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Sustainable Consumption for Biodiversity and Ecosystem Services

The cases of cotton, soy and lithium

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Preface

The impact of our ecological footprint on biodiversity and ecosystems is still not given enough attention, especially where it extends beyond borders. Instead, a greater emphasis is placed on the climate effects of consumption, though both global warming and biodiversity are closely linked. National footprint accounts indicate that, on average in global hectares, European countries use two to three times more productive land than is available within their domestic borders. Moreover, Earth Overshoot Day – the calculated date on which humanity's consumption of biological resources for the year exceeds earth's capacity to regenerate those resources – comes earlier every year.

What does this mean for the impact of consumption in the Global North on the biodiversity and ecosystem services in their countries of origin, especially in the Global South? What kinds of impacts occur, not only in terms of land consumption but also on other resources like water, energy and raw materials? And, what policies and measures might be effective in reducing the negative environmental impact on producer countries?

We commissioned a study to address these questions, taking Germany as an example for a Global North country. Firstly, the study identified the major agricultural, forestry, mining and extraction products imported to Germany. Secondly, it assessed the ecological impact of these products on their countries of origin. And thirdly, it analysed three case studies closely linked to our lifestyles: cotton for textiles, soy imported primarily for livestock feed, and lithium as a major component of batteries for e-mobility. The study then developed policy recommendations for decision-makers and proposed steps that might be taken by stakeholders and consumers.

The findings show that although mining and extraction only affect relatively small areas, they have a significant impact on biodiversity and ecosystems. Highly toxic pollutants affect air, soil and water quality and require immense quantities of water.

Within the clothing industry, still based on cotton, changes in consumer behaviour have been observed, known as "fast fashion". Germany's cotton imports require an average of 2,280 cubic metres of irrigation water per ton of cotton. Moreover, 16 percent of global insecticide sales in 2014 were used to produce cotton. Today, insecticides are a major cause of biodiversity loss worldwide. Also, highly toxic chemicals are needed for processing, such as dyeing.

German feed markets import soy grown in large monocultures. Its cultivation affects soil quality and biodiversity. Intensive use of agrochemicals destroys pollinators and pollutes water bodies. And the farmland continues to expand: the destruction rate of rainforests in Amazonia, for example, has just reached a new peak in 2019.

The present study provides valuable contributions not only for suggesting relevant policy measures but also for all of us to question our current consumption patterns. I would highly recommend reading more and finding out for yourself.

Prof. Dr. Beate Jessel
President of the German Federal Agency for Nature Conservation

Table of contents

1 Executive Summary

High levels of consumption of goods and services have become a defining characteristic of modern industrial societies. Consumers often rely on resources that are cultivated, extracted and, in some cases, also processed in other parts of the world. In many cases, the production and extraction of these materials have severe impacts on biodiversity and ecosystem services and negatively influence peoples' livelihoods.

This study aims to shed light on the impact of consumption on biodiversity and ecosystem services in the countries where raw materials originate. Taking Germany as an example of an industrialised society, the report analyses and illustrates global raw material flows from outside the European Union (EU) into Germany, exploring their environmental impact and considering measures for more sustainable consumption. Specifically, the analysis involves case studies on cotton, soy and lithium. Although German consumption serves as an example, the findings are also highly relevant for many other industrial nations – and in some cases even directly transferable.

The study addresses actors in the field of sustainable consumption on both the national and international level such as, for example, the One Planet Network or the German National Network on Sustainable Consumption. It primarily targets decision-makers who can guide us along the path towards sustainable consumption (and production) by fostering respective policies and measures.

1.1 Global raw material flows affect biodiversity and ecosystem services

The goods and materials imported into Germany are highly diverse and come from numerous regions across the world. To structure the analysis, the study differentiates between four types of raw materials and their product derivatives: agricultural biomass, woody biomass, metals and minerals as well as fossil resources.

