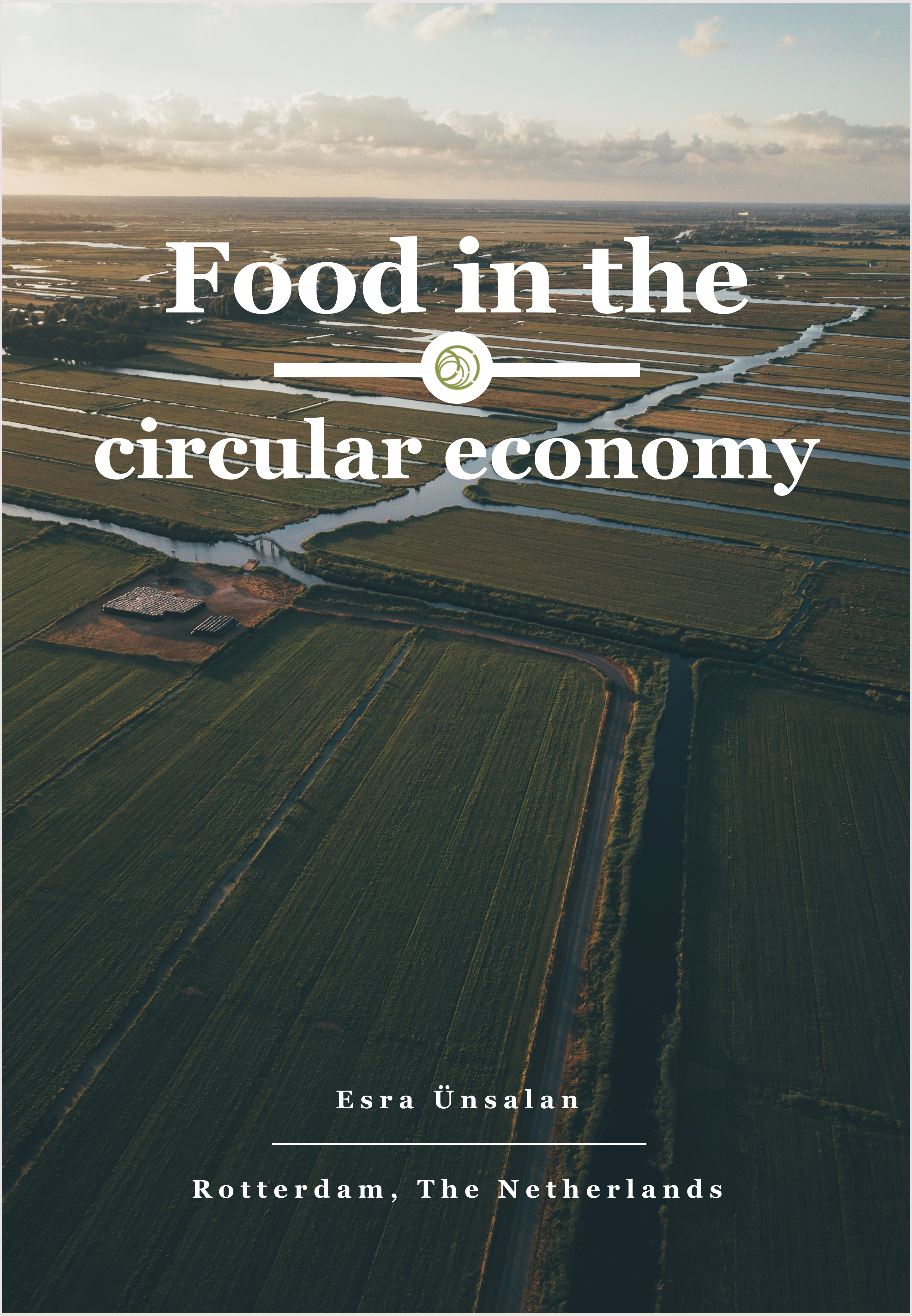

Food in the circular economy

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For the Hogeschool Rotterdam

Minor Circular Economy & Business Innovation

Cover design Esra Ünsalan

Photo credit Ben den Engelsen

January 2019

Rotterdam, the Netherlands

Introduction

The effects of climate change are being noticed all around the globe; through manifestations of extreme weather such as extremely high or low temperatures, heavy rainfall and drought, through rising ocean temperatures and through rising sea levels caused by the melting of the arctic regions.

The majority of these effects have been caused by rising CO_2 levels, which can be attributed to human influences. Since the beginning of the Industrial Revolution, global CO_2 levels have rapidly increased. This revolution has caused great welfare for many people, but has failed to respect our planetary boundaries. As the world population is expected to increase to 10 billion people by 2050, there is global concern for the prosperity of the planet, humans and animals. How can 10 billion people be fed in such a way that respects our planetary boundaries?

This book is an introductory guide for those with an interest in circular economy and the food industry. In this book, I outline the problems that the industrial food system has caused with scientific facts. Afterward, I will outline my vision of a circular food system and solutions based on those principles. The main focus of this publication is a global one, although in some cases specific Dutch information has been provided. This is due to the fact that local issues or solutions play a bigger part in the grand scheme of things.

In the first chapter, I will elaborate on the problems that cause climate and the impacts these have on a global and local scale. In the second chapter, the failings of the current food system are described with the three main systemic problems: the industrial food system contributes to environmental degradation, it is wasteful and it is not resilient and does not produce healthy outcomes. Afterwards, a conclusion of the failings of the linear food system is presented in the fourth chapter, which leads up to the posed solution. In the fourth chapter, the principles of the circular economy are provided and the vision for a circular food system is described in chapter five. The ways in which to achieve this vision is presented in chapter six. Lastly, a conclusion of my cases is provided in chapter seven.

Table of contents

Introduction 3

Definitions 5

1. Climate change on a global and local scale 6

2. Failings of the Industrial Food System 7

2.1 The Industrial Food System contributes to environmental degradation 8

2.2 The system is wasteful 13

2.3 The system is not resilient and does not produce healthy outcomes 14

3. Failings of the linear food system 15

4. The Circular Economy 16

5. A Circular Food System 17

7. Conclusion 22

References 23

Picture credits 27

Definitions

Aerosols

In this publication, aerosols refer to atmospheric aerosols. Atmospheric aerosols are tiny particles in the atmosphere that reflect sunlight.

Agro ecology

Agro ecology is the adaptation of agriculture to natural conditions and cycles, as well as to local needs.

Biodiversity

Biodiversity is the variation in organisms as a whole, including terrestrial, marine and other aquatic ecosystems and the ecological connections that they are a part of.

Food security

By food security, the plenty availability of food, qualitatively and quantitatively, against fair prices is meant.

Ecosystem services

The benefits that people have due to ecosystems. This includes supply services such as food, water, regulating services such as the control of floods and diseases; cultural services such as spiritual, recreational- and cultural benefits; and supportive services such as the food chain that maintains the conditions of life on earth.

Externalities

An externality is a positive or negative consequence of an economic activity that has an impact on unrelated parties. An example of a negative externality is pollution of a factory that impacts the health of the surrounding residents and the environment.

