perillo, L., Adami, M., … La Scala, N. (2015). Greenhouse gas balance from cultivation and direct land use change of recently established sugarcane (Saccharum officinarum) plantation in south-central Brazil. *Renewable and Sustainable Energy Reviews*, 52, 547-556. https://doi.org/10.1016/j.rser.2015.07.137

Desbureaux, S., & Brimont, L. (2015). Between economic loss and social identity: The multi-dimensional cost of avoiding deforestation in Eastern Madagascar. *Ecological Economics*, 118, 10-20. https://doi.org/10.1016/j.ecolecon.2015.07.002

Díaz, S., Settele, J., Brondízio, E. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES. https://www.ipbes.net/sites/default/files/downloads/spm_unedited_advance_for_posting_htn.pdf

Dutra De Armas, E., Rosim Monteiro, R. T., Valler Amâncio, A., Lopes Correa, R. M., & Guercio, M. A. (2005). Uso de agrotóxicos em cana-de-açúcar na bacia do rio Corumbataí e o risco de poluição hídrica. *Quimica Nova*, 28(6), 975-982. http://www.scielo.br/pdf/%0D/qn/v28n6/26824.pdf

Eklöf, P., Renström, C., Törnquist, M. (2012). *Marknadsöversikt – vegetabilier*. Jönköping. Jordbruksverket. 2012:26. https://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra12_26.pdf [2019-06-24]

EU 485/2013. Amending Implementing Regulation (EU) No 540/2011, as regards the conditions of approval of the active substances clothianidin, thiamethoxam and imidacloprid, and prohibiting the use and sale of seeds treated with plant protection products containing those active substances. Bryssel: European Commission

European Commisson. (2019). Committee for the common organisation of agricultural markets balance sheet. Available at: https://ec.europa.eu/agriculture/sites/agriculture/files/market-observatory/sugar/doc/balance-sheet_en.pdf [2019-05-14]

European Commission (2005). "Sugar reform will offer EU producers long-term competitive future". European Commission website. Available at: http://europa.eu/rapid/press-release_IP-05-776_en.htm [2019-05-14]

European Commission (2019). Sugar Trade Statistics. Committee for the common organization of agricultural markets. Available at: https://ec.europa.eu/agriculture/sites/agriculture/files/market-observatory/sugar/doc/trade-statistics_en.pdf [2019-05-14]

European Commission (2017). "The end of the sugar production quotas in the EU". European Commission website. Available at: http://europa.eu/rapid/press-release_MEMO-17-3488_en.htm [2019-05-14]

Fairtrade (2019). "Sugar". Fairtrade website. Available at: https://www.fairtrade.net/products/sugar.html [2019-05-14]

Fairtrade (2015). *Sugar crash – how EU reform is endangering the livelihoods of small farmers.* London: Fairtrade Foundation. http://www.fairtrade.org.uk/~/media/fairtradeuk/what%20is%20fairtrade/documents/policy%20and%20research%20documents/policy%20reports/faitrade%20foundation%20sugar%20crash%20report.ashx

Fammler, H., Weber, H. S., Fawzy, T., Kuris, M., Remmelgas, L., Veidemane, K., ... & Piwowarczyk, J. (2018). *The story of eutrophication and agriculture of the Baltic Sea*. Baltic Environmental Forum, GRID-Arendal, Institute of Oceanology Poland. https://www.responseable.eu/wp-content/uploads/key-story-eutrophication-0518.pdf

Fitzherbert, E. B., Struebig, M. J., Morel, A., Danielsen, F., Brühl, C. A., Donald, P. F., & Phalan, B. (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology and Evolution*, 23(10), 538-545. https://doi.org/10.1016/j.tree.2008.06.012

Food and Agriculture Organization of the United Nations FAO (2019). FAO website. Available at: http://www.fao.org/faostat/en/#data [2019-05-14]

Food and Agriculture Organization. (2004). *Human energy requirements: Report of a Joint FAO/WHO/UNU Expert Consultation.* Rome, 17-24 October 2001. In Food and Nutrition Technical Report Series. http://www.fao.org/3/a-y5686e.pdf

Gabarron-Galeote, M. A., Hannam, J. A., Mayr, T., & Jarvis, P. J. (2019). BEETSOIL: a decision support tool for forecasting the impact of soil conditions on sugar beet harvest. *Soil and Tillage Research*, 191, 131-141. https://www.sciencedirect.com/science/article/pii/S0167198718302605