With regard to agricultural biomass, soy (primarily for livestock feed), palm oil and rapeseed are the key products imported into Germany. From an environmental perspective, soy from Brazil and palm oil from Indonesia are of particular concern due to the continuous expansion of cultivation in highly biodiverse areas. The cultivation of the eight major imported agricultural goods alone covers 50,000 square kilometres or 13 percent of Germany's surface area. Besides the threat posed by land conversion and deforestation, the intensive use of pesticides in many agricultural commodities also has drastic effects on biodiversity, especially on insects and aquatic animals.

Concerning woody biomass, raw materials and products imported to Germany come primarily from Eastern European countries and Brazil. The intensification of forest use in Eastern Europe results in the conversion of near-natural forests with corresponding impacts on biodiversity. The practice of clear cutting also has an adverse impact on biodiversity and ecosystem services.

Iron ore imports exceed all other metal and mineral imports, the largest supplier being Brazil, where mining is carried out in large-scale open-cast mines. These practices are associated with the devastation of local landscapes and the release of toxic wastewater, destroying ecosystems permanently.

For fossil resources, petroleum, natural gas and coal make up the largest import share, with Russia being the main country of origin. The extraction of petroleum is associated with drastic environmental impacts on both biodiversity and ecosystem services. In Nigeria, for example, crude oil production is responsible for deforestation across vast areas of endangered mangrove forests.

1.2 Taking a closer look: the examples of cotton, soy and lithium

Since impacts on biodiversity and ecosystem services are highly localised and can only be fully captured if analyses are based on specific goods, chapters 4 to 6 explore three product examples in greater depth: cotton for apparel in the textile sector, soy as livestock feed for the food sector and lithium for batteries in the mobility sector. Across these cases, the following key impacts were identified in the study:

- **Loss of habitat:** this is often the result of change in land use as production sites expand to meet increasing demands. Land-use change is the most important global driver of biodiversity loss and has a major impact in all three examples.

- **Pollution of water and soil:** this is linked to industrial agricultural processes and is primarily caused by agrochemicals, as well as chemical agents used in processing. It is a major consequence of cultivating both cotton and soy.

- **Loss of scarce (fresh) water resources:** irrigation and resource extraction processes often require enormous amounts of water. Loss of (fresh) water resources is a central impact of the extraction of lithium from brine as well as the irrigation of cotton crops.

1.2.1 Cotton – Reducing clothing consumption to halt the negative effects of irrigation and agrochemical use

Cotton is one of the main resources for Germany's clothing industry, accounting for 30 percent of total textile fibre consumption. In 2016, cotton imports totalled 760,000 tonnes of textiles and 218,000 tonnes of fibre, yarn and fabric. The main cultivation areas for cotton for the German market are India, China, Pakistan and Turkey. Most cotton products reach Germany via Turkey and Bangladesh.

Cotton is a water-intensive, pest-prone crop that is grown primarily in semi-arid, water-scarce regions. Despite remaining relatively constant in recent years, global cotton cultivation continues to have an extremely negative impact on biodiversity and ecosystem services. Large-scale cotton irrigation can lead to changes of entire aquatic ecosystems. This study shows that some 2,300 million cubic metres of water are required annually to satisfy the cotton demands of German consumers. This is enough water to fill 920,000 Olympic-size swimming pools.

Agrochemicals are a further key concern in cotton-producing regions. Cotton cultivation relies heavily on the use of pesticides and other agrochemicals. Pesticide use has decreased as a result of the widespread introduction of genetically modified cotton varieties. However, as pests have become resistant, agrochemical use has been on the rise again. Cotton processing such as dyeing and textile finishing brings about additional environmental pressure in producer countries.

Clothing consumption has increased drastically in recent years, with fast fashion trends and (social) media creating a constant demand for new clothes. It has become common to replace garments rapidly, either due to poor quality but, above all, to keep up with fashion trends. The amount of cotton textiles consumed per capita is a crucial determinant of the overall environmental impacts. To alleviate these impacts, a large-scale shift in consumption patterns is needed. By far the most effective way to conserve biodiversity and ecosystem services in cotton production and processing countries is to reduce overall clothing consumption, for example by prolonging the use of apparel.