GHG

Stands for green house gas. These are gasses such as Carbon Dioxide, Nitrogen and Methane that contribute to global warming.

Ruminant

A ruminant is a type of animal that brings up food from its stomach and chews it again, for example a cow, sheep, or deer.

Topsoil

Topsoil is the upper layer of soil that has the highest concentration of organic matter and microorganisms and most of the Earth's biological soil activity occurs here. The layer is roughly 13 to 25 cm thick.

1. Climate change on a global and local scale

Climate change is a phenomenon that most people are probably familiar with. For those of you that aren't, climate change refers to any long-term trends or shifts in climate over many decades, around which climate variability is evident year to year (Healey, 2014). There is a great amount of evidence that suggests that the Earth's climate has warmed over the past century, due to both natural and anthropogenic (human) influences. There is much consensus between scientists that the Earth has warmed since the end of the Little Ice Age (1300–1850) when the amount of carbon dioxide in the atmosphere began to increase. This occurred at roughly the same time as the beginning of the Industrial Revolution (Philander, 2012).

The most profound and well-known anthropogenic influence is the rise of concentrations of greenhouse gases in the atmosphere, due to the increased use of nitrous oxide (in artificial fertilizers) and the burning of fossil fuels. Another human influence is the altering of concentrations of aerosols and ozone and modifying the land cover of the Earth's surface. Land management for food production and cutting down rainforests (in many cases for food production as well) is in most cases the reason for changing the Earth's land cover (Philander, 2012).

The impact of climate change is already being noticed worldwide as well as in the Netherlands. Over the last 100 years, the temperature worldwide has increased with 0.8 degrees and with 1.7 degrees in the Netherlands. Since 1950, the temperature in the Netherlands rose twice as fast as the world average. Furthermore, the amount of extremely hot days per year has increased by 19, and the amount of extremely cold days per year has decreased by 17 since 1950. Additionally, the annual amount of rainfall has increased with over 20% in the last 20 years and the intensity of rainfall has increased as well. These changes in weather and climate already have a negative impact on agriculture: specifically on yields. Last year, farmers experienced low yields on potatoes due to extreme drought (PBL, 2012; de Zwaan, 2018).

After the United States, the Netherlands is the biggest exporter of agricultural produce in the world. The Dutch agricultural sector exports roughly € 65 billion of agricultural produce annually. This makes up 17.5% of Dutch exports in total. One quarter of the agricultural produce is exported to Germany, the largest trade partner of The Netherlands. Accounting for 10% of the Dutch economy, the agricultural and horticultural sectors play a crucial role. 2.5% of employment is in agriculture and 1.5 % in the food industry (the Dutch Government, 2019a).

2. Failings of the Industrial Food System

Over the last 100 years, the agricultural system has been disrupted by several technologies that have transformed our food supply completely. Whereas food supply used to be from local farms that served local markets, it has become a vast global network of farmers, agribusinesses and stakeholders. The current food system strives to make all food available at all times and in all places.

The drive for efficiency, higher yields and lower costs has led to several unforeseen issues, not unlike those in other economic industries; such as the packaging industry and the plastic problem and the fossil fuel industry and the climate change problem. Negative externalities are rarely included in the sale price of food. This means that even if food seems to be cheap, the actual environmental and social costs are not included in that price. The biggest negative externality is that food production currently degrades the natural systems that we depend on, which makes these systems unproductive. This will be argued in more detail in the next paragraphs.

Agreeing on the flaws of the industrial food system can be difficult. In spite of this, consensus exists on the three main systemic problems, which will be elaborated upon in the following paragraphs. The industrial (linear) food system contributes to environmental degradation (§2.1), it is wasteful (§2.2) and it is not resilient and does not produce healthy outcomes (§2.3) (Ellen McArthur Foundation, 2015).

Figure 1. A Dutch farmer on his dry field

(De Zwaan, 2018).

2.1 The Industrial Food System contributes to environmental degradation

Agriculture has a great impact on our planet: it takes up half the Earth's land surface and causes 35% of all greenhouse gas (GHG) emissions; 70% of freshwater withdrawals is used for it; and it is the most significant source of the loss of biodiversity and deforestation. The contribution to GHG emissions comes from the conversion of aerosols, the loss of forests (and thus carbon sinks) and livestock management (Food and Agriculture Organization of the United Nations (FAO), 2011a).

From a local perspective, farming in the Netherlands is large-scale and intensive. The existing linear agricultural system in the Netherlands is based on individual supply chains dedicated to producing as much food as possible at minimal cost. In fact, 75% of the agricultural land is classified as high input per hectare, compared to an overall average of 26% in Europe as a whole. The intensive nature of Dutch agriculture inevitably puts significant pressure on several ecosystems. Primary agriculture and horticulture account for 13% of GHG emissions in the Netherlands (European Commission, 2015).

Today's agriculture finds itself at a crossroads due to a combination of factors. Climate change is already calculated to have a negative impact on food production and food security in some areas of the world, while there are expectations for the sector to meet a rise in demand by 70% to 100% within the next 40 years. This poses risks not only for natural resources, ecosystems and biodiversity, but also for food security (Lobell, 2011; FAO, 2018). To explain the environmental degradation due to the Industrial Food System, key topics have been used. These topics are land use, biodiversity, water, bioenergy and livestock.

Land use
The world has a total of 13.5 billion hectares of land surface, 4.9 billion hectares of which is currently used as agricultural land. Globally, 33% of all farmlands are moderately to highly degraded (FAO, 2017). Changes to the Earth's land surface can have adverse environmental impacts, as discussed in the first chapter. In the paragraphs below, several themes that fall into the topic of land use have been assessed. These themes are: deforestation and soil quality.

Deforestation
Forests cover roughly 30% of the Earth's land cover. They are important, since they produce oxygen and provide homes and the livelihood of 1.6 billion people and wildlife. Each year, 7.5 million hectares of forests are cut down and every minute over the last 13 years, an area the size of fifty soccer fields of forests was lost. Industrial agriculture is the biggest cause of deforestation in tropical and subtropical countries, since it accounted for 80% of deforestation from 2000-2010. Soy, palm oil and cattle ranching are in most cases the cause for deforestation (Global Forest Atlas, 2019a). 67% of all soy globally, is produced as feedstock for poultry and livestock (Global Forest Atlas, 2019b). According to IAASTD (2009), the land needed for agriculture in 2050 will increase with 10%, even in the case that yields will also increase (up to 300%). This may require even more forests to be cut down.

Forests act as carbon sinks, which makes them important against rising CO_2 levels and mitigating climate change. Ancient tropical forests absorb an estimated 4.6 Gigaton (Gt) CO_2 per year. Due to land alterations, the ability of soil to capture GHG, the sink capacity, decreases. Additionally, deforestation releases CO_2 and may account for 18-25% of global CO_2 emissions (IPPC, 2007; Eliasch, 2008; Lewis, 2009). Philip Fearnside (2007) of the National Institute for Research in Brazil said the following about deforestation: *"Deforestation sacrifices environmental services such as maintenance of biodiversity, water cycling and carbon stocks."* Furthermore, deforestation also has adverse effects on biodiversity due to habitat loss (IUCN, 2019). This will be explained in the paragraph about biodiversity.