Grassi, G., House, J., Dentener, F., Federici, S., Den Elzen, M., & Penman, J. (2017). The key role of forests in meeting climate targets requires science for credible mitigation. *Nature Climate Change*, 7, 220-226. https://doi.org/10.1038/nclimate3227

Guh, D.P., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C.L. and Anis, A.H., 2009. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC public health*, 9(1), p.88. https://doi.org/10.1186/1471-2458-9-88

Hallström, E., Röös, E., & Börjesson, P. (2014). Sustainable meat consumption: A quantitative analysis of nutritional intake, greenhouse gas emissions and land use from a Swedish perspective. *Food Policy*, 47, 81-90. https://doi.org/10.1016/j.foodpol.2014.04.002

Hess, T. M., Sumberg, J., Biggs, T., Georgescu, M., Haro-Monteagudo, D., Jewitt, G., … Knox, J. W. (2016). A sweet deal? Sugarcane, water and agricultural transformation in Sub-Saharan Africa. *Global Environmental Change*, 39, 181-194. https://doi.org/10.1016/j.gloenvcha.2016.05.003

Hoegh-Guldberg, O., D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K.L. Ebi, F. Engelbrecht, J.Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S.I. Seneviratne, A. Thomas, R. Warren, and G. Zhou, 2018: Impacts of 1.5ºC Global Warming on Natural and Human Systems. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I.Gomis, E. Lonnoy, T.Maycock, M.Tignor, and T. Waterfield (eds.)]. 175-311. In Press. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter3_Low_Res.pdf

Holden, J. & McGuire, P. (2014). *Irrigation of sugarcane Manual.* Australia. Sugar Research Australia Ltd 2014 BSES Limited. MN14002. https://sugarresearch.com.au/wp-content/uploads/2017/02/Irrigation-Manual-F-LowRes2.pdf

Hossain, P., Kawar, B., & El Nahas, M. (2007). Obesity and diabetes in the developing world—a growing challenge. *The New England Journal of Medicine*, 356, 213-215. January 18. https://www.nejm.org/doi/full/10.1056/NEJMp068177

International Sugar Organization (2018). International Sugar Organization website: Cane and Beet. Available at: https://www.isosugar.org/sugarsector/cane-and-beet [2019-05-27]

Kihlberg, M. (2005). Sockerreform drabbar odlare i tredje världen. Sveriges Radio, November 25. Available at: https://sverigesradio.se/sida/artikel.aspx?programid=83&artikel=741869 [2019-05-23]

Klenk, I., Landquist, B., Ruiz de Imaña, O. (2012). The Product Carbon Footprint of EU Beet Sugar. *Sugar Industry Journal*, 137(62), 169-177. https://www.academia.edu/4006729/The_Product_Carbon_Footprint_of_EU_Beet_Sugar_2012_

Kuemmerle, T., Levers, C., Erb, K., Estel, S., Jepsen, M. R., Müller, D., ... & Reenberg, A. (2016). Hotspots of land use change in Europe. *Environmental Research Letters*, 11(6), 1-14. https://iopscience.iop.org/article/10.1088/1748-9326/11/6/064020/pdf

Lana, M. & Wurbs, A. (2017). *Recommendations for sugarcane residues application*. Müncheberg. PURESBio. Report AP 7.

Leblois, A., Damette, O., & Wolfersberger, J. (2017). What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data. *World Development*, 92, 82-102. https://doi.org/10.1016/j.worlddev.2016.11.012

Machovina, B., Feeley, K. J., & Ripple, W. J. (2015). Biodiversity conservation: The key is reducing meat consumption. *Science of the Total Environment*, 536, 419-431. https://doi.org/10.1016/j.scitotenv.2015.07.022

Meadows, DH., Goldsmith, E. I., & Meadows, D. (1972). *The Limits to Growth*. New York, Universe.

Meadows, D. H., Meadows, D. L., & Randers, J. (1992). *Beyond The Limits To Growth*: *global collapse or a sustainable future.* London, Earthscan Publications Ltd.

National Food Agency (2019). Socker. Available at: https://www.livsmedelsverket.se/livsmedel-och-innehall/naringsamne/kolhydrater/socker [2019-05-23]

Netafim (2019). "Soil requirements". Netafim website. Available at: http://www.sugarcanecrops.com/soil_requirement/ [2019-05-14]

Nordic Council of Ministers. (2014). *Nordic Nutrition Recommendations 2012: integrating nutrition and physical activity.* Copenhagen, Nordic Council of Ministers. Nord 2014:002. https://www.livsmedelsverket.se/globalassets/publikationsdatabas/andra-sprak/nordic-nutrition-recommendations-2012.pdf

Nordic Sugar (2019). "Jord och näring". Nordic Sugar website. Available at: https://www.nordicsugar.se/kann-ditt-socker/naturens-sotma/saker-och-effektiv-betodling/jord-och-naring/ [2019-05-14]

Nordic Sugar (2018). "Ökad lönsamhet med sockerbetor i växtföljden". Nordic Sugar website. Available at: https://www.sockerbetor.nu/cps/rde/xchg/SID-A67177A3-D13F8CF1/agriportal/hs.xsl/11812.htm [2019-05-14]

Phillips, L. (2018). Smarter ways to irrigate sugar cane. *Farmer's weekly*, March 30.