Measures for advancing sustainable cotton consumption include:

- Promoting a culture of slow fashion and launching campaigns and educational materials that focus specifically on the ecological impacts of the textile sector by identifying target-group specific narratives
- Fostering independent standards such as the Global Organic Textile Standard (GOTS) or the Blue Angel Standard to increase the market share of certified organic cotton, for example by setting ambitious public procurement targets
- Increasing awareness for clothing made with sustainably produced renewable raw materials, such as hemp or flax from legal, sustainable and, where possible, local production
- Supporting international multi-stakeholder sustainability initiatives in the cotton and textile sector and encouraging task forces or working groups to be set up to specifically focus on biodiversity and ecosystem services

1.2.2 Soy – Promoting low-meat diets to halt land-use change and pesticide use

Soy is one of the most important agricultural commodities worldwide. Since the 1990s, the global share of land cultivated with soybeans has more than tripled. The annual soy demand in Germany lies at 5.8 million tonnes. With domestic production covering as little as one percent, Germany is reliant on soy imports, mainly from Brazil and the US. Most soybeans are processed into soybean meal, mainly used as animal feed. Some 80 percent of German demand for soy comes from the livestock industry.

Although agricultural imports from outside the EU are small in comparison to other raw material imports, the massive land use for soy has far-reaching environmental consequences. Between 2007 and 2017, the total area used for soy cultivation worldwide increased by 37 percent – from 92 to 126 million hectares. In Brazil alone, where soy is cultivated in highly biodiverse areas such as the Cerrado, German soy imports are linked with more than two million hectares of land used for soy cultivation. This is equivalent to around half the size of Switzerland.

Besides the threat of land-use change, the cultivation of genetically modified soy in Brazil and the US constitutes another highly controversial dimension of soy production. Worldwide, 83 percent of the soy cultivated is genetically modified. Herbicide-resistant weeds and invasive insects have led to the increasing use of pesticides that are associated with considerable risks and negative effects on biodiversity and other ecosystem services. Today, intensive pesticide use is among the main causes of biodiversity loss.

By far the most impactful way to conserve biodiversity and ecosystem services is a large-scale shift in consumption towards vegetarian and low-meat diets. Since Germany's demand for soy is driven primarily by the livestock sector, a decrease in the consumption of meat and dairy products could reduce the ecological pressures of soy cultivation on highly biodiverse areas immensely. Since Germans consume almost twice as much meat per week on average than recommended by the German Nutrition Society, a reduction in overall meat consumption would also have public health benefits.

Measures for reducing the impact of soy production include:

- Developing concrete information, fiscal and regulatory measures to enable consumers to reduce meat consumption and choose sustainable food options
- Promoting independent certification standards such as Ohne GenTechnik, Danube Soya and ProTerra to foster transparency along the value chain and increase the market share of sustainably produced and non-genetically modified soy
- Increasing the share of diverse local protein sources in animal feed by incentivizing and supporting the breeding, cultivation, marketing and processing of domestic organic protein crops
- Supporting international multi-stakeholder sustainability initiatives in the soy industry that promote sustainable production processes along the value chain

1.2.3 Lithium – Incentivise collective and non-motorised means of transport to avoid raw material extraction

The chemical element lithium is one of the key components in the battery technology used for cell phones, laptops, hybrid and electric cars, as well as grid storage. Global consumption has increased drastically in recent years, almost doubling between 2008 and 2016. Given the growing importance of electromobility as part of climate change mitigation approaches and the worldwide diffusion of digital hardware such as smartphones, global demand for lithium is likely to increase even further in the future. Germany alone would require 40,000 tonnes of lithium to meet its target of six million battery-electric vehicles by 2030.

Lithium is extracted from salt lakes in the Andes region. Brine is pumped through boreholes to the surface, where it is concentrated in evaporation pools. This leads to dehydration of the salt lakes. Approximately 2,700 cubic metres of water evaporate per ton of lithium. Assuming that German demand for lithium reaches 6 million electric cars by 2030, 1.1 billion cubic metres of water evaporation could be ascribed to German consumption alone. Both land-use change and water loss impact the very complex and highly specialised ecosystems of the region. Since these salt lakes are the natural habitat of various flamingo species, as well as a number of highly specialised and often endemic species, negative impacts on biodiversity are to be expected.