Figure 2. Aerial view cleared pine plantations in Western Australia

(Carbon Brief, 2018)

Soil quality

In modern agriculture, excessive tillage and heavy equipment accelerate erosion and water runoff. When crops are harvested and not replaced, the soil fertility decreases. Additionally, the frequent use of pesticides and fertilizers can increase toxicity, which reduces the supporting growth capacity of the soil. This frequently causes a vicious cycle; because the soil quality decreases as farmers use more synthetic fertilizers and pesticides, which leads to a further reduction of soil quality (Ellen MacArthur, 2017). Sadly, 25% of the Earth's surface is already affected by land degradation. An estimated one third of the world's cropland is losing fertile topsoil, which is extremely important to grow crops, and annually 75 billion tons of topsoil is lost. In total, this concerns more than 2 billion hectares of topsoil annually, an area twice the size of China. The degradation of soil also has a negative impact on agriculture, since it is more difficult to successfully grow crops on degraded soil. This results in lower yields, which might lead to food insecurities (FAO, 2015).

Biodiversity

Species-rich regions of the world are undergoing loss of biodiversity caused by intensive agriculture (Rosenzweig & Hillel, 2012). Converting land surface to agricultural land often has extensive negative consequences for biodiversity and ecosystems. Approximately 60% of ecosystems are threatened and much land is completely destroyed due to exhaustion. The bird population in agricultural areas has decreased by 70% over the past 30 years. Furthermore, the intensity of modern agriculture combined with selective breeding has greatly reduced the genetic diversity of plants, crops and agriculturally domesticated animals. Genetically modified or mixed crop species can repress local species (KPMG, 2014). It is estimated that one third of animals in agricultural systems are threatened or already extinct (Millennium Ecosystem Assessment, 2005; TEEB, 2009). A study of The World Wide Fund (2013), shows that the use of ten natural resources has a great impact on biodiversity and ecosystem services. These are: wild fish, farmed fish, beef, biofuel, cotton, dairy, palm oil, soy, sugar, wood, paper and pulp. Additionally, the consumption of meat, fish and dairy causes roughly 30% of the global biodiversity loss, while 80% of agricultural land is currently used for meat and dairy production (PBL, 2009).

Water

Globally, agriculture is responsible for 70% of all freshwater withdrawals. In Europe, 73 km3 of freshwater is withdrawn for agriculture annually (FAO, 2019). The total water footprint of livestock production accounts for 29% of the total water footprint of the agricultural sector (Mekonnen, & Hoekstra, 2012). Water availability is becoming an increasingly great problem, due to increasing urbanisation, increasing droughts and economic development (The Dutch Government, 2017).

In modern agriculture, many pesticides, fertilizers and other chemicals (to enhance crops for instance) pollute water sources. Most fertilizers are water soluble, so the run-off of fertilizers accumulates in rivers, lakes and oceans. This eventually leads to eutrophication. Run-offs lead to excessive richness of nutrients, such as phosphorus and nitrogen, algal blooms, hypoxic dead zones (when the oxygen level is not sufficient to support most organisms) and tainted drinking water supplies (Diaz & Rosenberg, 2008).

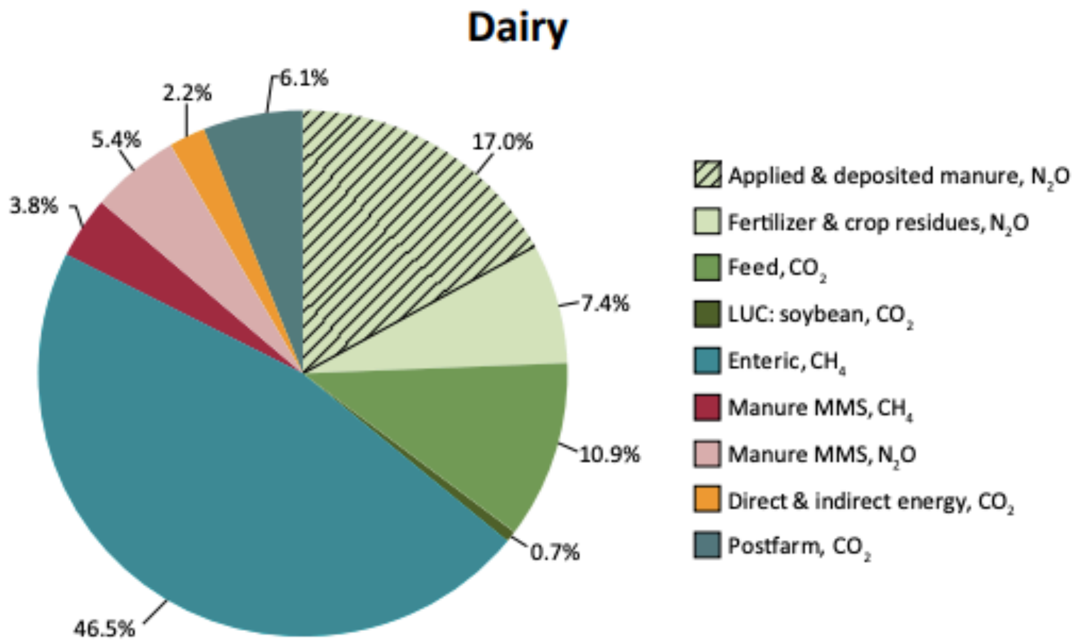
Bioenergy
Bioenergy is generated from plant feedstock, which can be wood, tree seeds, fruits or other crops. Most bioenergy to date is the traditional use of fuel wood and other biomass. In recent years, liquid bioenergy production has increased due to climate change reduction policies. Since fossil fuels are becoming increasingly scarce, it is estimated that 27-40% of global transport fuel will be bioenergy by 2050, whereas only 3% of global road transport is fuelled by bioenergy today. Bioenergy could pose a threat to food security because it is made from crops, in most cases suited for human consumption, and could therefore lead to lower food availability. Moreover, it might require the conversion of forests and grasslands and it has an impact on the price of agricultural commodities (International Energy Agency, 2011; WWF, 2012).