Pidgeon, J. D., Werker, A. R., Jaggard, K. W., Richter, G. M., Lister, D. H., & Jones, P. D. (2001). Climatic impact on the productivity of sugar beet in Europe, 1961-1995. *Agricultural and Forest Meteorology*, 109(1), 27-37. https://doi.org/10.1016/S0168-1923(01)00254-4

Rein, P. (2010). The Carbon Footprint of Sugar. *Zuckerindustrie*. *Sugar Industry*, 135(7), 427-434. https://www.researchgate.net/publication/290806471_The_carbon_foot-print_of_sugar

Renouf, M. A., & Wegener, M. K. (2007, January). Environmental life cycle assessment (LCA) of sugarcane production and processing in Australia. In *Proceedings of the Australian Society of Sugar Cane Technologists,* 29, 385-400. https://www.fcrn.org.uk/research-library/environmental-life-cycle-assessment-lca-sugarcane-production-and-processing

Rochette, P., Liang, C., Pelster, D., Bergeron, O., Lemke, R., Kroebel, R., ... & Flemming, C. (2018). Soil nitrous oxide emissions from agricultural soils in Canada: exploring relationships with soil, crop and climatic variables. *Agriculture*, *Ecosystems & Environment*, 254, 69-81. https://www.sciencedirect.com/science/article/pii/S016788091730467X

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, 461, 472-475. https://doi.org/10.1038/461472a

Rûdelsheim, P. L., & Smets, G. (2012). *Baseline information on agricultural practices in the EU.* Brussels. Perseus. https://www.europabio.org/sites/default/files/120605_report_eu_farming_practices_potato.pdf

Smith, K. A. (2017). Changing views of nitrous oxide emissions from agricultural soil: key controlling processes and assessment at different spatial scales. *European journal of soil science*, 68(2), 137-155. https://doi.org/10.1111/ejss.12409

Statistics Sweden (2019). SCB database: Jordbruksföretag efter län/riket och storleksklass. År 1981-2000, 2003- 2007. Available at: http://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__JO__JO0106/ForetagStorlekL/?rxid=19fbf2a4-9ed6-44ef-bb05-5f7e7d8a8e51 [2019-05-24]

Swedish Board of Agriculture (2019). Jordbruksverket website: "Jordbruksmarkens användning". Available at: http://www.jordbruksverket.se/omjordbruksverket/statistik/statistikomr/arealer/arkivstatistikarealer.4.67e843d911ff9f551db80003362.html [2019-05-27]

Swedish Board of Agriculture (2016). *Methods in Swedish sugar consumption statistics*. Sweden. Statens Jordbruksverk. 2016:02. http://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Livsmedel/Statistikrapport2016_02/201602..pdf

Swedish Board of Agriculture (2018). *Sveriges utrikeshandel med jordbruksvaror och livsmedel 2015-2017*. Sweden. Statens jordbruksverk. 2018:28. http://www.jordbruksverket.se/download/18.4be8ed94167c5303a16c028/1545213525047/Sveriges%20utrikeshandel%20med%20jordbruksvaror%20och%20livsmedel%202015-2017.pdf

Swedish Board of Agriculture (2012). *Yearbook of Agricultural Statistics*. Örebro. SCB-Tryck. https://www.jordbruksverket.se/download/18.50fac94e137b680908480004062/1370043498385/1_Historisk%20jordbruksstatistik.pdf

Swedish Board of Agriculture (2018). *Agricultural Statistics 2018 including food statistics – tables*. Örebro. SCB. https://www2.jordbruksverket.se/download/18.25e61c93165e6d4904743531/1537271565516/JS_2018v2.pdf

Tsiafouli, M.A., Thébault, E., Sgardelis, S.P., De Ruiter, P.C., Van Der Putten, W.H., Birkhofer, K., Hemerik, L., De Vries, F.T., Bardgett, R.D., Brady, M.V. and Bjornlund, L., 2015. Intensive agriculture reduces soil biodiversity across Europe. *Global change biology*, 21(2), 973-985. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.12752