The most effective way to reduce ecological pressure caused by lithium extraction is to shift mobility away from individualised means of transport such as cars, towards public and non-motorised means of transport. Avoiding raw material extraction in the first place leaves ecosystems intact, conserving them for future generations. In the near future, however, total independence of motorised transport is unlikely, and e-mobility is instrumental in achieving larger mobility transition. Identifying scope for limiting the environmental challenges associated with raw material extraction – closing material cycles by recycling, for example – is therefore of crucial importance.

Measures to decrease lithium extraction include:

- Promoting public and non-motorised transport, particularly in urban areas, for example by introducing free public transport and congestion charges
- Promoting public and non-motorised transport by developing target-group specific information campaigns, educational materials and narratives that include the impact of e-mobility on biodiversity and ecosystem services
- Supporting research and development into improving recycling technologies for lithium-ion batteries and setting up the necessary infrastructure for battery collection and pre-treatment
- Revising the existing legal framework for battery recycling to include raw material-specific collection targets

1.3 Preserving biodiversity and ecosystem services calls for major steps towards sustainable consumption

Consumption and production systems are interlinked in many ways. The negative impacts on consumption in industrialised countries are unjustly distributed and affect primarily the natural environments and livelihoods of people in producer countries, often located in the Global South. Consumers and governments of countries with a high purchasing power thus carry responsibility for environmental degradation and related social and economic inequalities in the Global South. A move away from harmful and damaging processes on the supply side is only likely to occur if consumers in industrialised countries demand sustainably produced goods and services and if governments lay down the necessary legal and regulatory frameworks.

To lessen the impact of industrialised nations' consumption on global biodiversity and ecosystem services, major steps towards sustainable consumption are needed. General recommendations for decision makers in industrialised countries include:

- Encourage sufficiency-oriented lifestyles to promote sustainable consumption levels and increase awareness for the biodiversity and ecosystem service impacts of consumption
- Increase transparency along the value chain and promote ambitious labels that set biodiversity standards to facilitate sustainable purchasing decisions
- Use public procurement as leverage to promote biodiversity and ecosystem service-friendly goods and services
- Develop target-specific narratives on biodiversity and ecosystem services for consumer information and education
- Support international stakeholder initiatives and round tables in different raw material industries and sectors to encourage sustainable value chains
- Close material cycles through recycling and upcycling to reduce long-term raw material consumption
- Evaluate and carefully consider alternative raw materials that may have less impact on biodiversity and ecosystem services

In sum, major social and cultural changes are needed to significantly reduce the impact that consumption in industrialised nations has on biodiversity and ecosystem services worldwide: with regard to cotton, soy and lithium what we need is a shift towards sustainable diets, practices of slow fashion and mobility concepts that are less dependent on individual, motorised transport.

2 How Consumption, Biodiversity and Ecosystem Services are Interrelated

2.1 Global trend: biodiversity and ecosystem services at risk

High levels of consumption of goods and services have become a defining characteristic of modern industrial societies. This trend not only leads to ever increasing use of resources but also poses a high risk to biodiversity and ecosystem services in other parts of the world. Agricultural production is the main driver for land degradation and global loss of terrestrial biodiversity.[1] It is responsible for 80 percent of deforestation and 70 percent of freshwater consumption on Earth. Land-use changes resulting from agricultural expansion result in the loss of biodiverse habitats such as tropical rainforests, which are home to 50 percent of all animal and plant species worldwide. Recent studies show that one million animal and plant species are currently under threat, a quarter of all of monitored species.[2] Besides agriculture and forestry, mining and oil production also cause major environmental damage and contribute to the loss of biodiversity and ecosystem services, for example through the emission of highly toxic pollutants.[3]

German consumption causes biodiversity loss worldwide

To some extent, increasing environmental pressure from raw material production can be explained by the growing world population. To an even greater degree, however, it is caused by rising consumption levels in industrialised countries. Studies on ecological footprints show that resource consumption in Europe is around two to three times higher than the area available on the continent. To cover German consumption, we therefore rely on resources that are cultivated, extracted and sometimes processed in other parts of the world. Highly complex global supply chains telecouple environmental and socioeconomic systems over large distances. The environmental impacts of German consumption thus often occur in faraway places.[4] Studies show that almost 30 percent of global species threats in the Global South can be attributed to the production of agricultural products, textiles and other raw materials that are destined for consumption in the Global North.[5] When assessing the environmental footprint of consumption, it is thus crucial to consider the entire supply chain (Figure 1).