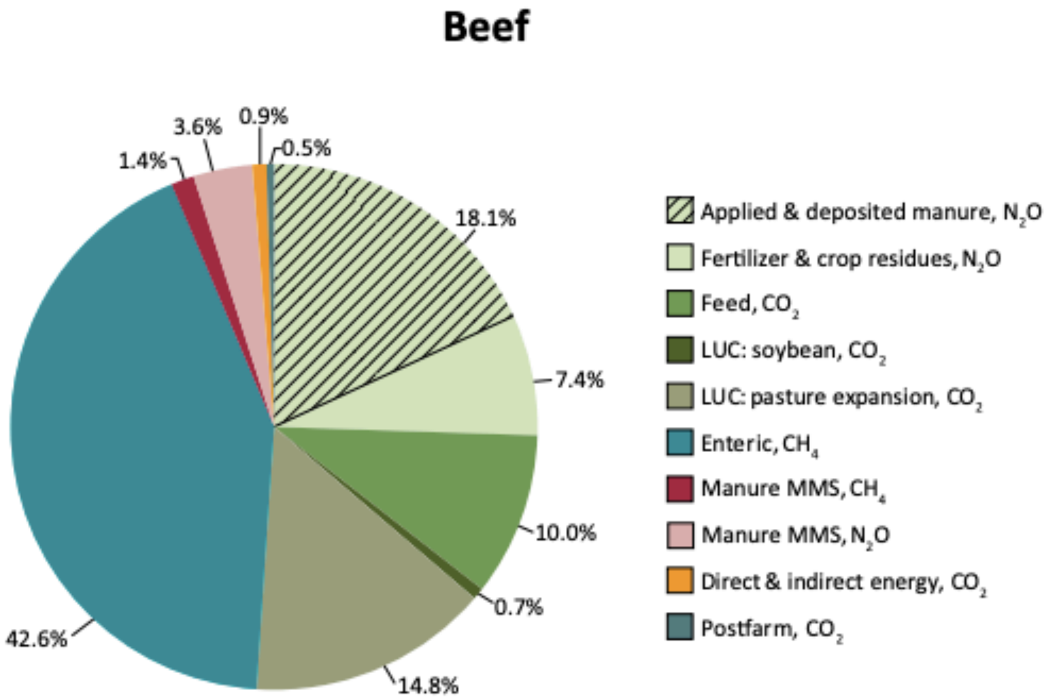
Livestock
In the Brazilian Amazon, beef production is the biggest contributor to the conversion of land surface. Beef contributes to 25% of global LULUCF (Land Use, Land-Use Change and Forestry) emissions (Cederberg, Meyer, & Flysjö, 2009). In effect, beef is the biggest cause of loss of biodiversity, more so than any other commodity. Even though it is estimated that cattle pastures take up 70% of all agricultural land and only 6-11% of all food is provided by it (Union of Concerned Scientists, 2011).

Furthermore, cattle contribute directly to GHG emissions due to the methane in cattle manure and carbon and nitrous oxide through food intake. Globally, ruminants produce an estimated 5.7 Gt of CO_2 equivalents per year, which is roughly 80% of the livestock sector emissions. Beef production emits 35% of the livestock industry emissions and milk production is responsible for another 30%. Beef and milk production combined are responsible for 4.6 Gt of CO_2 equivalents per year (Opio et. al., 2013). According to Berners-Lee et al (2012), all foods that emit more that 0.1 kg CO_2 eq, expect for one, are meat or dairy foods.

Furthermore, large amounts of land are needed to grow feedstock for cattle (typically soy and corn). As mentioned in the paragraph about deforestation, soy is one of the biggest contributors to deforestation and 67% of produced soy is used as feedstock. In the pie charts on the following page, the contributions of different processes to global GHG emissions are depicted for dairy and beef.

Figure 3. The relative contributions of different processes to the total GHG emissions from the global cattle industry





(Opio et. al., 2013)

2.2 The system is wasteful

Globally, 1.3 billion ton of food is wasted every year. In China, 500 million people could be fed by that amount of food (FAO, 2011b). Food is wasted throughout the entire chain, from farm to plate, due to various causes. One reason why, is when yields exceed demand and surplus food is wasted. Sometimes, the surplus is sold to processors or as animal feed, although this is often not financially profitable. Another reason for food waste is the high appearance standards for fresh products imposed by supermarkets. Supermarkets reject produce if it does not meet their standards concerning weight, size, shape and appearance. In most cases, it is cheaper to dispose of food that is not the right shape or size than it is to use, re-use or re-purpose it (FAO, 2011b; Stuart, 2009). This is a clear example of a perverse incentive.

Within the EU, 20% of the total amount of food produced for EU citizens is wasted, which comes down to 173 kg of food per person per year. It is estimated that 60% of consumer losses are still edible (Milieu Centraal, 2017). FAO (2011) assumed the waste percentages for each commodity group per step in the food supply chain (FSC) in Europe. The figure below indicates the consumption phase wastes the most commodity groups (4 out of 7), followed closely by the agricultural production phase (3/7). Bear in mind that these are estimations and the true ratios might be different.

Figure 4. Estimated waste percentages for each commodity group per step in the food supply chain (FSC) in Europe

Estimated/assumed waste percentages for each commodity group in each step of the FSC for **Europe incl. Russia**.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution: Supermarket Retail	Consumption
Cereals	2%	4%	0.5%, 10%	2%	25%
Roots and tubers	20%	9%	15%	7%	17%
Oilseeds and pulses	10%	1%	5%	1%	4%
Fruits and vegetables	20%	5%	2%	10%	19%
Meat	3.1%	0.7%	5%	4%	11%
Fish and seafood	9.4%	0.5%	6%	9%	11%
Milk	3.5%	0.5%	1.2%	0.5%	7%

(FAO, 2011b)

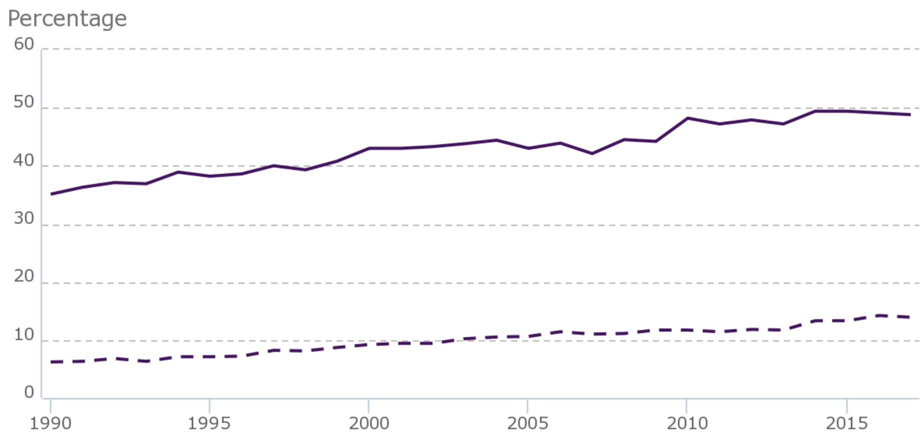
The United Nations aims to reduce global food waste with 50% in 2030, which is one of the Sustainable Development Goals. The European and Dutch ministers of Agriculture have adopted this goal and are helping consumers and companies to reduce their food waste (The Dutch Government, 2019b). This means that there is a big interest in reducing food waste, especially since so many people are still hungry today.

2.3 The system is not resilient and does not produce healthy outcomes

Although the current food quantities produced worldwide should be sufficient for all, over 820 million people are currently undernourished, which is roughly one out of nine people in the world. The majority of them reside in Asia, Sub-Saharan Africa and Oceania. This is particularly shocking, since more food is produced than ever, in total and per capita and despite the growing world population and obesity rates are inclining (FAO, 2018).

In 2019, 1.9 billion people were obese or overweight worldwide and in the Netherlands, 47% of adults (over 18 years old) were overweight in 2017 (WHO, 2018; Volksgezondheid en zorg, 2018). The figure below shows the trend of overweight and obese adults in the Netherlands from 1990 to 2017, which is inclining.