United Nations. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables.* New York. United Nation: Department of Economic and Social Affairs, Population Division. ESA/P/WP/248. https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf

United States Department of Agriculture USDA (2018). Basic report: 19335, Sugars, granulated. National Nutrient Database for Standard Reference, USDA website. Available at:
https://ndb.nal.usda.gov/ndb/foods/show/19335?fgcd=&manu=&format=&count=&max=25&offset=&sort=default&order=asc&qlookup=19335&ds=&qt=&qp=&qa=&qn=&q=&ing [2019-06-24]

World Bank (2019). World Bank Database. “Rural population”. Available at: https://data.worldbank.org/indicator/SP.RUR.TOTL?locations=XL [2019-05-21]

World Health Organization. (2015). *Guideline: Sugars intake for adults and children*. Geneva. World Health Organisation. https://apps.who.int/iris/bitstream/handle/10665/149782/9789241549028_eng.pdf;jsessionid=2C75F737D6934D65EAB508E16A29B088?sequence=1

World Poverty Clock (2019). World Poverty Clock website. Available at: https://worldpoverty.io/?utm_source=google&utm_medium=search&utm_campaign=Worldpovertyclock&campaignid=1695797724&adgroupid=71780550171&adid=329359359825&gclid=Cj0KCQjww47nBRDlARIsAEJ34bnPmEeWvKUig8d0eFfmGgRH9k5MecYRHw1D6TtYr5N41W2BXnETbiIaArtbEALw_wcB [2019-05-21]

Yamane, T., Curley, R., Etheredge, L., Lotha, G., Petruzzello, M., Sampaolo, M. (2016). Sugar beet. Encyclopaedia Britannica website. Available at: https://www.britannica.com/plant/sugar-beet [2019-05-14]

Zhang, Z., Lohr, L., Escalante, C., & Wetzstein, M. (2010). Food versus fuel: What do prices tell us? *Energy Policy*, 38(1), 445-451. https://doi.org/10.1016/j.enpol.2009.09.034

Öborn, I., Bengtsson, J., Hedenus, F., Rydhmer, L., Stenström, M., Vrede, K., Magnusson, U. (2013). Scenario development as a basis for formulating a research program on future agriculture: A methodological approach. *Ambio*, 42(7), 823-839. https://doi.org/10.1007/s13280-013-0417-3

5.1 Unpublished material

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7 Appendix

Appendix I

Table A: Table of standard values of sugar content for products which are a part of Swedish import and export. (Own categorisation of data from Jordbruksverket).

KN numbers	Suger content (%)	Cate-gory	KN numbers	Sugar content (%)	Cate-gory	KN numbers	Sugar content (%)	Cate-gory
2007:10:99	5	F	2008:50:19	20	P	2008:99:43	15	Q
2007:91:10	55	F	2008:50:31	5	P	2008:99:45	15	Q
2007:91:30	20	N	2008:50:39	5	P	2009:31:11	30	R
2007:91:90	20	N	2008:50:51	20	P	2009:31:51	30	R
2007:99:10	55	N	2008:50:59	5	P	2009:31:91	30	R
2007:99:20	55	N	2008:50:61	20	P	2009:39:11	30	R
2007:99:31	55	N	2008:50:69	5	P	2009:39:19	30	R
2007:99:33	55	N	2008:50:71	20	P	2009:39:31	30	R
2007:99:35	55	N	2008:93:11	20	P	2009:39:51	49	R
2007:99:39	55	N	2008:93:19	20	P	2009:39:55	12	R
2007:99:50	20	N	2008:93:21	5	P	2009:39:91	49	R
2007:99:93	5	N	2008:93:29	5	P	2009:39:95	12	R
2007:99:97	5	N	2008:93:91	15	P	2009:41:92	30	R
2008:11:10	5	N	2008:93:93	15	P	2009:49:11	30	R
2008:20:11	20	O	2008:97:03	15	Q	2009:49:19	30	R
2008:20:19	10	O	2008:97:05	15	Q	2009:49:30	30	R
2008:20:31	20	O	2008:97:12	20	Q	2009:49:91	49	R
2008:20:39	10	O	2008:97:14	20	Q	2009:49:93	12	R
2008:20:51	20	O	2008:97:16	20	Q	2009:50:10	30	R
2008:20:59	10	O	2008:97:18	20	Q	2009:61:10	30	R
2008:20:71	20	O	2008:97:32	5	Q	2009:61:90	30	R
2008:20:79	15	O	2008:97:34	5	Q	2009:69:11	30	R
2008:30:11	15	P	2008:97:36	5	Q	2009:69:19	30	R
2008:30:19	15	P	2008:97:38	5	Q	2009:69:51	30	R
2008:30:31	5	P	2008:97:51	15	Q	2009:69:59	30	R
2008:30:39	5	P	2008:97:59	15	Q	2009:69:71	49	R
2008:30:51	15	P	2008:97:72	15	Q	2009:69:79	49	R
2008:30:55	15	P	2008:97:74	15	Q	2009:69:90	12	R