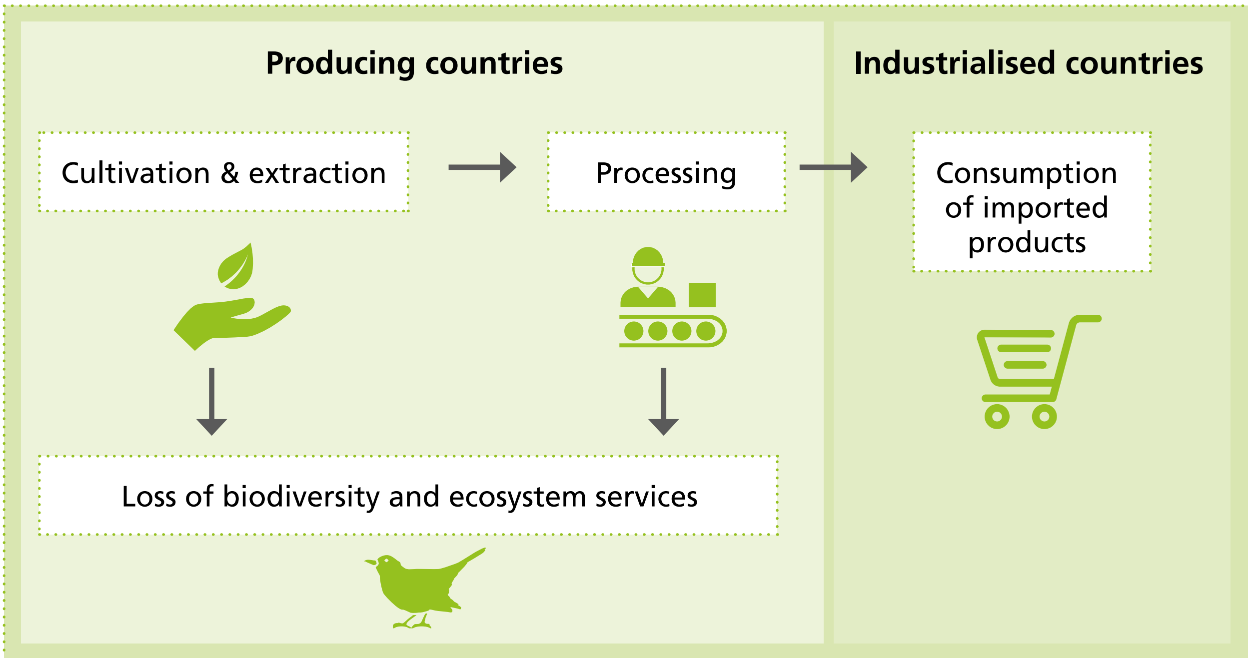


Figure 1: **How consumption leads to loss of biodiversity and ecosystem services worldwide**

2.2 German consumption at an all-time high

Germany's current household consumption of goods and services has reached an all-time high, with a total expenditure of 1,732 billion euros in 2018.[6] This places Germany fourth in a global comparison of private consumption expenditure after the United States, China and Japan, and 14th for per capita consumption.

Awareness does not necessarily go hand in hand with sustainable consumption

German consumers have a relatively high level of awareness for the importance of sustainable consumption.[7] Studies show that the majority of Germans believe that lifestyle changes and consumption restrictions are necessary for nature conservation purposes.[8] However, these general orientations stand in contrast with non-sustainable consumer behaviour in many areas. This discrepancy between attitudes and behaviour can have many causes, such as a lack of economic incentives, habitual behaviour

What are ecosystem services and biodiversity?