Figure 5. Trend of overweight and obese adults in the Netherlands from 1990 to 2017



——— Overweight, total (men and women) - - - Obese, total (men and women)
(Volksgezondheid en zorg, 2018)

As a result, obesity can cause diseases such as cardiovascular disease, type 2 diabetes, cancer and other chronic illnesses, such as asthma, osteoarthritis and chronic back pain. Furthermore, people who are obese have a higher risk of mental health issues such as anxiety, depression and addiction (Paolicelli, 2016). Obesity also has societal and economical consequences; the number of years one lives unhealthy (with illnesses and restrictions) due to obesity increases societal costs. This includes costs due to incapacity for work, absenteeism and health care costs (Narbro et al., 1996; Neovius et al., 2012).

In addition, the coexistence of malnutrition and obesity within individuals, households and populations, and across lifetime, is referred to as the double burden of malnutrition. For instance, an obese individual might suffer from nutrient deficiencies (WHO, 2017). These facts demonstrate that the current food system is not resilient and does not produce healthy outcomes.

3. Failings of the linear food system

All the aforementioned problems showcase the failings of the industrial food system. A new direction is urgently needed, particularly because of the increasing pressures on the food system. The majority of the scientific community believes that global warming is caused by humans and thus, human actions can be taken to stop the problem (Philander, 2012).

There is a need for environmentally sustainable growth and intensification of agriculture under current and future climate and resource availabilities. A concept like efficiency needs to be transformed, into a concept that uses all resources as optimally as possible. This transcends farm-level changes and is also relevant at local, regional, national and international levels. Optimizing the chain of systems as a whole is significantly different compared to maximizing yield on a field, stable, greenhouse or farm level.

Nature, the main source of our food, has its own mechanism. This mechanism is dependent on natural processes, such as photosynthesis and biodegradation. It is interesting that these processes take place in endless continuous cycles, in contrast to our current linear system. These natural endless processes provide key insights into the needed changes to the man-made linear food system. Could the transformation of a linear system into closed-loop cycles be the answer to the failings of the industrial food system? What would such a system look like? But first, what are the basic principles of a closed-loop system? In the following chapter, these principles, the ground rules of the circular economy, will be explained.

Figure 6. Man standing on a pile of food waste

(Agescimarche, 2019)

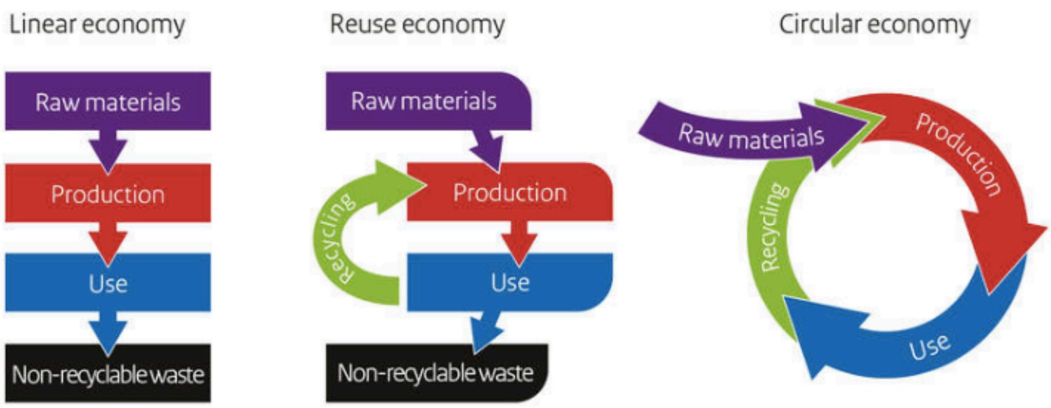
4. The Circular Economy

In a linear economy, a product is produced with raw materials, then the product is used and lastly, it is thrown away. In a circular economy the loop between raw materials and waste is closed, ensuring all resources are used as efficiently as possible, which in this way mimics naturally occurring processes.

In a circular economy, products are designed to be reusable and (when applicable) easily repairable. Reusing products, parts and materials is another key element of the circular economy. Additionally, applying these principles minimizes waste. In a circular economy, resources and products are produced and used in a responsible manner.

The circular economy is not just about making adjustments to minimize the negative impact of the linear economy by recycling some products (which is in fact a reuse economy). The transition toward a circular economy is a universal conversion that generates business and economic opportunities, environmental and societal benefits and builds long-term flexibility and strength. In the figure below, depictions of the linear, reuse and circular economy are provided.

Figure 7. Depictions of a linear, reuse and circular economy



(Government, 2019c)

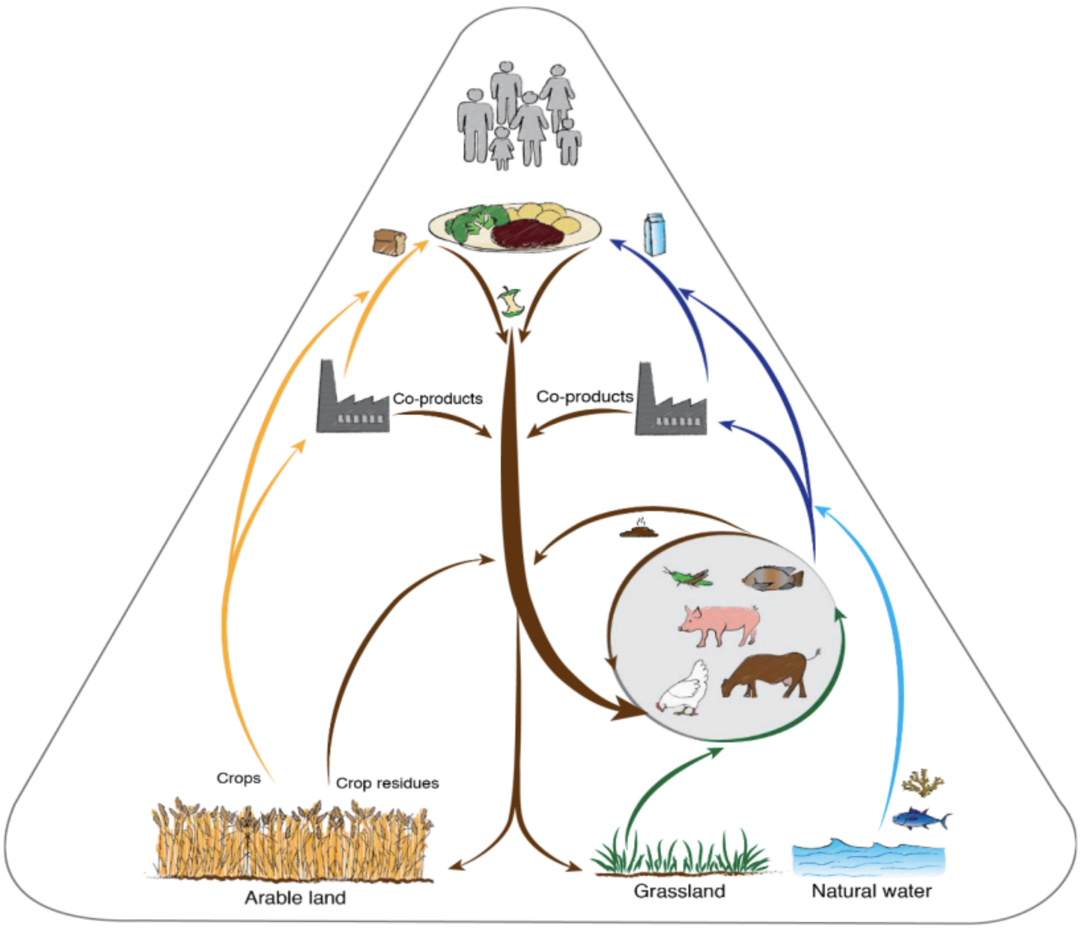
The Dutch government aims for the Dutch economy to be fully circular in 2050 and has developed a government wide program to achieve this goal (Government, 2019c). Examples of these programs are: From Waste To Resource (VANG), Green Growth and Biobased Economy principles. This clearly reflects the national demand for a circular economy and therefore a circular food system might be a solution to the aforementioned issues of the linear agricultural system.