2008:30:59	15	P	2008:97:76	15	Q	2009:71:20	30	R
2008:30:71	15	P	2008:97:78	15	Q	2009:79:11	30	R
2008:30:75	15	P	2008:99:11	15	Q	2009:79:19	30	R
2008:30:79	15	P	2008:99:19	15	Q	2009:79:30	30	R
2008:40:11	20	P	2008:99:21	20	Q	2009:79:91	49	R
2008:40:19	20	P	2008:99:23	5	Q	2009:89:36	30	R
2008:40:21	5	P	2008:99:24	20	Q	2009:89:38	30	R
2008:40:29	5	P	2008:99:28	20	Q	2009:89:50	30	R
2008:40:31	20	P	2008:99:31	20	Q	2009:89:61	49	R
2008:40:39	5	P	2008:99:34	20	Q	2009:89:63	12	R
2008:40:51	20	P	2008:99:36	5	Q	2009:89:71	30	R
2008:40:59	10	R	2008:99:37	5	P	2009:89:73	30	R
2008:40:71	20	R	2008:99:38	5	P	2009:89:79	30	R
2008:40:79	10	R	2008:99:40	5	P	2009:89:85	49	R
2008:50:11	20	R	2008:99:41	15	P	2009:89:86	49	R
2009:89:88	12	R	2008:60:39	5	P	2009:81:51	49	R
2009:89:89	12	R	2008:60:50	15	P	2009:81:59	12	R
2009:90:11	30	R	2008:60:60	15	P	2009:89:11	30	R
2009:90:19	30	R	2008:70:11	20	P	2009:89:19	30	R
2009:90:21	30	R	2008:70:19	20	P	2009:89:34	30	R
2009:90:29	30	R	2008:70:31	5	P	2009:89:35	30	R
2009:90:31	49	R	2008:70:39	5	P	0402:10:91	35	V
2009:90:39	12	R	2008:70:51	20	P	0402:10:99	35	V
2009:90:41	30	R	2008:70:59	20	P	402:29:11	35	V
2009:90:51	30	R	2008:70:61	20	P	402:29:15	35	V
2009:90:71	49	R	2008:70:69	10	P	402:29:19	35	V
2009:90:73	12	R	2008:70:71	20	P	0402:29:91	35	V
2009:90:92	49	R	2008:70:79	10	P	0402:29:99	35	V
2009:90:94	49	R	2008:80:11	20	P	0402:99:10	43	V
2009:90:95	12	R	2008:80:19	20	P	0402:99:31	43	V
2009:90:96	12	R	2008:80:31	5	P	0402:99:39	43	V
811:10:11	20	S	2008:80:39	5	P	0402:99:91	43	V
811:10:19	10	S	2008:80:50	15	P	0402:99:99	43	V
811:20:11	20	S	2008:80:70	15	P	403:10:31	10	V
811:20:19	10	S	2008:91:00	15	P	403:10:33	10	V
0811:90:11	20	S	2008:99:48	15	P	403:10:39	10	V
0811:90:19	20	S	2008:99:49	15	P	403:10:51	35	V
0811:90:31	5	S	2008:99:51	15	P	403:10:53	35	V
0811:90:39	5	S	2008:99:63	15	P	403:10:59	35	V