Ecosystem services refer to the benefits humans obtain from nature. The concept became popular through the United Nations Millennium Ecosystem Assessment (2005) and has recently developed into an influential approach to conceptualise the relationship between nature and society. Ecosystem services fall into the following four categories:

- **Supporting services** refer to basic ecosystem functions such as nutrient cycling, soil formation and primary production
- **Provisioning services** comprise products obtained from ecosystems such as food, water and wood
- **Regulating services** contribute to the maintenance of ecosystem processes and include good air and soil quality, or flood and disease control
- **Cultural services** include non-material services provided by ecosystems, for example recreation, mental and physical health, aesthetic appreciation or spiritual experiences

Biodiversity is the variety among living organisms. This includes variability within species, between species and of ecosystems. Biodiversity influences every ecosystem function and process, whether directly or indirectly. As such, it is sometimes regarded as a basic supporting service and is of high relevance for all ecosystems and ultimately for human well-being.

patterns, low perceived self-efficacy or situational circumstances such as inconvenience or peer pressure. From a practical perspective, information deficits coupled with information overload, as well as the lack of affordable alternatives play an important role here. The obstacles in the way of sustainable consumption outlined above show how important political intervention is if progress is to be made in the area of biodiversity conservation and ecosystem service protection.

2.3 Increasing international and national efforts for sustainable consumption

In recent years, it has become increasingly clear that changes in the production and processing of goods will not suffice to reduce the environmental impacts of consumption to a sustainable level. In addition to more sustainable supply chains, a change in consumption patterns is necessary. Consequently, sustainable consumption has received increasing attention at both national and international level. Transparency and information on product footprints, as well as fiscal and regulatory instruments are being discussed with a view to their ability to influence consumer behaviour.

The 2012 United Nations Conference on Sustainable Development (Rio+20) adopted the 10-Year Framework for Sustainable Consumption and Production (10YFP) to develop and scale up policies and initiatives promoting sustainable consumption and production (SCP). The importance was reaffirmed in 2015 through the Sustainable Development Goal No. 12, which seeks to "[ensure] Sustainable Consumption and Production Patterns." To follow up on the commitments of the 10YFP, the One Planet Network – a multi-stakeholder partnership – was formed to bring together stakeholders, expertise and resources in six programmes, each centering on a different subject matter. These include programmes on consumer information for SCP and sustainable food systems.

At the European level, strategic activities to promote sustainable consumption have more or less come to a standstill following The Sustainable Consumption and Production Action Plan in 2008 and the Single Market for Green

Procurement Initiative in 2013. On the national level, Germany has adopted a National Programme on Sustainable Consumption in 2016, following a dialogue process over the years from 2004 to 2009. The programme presents an inter-departmental strategy for societal change through sustainable lifestyles and provides recommendations in the fields of mobility, food, living and household, working and offices, clothing and leisure time and tourism.

Focus often on climate change rather than on biodiversity and ecosystem services

Often these strategies primarily consider the climate change impacts of consumption, with less attention being paid to the impact on biodiversity and ecosystem services.[9] Strategies that focus specifically on biodiversity, such as the German National Strategy for Biological Diversity or the Nature Conservation Offensive 2020, address consumption to a very limited extent only. Reports from international initiatives such as The Economics of Ecosystems and Biodiversity (TEEB) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), however, bring to light the threat that consumption poses to biodiversity and ecosystem services. These reports clearly demonstrate the urgent need to increase policy efforts for sustainable consumption in order to conserve natural environments for future generations. The current United Nations process on the Post 2020 Global Biodiversity Framework in the context of the Convention of Biological Diversity calls for mainstreaming the issues of biodiversity loss into key sectors. The findings of the present report provide starting points as to how biodiversity can be integrated into consumption policy.