5. A Circular Food System

The concept of circularity, described in the previous paragraph, is based on closing material loops, which reduces resource consumption, waste and emissions. Circular agriculture is based on this principle by optimizing the use of all biomass and closing (nutrient) cycles. Additionally, the use of finite resources and acreage is minimized, the use of regenerative resources is encouraged and the leakage of natural resources such as carbon, nitrogen, phosphorus and water is prevented. Fewer imports of finite resources will be necessary by keeping and reusing residuals of biomass and food processing.

By looking at the chain as a whole it is possible to optimally use land, water, chemicals and nutrients whilst reducing or eliminating waste completely by using residual biomass elsewhere in the chain. The image below shows what a circular food system might look like. In the next chapter, solutions have been given to the main environmental issues and key topics of the industrial food system, described in chapters two and three.

Figure 8. A possible scenario for a circular food system



(Van Zanten, 2019)

6. Solutions of a Circular Food System

Land-use

To avoid further deforestation and the negative impacts on the environment that come with that, it is important to use the land that is already purposed for growing crops as efficiently and environmentally sustainable as possible. The primary purpose and use of arable land should be for the production of food crops for human consumption. This means that livestock should not be grazing on arable land, but rather on land that is unsuited for growing crops, such as grass fields. It is also important to seek ways to increase yields that do not harm the environment.

Growing crops in the correct sequence and at the right frequency can increase potential yields. Simultaneous cultivation of several crops on one field, intercropping, can also increase potential yields. Intercropping systems have 46% higher yields than systems with sole crops. For example, combining a legume and a cereal crop on one field is beneficial due to the biological nitrogen fixation of the legume. Furthermore, crop rotation can interfere with some spatial or temporal cycles of pests and diseases (Raseduzzaman & Jensen, 2017). These are some ways in which the food system can become more efficient and yields can be increased within the planetary boundaries. Nutrient loops are another essential part of a circular food system.

Nutrient loops

Nutrient and other resource loops should be closed in a circular food system. Waste contains nutrients that should be seen and used as a precious resource. Returning these to farms will contribute to the regeneration and strengthening of soils. Phosphorus is one of the most important nutrients for plants that is currently lost in the linear system. Phosphorus is an important element for photosynthesis, which is vital for crops and thus for our food. Phosphorus is lost when crops are harvested and can be found in human excreta. Since this goes into our sewage system, the nutrients are currently lost. It is however possible to recover phosphorus and nitrogen from wastewater. There are several companies and technologies already available. In case one on the next page, the technology of one of these companies is described.

Case 1: Ostara Nutrient Recovery Technology

One company that has a solution is Ostara Nutrient Recovery Technology. This company developed a technology that can recover 85% of the phosphorus and 15% of the nitrogen from wastewater. This is then transformed into a high-end fertiliser with great efficiency. Studies have shown that using this fertiliser instead of traditional fertiliser reduces CO_2 eq emissions and results in higher yields and greater economic benefits. Additionally, the risk of fertilizer run off is reduced, because the fertilizer is not water-soluble.

(Cordell et al., 2011)

By-products and waste products

Inevitably, food production leads to by-products, like residues of crops, food losses, co-products from industrial food processing. These by-products should be minimized throughout the chain, especially when they are edible for humans, which should be reused as human food wherever possible. If this is no longer possible, they should be used for another purpose, such as feedstock for livestock or to enrich the soil.

Crops that serve multiple purposes have a special role, as foodstock and as feedstock (the remains: leaves and stems) for livestock or natural fertilizers to improve the quality of the soil. Ensuring the soil quality should be the main purpose of recycling by-products, since this is the foundation of agriculture. The case of one company that uses a waste product to create a new product, suited for human consumption, is given below in case two.

Case 2: Rotterzwam

Rotterzwam is a Dutch company that uses a waste product, coffee grounds, to grow oyster mushrooms. Coffee is a very ineffective product, because only 0.2% of it ends up in your cup. The rest is discarded in the general waste bin. Rotterzwam found a way to use the enzymes that are in these coffee grounds to create a new product suited for human consumption. The mushrooms are sold in local restaurants. Additionally, traditional Dutch snacks such as bitterballen and krokketten are made from these oyster mushrooms, creating a high-value product.

(Rotterzwam, 2019)

Livestock
In some publications, livestock is considered to be a valuable asset to a circular food system. In this scenario, livestock is to consume by-products and food waste that is not suited for human consumption. Livestock then converts this into valuable food and manure (Boer & Ittersum, 2018).

Other publications suggest that climate change cannot be mitigated sufficiently without dietary changes towards more plant-based and "flexitarian" diets. These dietary changes would reduce GHG emissions as a result of our food system by more than half. Additionally, this would reduce the number of practises that have adverse environmental impacts such as fertilizer application, the use of cropland and use of freshwater (Springmann et al., 2018).

Personally, I believe the potential benefits of keeping livestock for their meat and manure does not weigh up against the disadvantages: deforestation, GHG emissions, water use, health problems and animal cruelty. According to FAO (2008), annually 56 billion animals are slaughtered, not including fish and other sea-animals, and this number is expected to increase because of growing welfare and the growing world population. I fully admit that my view is not 100% objective, as I only eat plant-based foods myself, but I really believe that the only reason why people still eat meat is because of the taste. No one wants to really see the extent of the hurt they cause due to their dietary choices. There might be a way to get the taste of meat without these disadvantages. It is provided in case three.

Case 3: Cultured Meat

Willem van Eelen first patented the concept of cultured meat, also called clean meat, in 1997. He was the first that had the idea to grow meat. Between 2010 and 2013, the first lab grown hamburger was born and it was presented to the media by Mark Post, a Dutch Physiologist who created the hamburger. A American company called Just purchased Van Eelen's patent. Just has successfully grown several types of meat such as chicken nuggets, duck chorizo and sausages. Currently, the only thing standing in their way to enter the Dutch market is the new European novel food legislation. Admittedly, the way in which the clean meat is produced is important to assess if it has less environmental impact than traditional meat production. Factors such as energy usage and water usage need to be taken into account. Given these points, the future of clean meat is still undetermined but it is an interesting and hopeful solution, with great benefits over traditional meat that might be closer to reality than suspected.