2001:10:00	5	T	2008:99:67	15	P	0403:10:91	10	V
2001:90:40	5	T	2009:11:11	30	R	0403:10:93	10	V
2001:90:50	5	T	2009:11:19	30	R	0403:10:99	10	V
2001:90:65	5	U	2009:11:91	49	R	0403:90:31	35	V
2001:90:70	5	U	2009:11:99	12	R	0403:90:33	35	V
2001:90:92	5	U	2009:12:00	30	R	0403:90:39	35	V
2001:90:97	5	U	2009:19:11	30	R	0403:90:61	10	V
2006:00:10	45	U	2009:19:19	30	R	0403:90:63	10	V
2006:00:31	57	P	2009:19:91	49	R	0403:90:69	10	V
2006:00:35	57	P	2009:19:98	12	R	0403:90:71	35	V
2006:00:38	35	P	2009:21:00	30	R	0403:90:73	35	V
2006:00:91	5	P	2009:29:11	30	R	0403:90:79	35	V
2006:00:99	5	P	2009:29:19	30	R	0403:90:91	10	V
2007:10:10	20	N	2009:29:91	49	R	0403:90:93	10	V
2007:10:91	5	N	2009:29:99	12	R	0403:90:99	10	V
2008:50:79	10	P	2009:79:98	12	R	404:10:26	10	W
2008:60:11	20	P	2009:81:11	30	R	404:10:28	10	W
2008:60:19	20	P	2009:81:19	30	R	404:10:32	10	W
2008:60:31	5	P	2009:81:31	30	R	404:10:34	10	W
404:10:36	10	W	1704:90:30	45	Å	1806:10:15	4	A
404:10:38	10	W	1704:90:51	60	AB	1806:10:20	60	A
0404:10:72	10	W	1704:90:55	60	Z	1806:10:30	75	A
0404:10:74	10	W	1704:90:61	60	Å	1806:10:90	90	A
0404:10:76	10	W	1704:90:65	60	AC	1806:20:10	35	B
0404:10:78	10	W	1704:90:71	60	Å	1806:20:30	35	B
0404:10:82	10	W	1904:90:10	10	AD	1806:20:50	35	B
0404:10:84	10	W	1904:90:80	10	AE	1806:20:70	35	B
0404:90:81	10	V	1904:90:90	10	AE	806:20:80	35	B
0404:90:83	10	V	1905:10:00	3	AF	1806:20:95	35	B
2105:00:10	20	X	1905:20:10	25	AG	1806:31:00	35	B
2105:00:91	20	X	1905:20:30	45	AG	1806:32:10	35	B
2105:00:99	20	X	1905:20:90	65	AG	1806:32:90	35	C
0404:90:89	10	V	1905:31:11	27	AG	1806:90:11	10	C
1704:90:75	60	Y	1905:31:19	27	AG	1806:90:19	35	C
1704:90:81	60	Z	1905:31:30	27	AG	1806:90:31	35	C
1704:90:99	60	Å	1905:31:91	27	AG	1806:90:39	35	C
1806:10:10	60	Å	1905:31:99	27	AG	1806:90:60	35	D
1806:90:50	35	Å	1905:32:05	27	AG	1806:90:70	35	D
2106:90:30	10	Ä	1905:32:11	27	AG	1806:90:90	30	D

2106:90:51	10	Ä	1905:32:19	27	AG	2101:12:92	20	E
2106:90:55	10	Ä	1905:32:91	27	AG	2101:12:98	20	E
2106:90:59	55	Ä	1905:32:99	27	AG	2101:20:20	20	F
409:00:00	75	Ö	1905:40:10	13	AH	1905:90:10	4	AJ
1704:10:10	58	Ö	1905:40:90	13	AH	1905:90:30	4	AJ
1704:10:11	58	Ö	1704:10:19	58	Ö	1704:10:90	70	Ö
1704:10:91	70	Ö	1704:10:99	70	Ö	1905:90:45	10	AJ
1905:90:55	10	AJ	1905:90:60	35	AJ			

Table B: Categorisation of product groups and their mean sugar content. The total amount of imported and exported goods in 2017 and the total amount of sugar import and export based on average values of sugar content.

Category	**Product group**	**Mean sugar content (%)** (a)	**Import (tonnes)** (b)	**Import sugar (tonnes)** (c) c=(a/100)*b	**Export (tonnes)** (d)	**Export sugar (tonnes)** (e) e=(a/100)*d
A	Cocoa mixes	57	1744	998.44	1444	826.69
B	Baking chocolate	35	39498	13824.3	29371	10279.85
C	Chocolate confect	30	20444	6133.2	15791	4737.3
D	Other cocoa products	34	13644	4604.85	25466	8594.775
E	Coffee essences	20	6421	1284.2	4935	987
F	Tea and extract	20	4873	974.6	1235	247
G	Flour mixes	20	24352	4755.9456	21888	4274.726
H	Malt extract	18	2542	444.85	116	20.3
I	Tomato sauces	16	57068	8845.54	29673	4599.315
J	Other sauces	12	14018	1682.16	16720	2006.4
K	Soups and bouillions	3	22830	684.9	5073	152.19
L	Alcoholic beverages	16	14425	2322.425	125266	20167.83
M	Non-alcoholic beverages	6	269925	14845.875	94028	5171.54
N	Jam	32	14479	4681.0607	8426	2724.126
O	Conserved pineapple	16	10299	1609.2188	529	82.65625