2.4 Aims of the study: gaining insights into global material flows

The aim of this study funded by the German Federal Agency for Nature Conservation (BfN) is twofold. Drawing upon the example of Germany, the study's first aim is to provide insights into the impacts of industrial nations' consumption on biodiversity and ecosystem services elsewhere in the world. This requires an understanding of the global raw material flows from outside the EU into Germany and an analysis of their various origins. Insights into global material flows in turn allow for an examination of the impacts that the production and extraction of these materials have on biodiversity and ecosystem services. In this respect, the study helps provide a better understanding of what raw materials we consume, where they come from and how severe the ecological impacts of their extraction and production are.

The study's second aim is to develop case-specific recommendations for action to promote sustainable consumption. Impacts on biodiversity and ecosystem services are highly localised and can only be fully captured if analyses are based on specific goods. Therefore, the study focuses on three cases to illustrate the impacts of German consumption. These are soy for the food sector, lithium for the mobility sector and cotton for the textile sector. Soy, which is used primarily for animal feed, is selected as a case study because it constitutes Germany's largest agricultural import from outside the EU and has tremendous impacts on biodiversity and ecosystem services in the countries of production – primarily Brazil. Cotton is examined since clothing consumption is increasing continuously and cotton production has significant environmental impacts in the areas of cultivation. Lithium is a major component of all kinds of batteries. In particular, the demand for lithium for e-mobility is expected to drastically increase if climate protection targets are to be met. The study examines lithium as a raw material whose impacts are likely to increase in the near future.

Germany serves as an example in this report, but the findings of this study are highly relevant for many other industrial countries – and are at times even directly transferable.

The study primarily targets decision-makers who can steer towards sustainable consumption (and production) by fostering the relevant policies and measures. This report presents recommendations on how to address the challenges for each of the three case studies. The final chapter looks at the general strategies for more sustainable consumption. These measures can help implement and develop the national and international initiatives.

Methodological approach: a multi-step analysis

To analyse the impacts of German consumption on biodiversity and ecosystem services in other parts of the world, the following analytical steps were carried out:

1. **Visualisation of global material flows:** Analysis of global material flows into Germany based on data from Germany (destatis), the EU (Eurostat) and the Food and Agricultural Organisation of the United Nations (FAOSTAT) → chapter 3
2. **Assessment of impacts on biodiversity and ecosystem services:** Literature review of the impacts of German imports on biodiversity and ecosystem services in producing countries. This results in an impact rating scheme that considers land use, as well as estimated biodiversity and ecosystem service losses → chapter 3
3. **Analysis of three cases:** In-depth study of cotton, soy and lithium as relevant case studies in the fields of clothing, food and mobility → chapters 4, 5, 6
4. **Evaluation of policy options:** Identification and evaluation of promising policies and measures – using the selected cases as examples – to reduce the pressure that German consumption puts on biodiversity and ecosystem services in other parts of the world → chapters 4, 5, 6
5. **Synthesis:** Identification of promising trajectories of change and overall conclusions → chapter 7

3 Global Material Flows and Their Impact on Biodiversity and Ecosystem Services

3.1 What does Germany import from where?

The goods and materials consumed in Germany are imported from numerous regions of the world. To consider the impact German consumption has elsewhere in the world, it is necessary to understand what raw materials Germany imports in which quantities and from where they are being imported.

Import statistics differentiate between four types of goods and their product derivatives:

- Agricultural biomass
- Woody biomass
- Mineral raw materials, metals and metal ores
- Fossil resources

Figure 2 provides an overview of the total imports for these types of goods, detailing imports both from within and outside the EU. This gives us a better understanding of the types and quantities of goods imported from global markets in comparison to EU markets. The data show that agricultural and forestry biomass as well as mineral raw materials and metals are imported primarily from within the EU, while fossil resources come for the most part from outside the EU.