(Sprundel, 2018)

Bioenergy

Renewable energy, such as solar, wind or waterpower energy can be produced in numerous ways. Food on the other hand, cannot. Therefore growing crops for the purpose of producing biofuel, on arable land suited to grow crops that are suited for human consumption, is not sustainable. Furthermore, biomass contains many nutrients that are lost when incinerated. Losing precious resources like these is not in accordance with the principles of the circular economy. Even though bioenergy could be useful in the grand scheme of things, reducing CO_2 emissions and minimizing the extraction and use of finite fossil fuels, this is considered out of the scope of this publication.

7. Conclusion

Since the global population is expected to grow to 10 billion in 2050, there is a need to produce more food. It is evident that the industrial food system causes environmental degradation, that it is wasteful, that it is not resilient and that it does not produce healthy outcomes. The industrial food system is already exceeding our planetary boundaries with the current population size. Maintaining the industrial food system is therefore unsustainable. For too long, the sole focus of the agricultural industry has been an economical one. Especially since this produces perverse incentives, as can be seen in manifestations of the industrial food system like animal cruelty and the fact that it is cheaper to throw away perfectly edible food that has the wrong size or shape than to use it.

There is a need for a change. Changing our mind-set, belief, focus and behaviour is all that is needed to turn the industrial food system into a circular one. With cases such as Rotterzwam, clean meat and Ostara Nutrient Recovery Technology, it is evident that change is possible. We need to invest in making these solutions feasible and economically profitable. Globally, 1.3 billion tons of food is wasted every year. The fact that it is in many cases cheaper to get rid of food that 'looks wrong' than doing something useful with it, is what is really wrong. Especially since more than 820 million people are still hungry.

We need to find a way to minimize these perverse incentives and to simulate the principles of the circular economy, like re-using and re-purposing food, in such a way that these are economically competitive. Governments need to assist farmers who want to apply these circular economy principles with information and make them financially sustainable. We need to change our attitude towards food and understand that nature in itself holds many of the solutions to fix our broken food system, allowing everyone to have access to delicious, nutritious, healthy and affordable food.

Figure 9. Crops growing on a field

(Unsplash, 2019)

References

Agescimarche. (2019). *Food truck for sale*. Retrieved from https://agescimarche.it/food-truck-for-sale-%E2%80%93-komfyr-bruksanvisning.html

Boer, I. J. M. d., & Ittersum, M. K. v. (2018). *Circularity in agricultural production*. Retrieved from https://www.wur.nl/upload_mm/5/1/4/3023fe4c-9acb-4fa8-8f5f-326a6d3f7348_3939_Circularity-in-agricultural-production-20122018-1.pdf

Carbon Brief. (2018). Deforestation has driven up hottest day temperatures, study says. Retrieved from https://www.carbonbrief.org/deforestation-has-driven-up-hottest-day-temperatures

Cederberg, C., Meyer, D., & Flysjö, A. (2009). Life Cycle Inventory of Greenhouse Gas Emissions and Use of Land and Energy in Brazilian Beef Production. *The Swedish Institute for Food and Biotechnology*. Retrieved from https://www.diva-portal.org/smash/get/diva2:943348/FULLTEXT01.pdf

Cordell, D., Rosemarin, A., Schröder, J. J., & Smitc, A. L. (2011). Towards global phosphorus security: A systems framework for phosphorus recovery and reuse options. *Chemosphere, 84*(6), 747-758. doi:https://doi.org/10.1016/j.chemosphere.2011.02.032

Diaz, R., & Rosenberg, R. (2008). Spreading Dead Zones and Consequences for Marine Ecosystems. *Science, 321(5891):926-9*. doi:10.1126/science.1156401

Eliasch, J. (2008). Climate change: financing global forests. *The Eliasch review.* Retrieved from http://www.occ.gov.uk/activities/eliasch/full_report_eliasch_review(1).pdf

Ellen MacArthur Foundation. (2015). *Growth within: A Circular Economy Vision for a competitive Europe*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

Ellen MacArthur Foundation. (2017). *Urban Biocycles*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/Urban-Biocycles_EllenMacArthurFoundation_21-06-2017.pdf

European Commission. (2015). *Factsheet on 2014-2020 Rural Development Programme for the Netherlands*. Retrieved from https://ec.europa.eu/agriculture/rural-development-2014-2020/country-files/nl_en.

Fearnside, P. M. (2007). Deforestation in Amazonia. From Encyclopaedia of Earth www.eoearth.org/article/Deforestation_in_Amazonia

Food and Agriculture Organization of the United Nations (FAO). (2008). *FAOSTAT. 2008*. Retrieved from http://faostat.fao.org/

Food and Agriculture Organization of the United Nations (FAO). (2011a). *The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk*. Retrieved from http://www.fao.org/docrep/017/i1688e/i1688e.pdf

Food and Agriculture Organization of the United Nations (FAO). (2011b). *Global food losses and food waste – Extent, causes and prevention* (978-92-5-107205-9). Retrieved from http://www.fao.org/3/a-i2697e.pdf

Food and Agriculture Organization of the United Nations (FAO). (2015). *Status of the World's Soil Resources*. Retrieved from http://www.fao.org/3/a-i5199e.pdf