P	Other conserved fruit	15	22905	3447.2025	2107	317.0403
Q	Fruit and nuts mixes	14	21219	2917.6125	2638	362.725
R	Lemonade	30	122039	37136.468	17965	5466.75
S	Frozen berries	14	31913	4388.0375	16782	2307.525
T	Pickled vegetables	5	11486	574.3	2063	103.15
U	Other pickled products	5	11690	584.5	212	10.6
V	Milk products	19	147852	27500.472	119609	22247.27
W	Whey products	10	53667	5366.7	46802	4680.2
X	Ice cream	20	26147	5229.4	16781	3356.2
Y	Toffee	60	5759	3455.4	1975	1185
Z	Pastils	60	847	508.2	31	18.6
Å	Other sugar confectionaries	40	22492	8996.8	11754	4701.6
Ä	Syrup	21	37328	7932.2	19335	4108.688
Ö	Chewing gum	64	761	487.04	143	91.52
AB	Almond paste	60	1777	1066.2	1467	880.2
AC	Wine gum	60	36804	22082.4	18955	11373
AD	Rice mixes	10	1493	149.3	1168	116.8
AE	Baking mixes	10	5230	523	597	59.7
AF	Crisp bread	3	7521	225.63	24334	730.02
AG	Sweet biscuits	31	23869	7435.1935	31404	9782.346
AH	Crusts	13	2141	278.33	8241	1071.33
AJ	Other bread and pastry	14	120922	17231.385	89681	12779.54
AK	Honey	75	4890	3667.5	191	143.25
	Total pro-cessed food			228875		150765
AL	Raw sugar, white sugar	100	62332	62332	76064	76064
TOTAL				291207		226829

Table C: The most important categories for the Swedish sugar import via processed food. Top five exporters for each product group (when all the top five countries are EU nations, they are indicated with the number (5)).

Category	Top 5 countries	Part of cane sugar (p)	Import (mkr)	Part of all sugar import per category (c) (c=a/b)	Total imported sugar for each category (tonnes) (d)	Amount of sugar from each country (tonnes) (e) (e=c*d)	Amount cane sugar from each country (tonnes) (f) (f=p*e)
R	EU (5)	0.067	-	-	37136	-	2488.112
V	EU (5)	0.067	-	-	27500	-	1842.5
Å	EU (5)	0.067	-	-	31079	-	2082.293
AJ	EU (5)	0.067	-	-	24666	-	1652.622
M	EU (5)	0.067	-	-	14846	-	994.682
B	EU (5)	0.067	-	-	13824	-	926.208
I	EU (4)	0.067	767.9	0.821	-	7268.182538	486.96823
	USA	0.5	166.7 (a)	0.179	-	1577.817462	788.908731
	Total	-	934.6 (b)	1	8846	-	1275.877
Ä	EU (4)	0.067	577.6	0.834	-	6617.829265	443.3945607
	Paraguay	1	114.7 (a)	0.166	-	1314.170735	1314.170735
	Total	-	692.3 (b)	1	7932	-	1757.565
SUM							26039.72

Table D: The most important categories for the Swedish sugar import via processed food (representing 72 percent of all). The sugar from EU countries is assumed to originate from canes to 6.7 percent. The content of cane sugar varies in countries outside the EU. For the US sugar import, approximately 50 percent is cane sugar, whereas all the sugar from Paraguay comes from canes.

Product groups	Sugar import through processed food (tonnes) (a)	Cane sugar import from EU (tonnes) (b) (b=0.067*a)	Cane sugar from other countries (tonnes) (c)	Total import of cane sugar through processed food (tonnes) (d) (d=b+c)
R	37136	2488.112	0	2488.112
V	27500	1842.500	0	1842.500
Å	31079	2082.293	0	2082.293

AJ	24666	1652.622	0	1652.622
M	14846	994.682	0	994.682
B	13824	926.208	0	926.208
I	8846	486.968	788.908731	1275.877
Ä	7932	443.395	1314.170735	1757.565
TOTAL	165829	10916.77979	2103.079466	13019.860

Part cane sugar of imported sugar through processed food (main categories): 13019.86 tonnes/165829 tonnes=0.0785 (=8%)
Overall import of cane sugar through processed food: 0.0785*291200 tonnes=22860 tonnes

Table E: Corresponding land-use

	Amount 2017 (tonnes) a	Average sugar content in crop (%) b	Average crop yield (tonnes per ha) c	Average sugar yield (tonnes per ha) d	Land use (ha), whole population e=a/d e	Land use (ha), per capita f=e/10230185 f
Swedish production (beet sugar)	306 906	8-22[1]	63.8[2]	9.96[3]	30 814	
Beet sugar export	226 800	8-22	63.80	9.96	22 771	
Beet sugar import	268 300	8-22	79.2[4]	12.7[3]	21 126	
Cane sugar import	22 860	7-18[1]	70.9[4]	6.7*	3412	
Swedish consumption (prod+imp-exp)	371 266	-	-	-	32 581	0.0032
Swedish Consumption (according to Jordbruksverket)	380 000**			11.395**	33 348**	0.0033

Source: 1) Britannica, 2) Own calculations, see Appendix I, 3) European Commission, 4) FAO (Yield EU and World):

*Global cane production (2014) 1.88*10^9 tonnes
Global sugar production (2014) 1.77*10^8 tonnes
Global yield of canes/ha: 70.9 tonnes/ha
Global yield of sugar/ha: 70.9/(1.88*10^9/1.77*10^8)=6.6622 tonnes/ha

**To compare with 380 000 tonnes, which is the approximate consumption according to statistics from Jordbruksverket, based on a yearly consumption of 37.5 kg per capita and a population of 10 230 285 inhabitants. Assuming the average sugar yield is the same (371200/32548=11.395 tonnes/ha), the corresponding land use is 33348 hectares.

Appendix II

Scenario 3: adjusting Swedish sugar consumption to close the gap to production

Adjusted consumption: 306906/10230185=0.03000 tonnes/person=30.0 kg/person

Table F: Statistics on the age of Swedish population

Age	**Men**	**Women**
15-19	293802	265711
20-24	311168	286425
25-29	380948	360374
30-34	354455	335686
35-39	328012	312107
40-44	323915	311921
45-49	333690	324649
50-54	349187	338662
55-59	302734	296233
60-64	282697	282369
65-69	271523	277788
70-74	275471	288177
75-79	190937	209682
80-84	115206	146321
85-89	62775	99528
90-94	24347	51900
95-99	4994	14995
100+	362	1705
Total	10230185	
Adults (20+)	7850943	

Source: Statistics Sweden

Table G: Statistics on the mean height and weight of the Swedish population in 2011

	Mean height (cm)	Margin	Mean weight (kg)	Margin
Men 16+	179,4	± 0,2	82,9	± 0,4
Women 16+	165,7	± 0,2	67,4	± 0,3

Source: Statistics Sweden (Medelvärden av längd, vikt och BMI)

Table H: Statistics on mean values of energy requirements for men 85 kg and women 65 kg. A moderately active lifestyle is assumed.

	Energy requirement (kcal) a	Recommended max. value of sugar intake (kcal) 0.10*a
Men 18-29	3450	-
Men 30-59	3250	-
Men 60+	2750	-
Men, average	3150	315
Women 18-29	2550	-
Women 30-59	2400	-
Women 60+	2200	-
Women, average	2383	238

Source: FAO. Recommend intake based on the WHO guidelines saying that no more than 10 percent of the daily energy intake should be white sugar.

Number of calories per unit sugar (according to USDA): 387 kcal per 100 g sugar=3.87 kcal/g

Table I: Calculations of the maximal sugar intake for men and women according to the recommendations from WHO. Sugar consumption per capita and whole population (10230185 people). Corresponding land-use based on a sugar yield of 10.0 tonnes per hectare.

	Sugar (g) per capita and day a=(kcal/3.87)	Sugar (kg) per capita and year b=(a*365)/1000	Sugar (1000 tonnes), whole population c=(b*10230185)/1000	Land-use, whole pop. (1000 ha) e=c/10
Men (315 kcal)	81.4	29.7	-	-
Women (238 kcal)	61.5	22.4	-	-
Mean men+women	71.4	26.1	267 000	26.7

Table J: Calculations of the maximal sugars intake for men and women according to the recommendations from Livsmedelsverket. Corresponding land-use based on a sugar yield of 10.0 tonnes per hectare.

	Sugar (g) per capita and day a	Sugar (kg) per capita and year $b=(a*365)/10^3$	Land use (m^2) $c=(b/10^3)/(10/10^4)$	Sugar (1000 tonnes), whole population $d=(b*10230185)/10^6$	Land use (1000 ha) e=d/10
Men	75.0	27.4		-	-
Women	50.0	18.3		-	-
Mean Men+women	62.5	22.8	22.8	233	23.3