Food and Agriculture Organization of the United Nations (FAO). (2017). *The future of food and agriculture: Trends and challenges*. Retrieved from http://www.fao.org/3/a-i6583e.pdf
Food and Agriculture Organization of the United Nations (FAO). (2018). *The State of Food and Agriculture 2018*. Retrieved from http://www.fao.org/3/I9549EN/i9549en.pdf
Food and Agriculture Organization of the United Nations (FAO). (2019). Water use: Thematic discussion. Retrieved from http://www.fao.org/nr/water/aquastat/water_use/index.stm
Global Forest Atlas. (2019a). Industrial Agriculture. Retrieved from https://globalforestatlas.yale.edu/land-use/industrial-agriculture
Global Forest Atlas. (2019b). Soy Agriculture. Retrieved from https://globalforestatlas.yale.edu/land-use/industrial-agriculture/soy-agriculture
Healey, J. (2014). *The climate change crisis*: Thirroul, N.S.W.: Spinney Press.
IAASTD. (2009). *Agriculture at a Crossroads Global Report* (978-1-59726-539-3). Retrieved from http://wedocs.unep.org/bitstream/handle/20.500.11822/8590/Agriculture_at_a_Crossroads_Global_Report.pdf?sequence=3&isAllowed=y
Intergovernmental Panel on climate change (IPCC). (2007). *Ar4 synthesis report, summary for Policy makers* Retrieved from New York: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf
International Assessment of Agricultural science and Technology (IAASTD). (2009). *Agriculture at a crossroads. Global report.* Retrieved from http://apps.unep.org/redirect.php?file=/publications/pmtdocuments/-Agriculture at a crossroads - Synthesis report-2009Agriculture_at_Crossroads_Synthesis_Report.pdf
International Energy Agency. (2011). Technology Roadmap: Biofuels for Transport. Retrieved from http://www.iea.org/papers/2011/biofuels_roadmap.pdf.
International Union for Conservation of Nature (IUCN). (2019). Red List of Threatened species. Threats: Agriculture & Aquaculture. Retrieved from https://www.iucnredlist.org/search/grid
Jeffries, N. (2018). A circular economy for food: 5 case studies. Retrieved from https://medium.com/circulatenews/a-circular-economy-for-food-5-case-studies-5722728c9f1e
KPMG. (2014). *Grip op grondstoffen: Leveringszekerheid en biodiversiteit* Retrieved from https://www.fnli.nl/wp-content/uploads/2015/01/KPMG-Grip-op-grondstoffen-web.pdf
Lewis, s. L., & White, L. (2009). Increasing carbon storage in intact African tropical forests. *Nature 457: 1003-U3.*
Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate Trends and Global Crop Production since 1980. *Science, 333:616–620*.
Mekonnen, M. M., & Hoekstra, A. Y. (2012). A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems (2012) 15: 401–415*. Doi:10.1007/s10021-011-9517-8
Milieu Centraal. (2017). *Feiten en cijfers over verspillen van voedsel door consumenten in 2016*. Retrieved from https://www.milieucentraal.nl/media/3725/factsheet-voedselverspilling-huishoudens-mei-2017.pdf

Millennium Ecosystem Assessment. (2005). *Ecosystems and human Well-being: Biodiversity synthesis*. Retrieved from http://www.millenniumassessment.org/documents/document.354.aspx.pdf

Narbro, K., Jonsson, E., Larsson, B., Waaler, H., Wedel, H., & Sjöström, L. (1996). Economic consequences of sick leave and early retirement in obese Swedish women. *Int J Obes Relat Metab Disord. 1996 Oct;20(10):895-903.*

Neovius, K., Rehnberg, C., Rasmussen, F., & Neovius, M. (2012). Lifetime productivity losses associated with obesity status in early adulthood: a population-based study of Swedish men. *Appl Health Econ Health Policy. 2012;10(5):309-17*. doi:10.2165/11632770-000000000-00000

Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., . . . Steinfeld, H. (2013). Greenhouse gas emissions from ruminant supply chains - A global life cycle assessment *Food and Agriculture Organization of the United Nations (FAO)*. Retrieved from http://www.fao.org/docrep/018/i3461e/i3461e.pdf

Paolicelli, C. W. (2016). *Weight Management and Obesity*.

Philander, S. G. (2012). *Encyclopedia of Global Warming and Climate Change* (2 ed.): Thousand Oaks, Calif: SAGE Publications, Inc.

Planbureau voor de Leefomgeving (PBL). (2009). Milieubalans 2009. Retrieved from https://www.pbl.nl/sites/default/files/cms/publicaties/500081015.pdf

Planbureau voor de Leefomgeving (PBL). (2012). *Effecten van klimaatverandering in Nederland: 2012*. (500193003). Den Haag: Planbureau voor de Leefomgeving Retrieved from https://www.pbl.nl/sites/default/files/cms/publicaties/PBL_2012_Effecten-van-klimaatverandering_500193003_0.pdf.

Rajendra K. Pachauri, e. a. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In IPCC (Ed.), (pp. 104). Geneva.

Raseduzzaman, M., & Jensen, E. S. (2017). Does intercropping enhance yield stability in arable crop production? Ameta-analysis. *European Journal of Agronomy 91:25-33*. doi:10.1016/j.eja.2017.09.009

Rosenzweig, C., & Hillel, D. (2012). *Handbook Of Climate Change And Agroecosystems: Global And Regional Aspects And Implications*: Joint Publication With The American Society Of Agronomy. London: Imperial College Press.

Rotterzwam. (2019). The Challenge. Retrieved from https://www.rotterzwam.nl/en_US/page/de-uitdaging

Springmann M. et al. (2018). Options for keeping the food system within environmental limits. *Nature, 562*, 519–525.

Sprundel, M. v. (2018). Kweekvlees – van het lab naar het schap? From NEMO Kennislink https://www.nemokennislink.nl/publicaties/kweekvlees-van-het-lab-naar-het-schap/

Stuart, T. (2009). *Waste – uncovering the global food scandal*. London: Penguin Books.

The Dutch Government. (2017). Dutch Development Results 2016 in Perspective. Retrieved from https://www.dutchdevelopmentresults.nl/theme/water

The Dutch Government. (2019a). Agriculture and horticulture. Retrieved from https://www.government.nl/topics/agriculture/agriculture-and-horticulture

The Dutch Government. (2019b). Vermindering voedselverspilling. Retrieved from https://www.rijksoverheid.nl/onderwerpen/voeding/vermindering-voedselverspilling

The Dutch Government. (2019c). From a linear to a circular economy. Retrieved from https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy

The Economics of Ecosystems and Biodiversity (TEEB). (2009). *TEEB for National and International Policy Makers* Retrieved from http://www.teebweb.org/wp-content/uploads/Study and Reports/Reports/National and International Policy Making/TEEB for National Policy Makers report/TEEB for National.pdf

Union of Concerned Scientists. (2011). The Root of the Problem: What's Driving Tropical Deforestation Today? . Retrieved from https://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/UCS_RootoftheProblem_DriversofDeforestation_FullReport.pdf

Unsplash. (2019). Picture farmer. Retrieved from https://unsplash.com/photos/Yy-dHQP-Ax0

Volksgezondheid en zorg. (2018). *Overgewicht: Cijfers & Context: Huidige situatie: Overgewicht volwassenen 2017*. Retrieved from https://www.volksgezondheidenzorg.info/onderwerp/overgewicht/cijfers-context/huidige-situatie - node-overgewicht-volwassenen

World Health Organization (WHO). (2017). *The double burden of malnutrition. Policy brief*. Retrieved from http://apps.who.int/iris/bitstream/handle/10665/255413/WHO-NMH-NHD-17.3-eng.pdf?ua=1

World Health Organization (WHO). (2018). *Obesity and overweight*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

World Wide Fund (WWF). (2012). *The 2050 Criteria Guide to Responsible Investment in Agricultural, Forest, and Seafood Commodities* Retrieved from http://awsassets.panda.org/downloads/the_2050_critera_report.pdf

Zanten, H. v. (2019). *The role of farm animals in a circular food system*. Retrieved from https://www.wur.nl/upload_mm/d/0/8/04c5cc5d-7bf8-48cf-bb20-2d556a2a13f5_07 Hannah van Zanten Do animals have a role in future food systems.pdf

Zwaan, I. d. (2018). Honderden boeren claimen droogteschade bij verzekeraars. *Volkskrant*. Retrieved from https://www.volkskrant.nl/nieuws-achtergrond/honderden-boeren-claimen-droogteschade-bij-verzekeraars~b680e1cb/

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