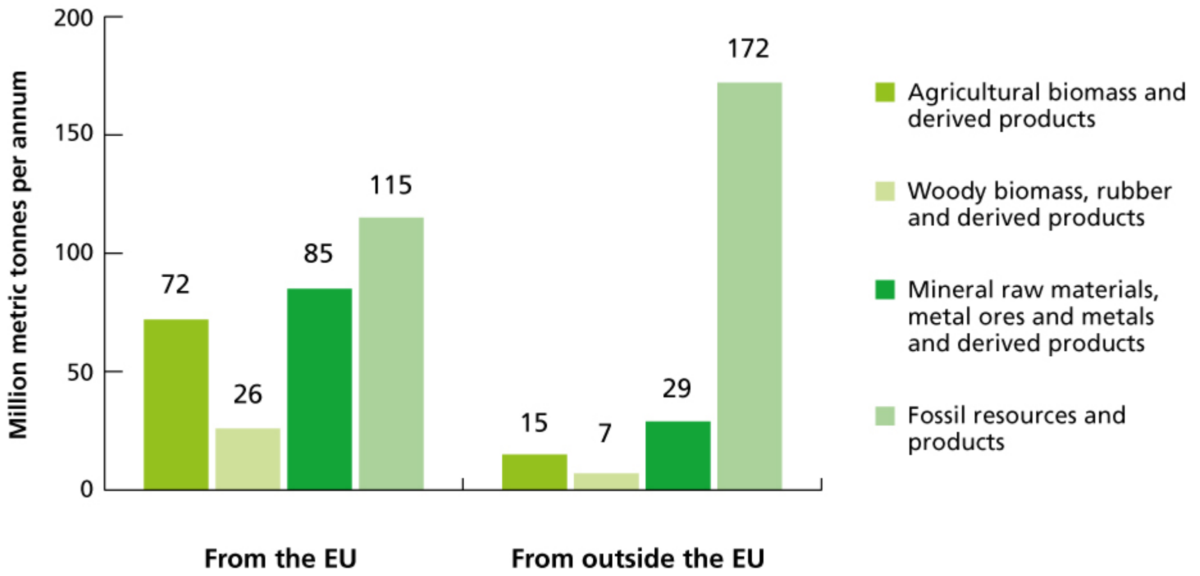


Figure 2: **Goods imported into Germany from within and outside the EU in 2017;** *Source: Eurostat Comext*

Since the study examines the impacts of Germany's consumption on a global scale, it focuses on raw material and product imports from outside the EU. There is no doubt, however, that raw materials cultivated or extracted within the EU also impact biodiversity and ecosystem services adversely.

With regard to the scope of the following data, it is important to note that product derivatives refer solely to simply processed, direct products. For instance, the data on wood includes saw products but not furniture or books. Similarly, the data on steel include steel beams but not cars. Cars imported from Japan, for example, also introduce raw materials into Germany from various countries around the world that are not considered here owing to the complexity of the trade flows.

3.2 Agricultural product imports: soy accounts for more than 40 percent of the total volume

In 2017, Germany imported a total of 87 million tonnes of agricultural biomass and products, 14.6 million tonnes of which were imported from countries outside the EU. The majority of these products are oil plants, predominantly soy, but also palm oil and rapeseed. Other major imports are vegetables, fruits and nuts, coffee, tea, cocoa and spices and non-food products such as textiles. Live animals and animal products make up a relatively small share of agricultural imports (Table 1).

Agricultural biomass imports into Germany	Quantity (million tonnes)
Total agricultural biomass imports	**87**
Agricultural biomass imports from outside the EU	**14.6**
Soy oil and meal	5.8
Vegetable oils (palm oil, rapeseed oil etc.)	1.0
Vegetables, fruits and nuts	2.1
Coffee, tea, cocoa and spices	1.5
Live animals and animal products	0.2
Other food products (cereals, fish, sugar etc.)	2.7
Non-food products (textiles etc.)	1.3

Table 1: **Agricultural products imported into Germany from outside the EU in 2017, by type and quantity;** *Source: Eurostat Comext*

Agriculture is the most relevant driver of biodiversity loss, particularly in the tropics

A recent report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services shows that since the 1970s land-use change has had the largest negative impact on biodiversity, with agricultural expansion being the most widespread form of land-use change.[10]

Oil seeds crops used specifically for livestock feed and thus linked to meat consumption are the key agricultural commodity imported into Germany. The cultivation of these crops is associated with large-scale land-use change and impacts local biodiversity accordingly. The major producer countries for soy meal are Brazil and the US (Figure 3). The steady increase in soy cultivation in Brazil, in particular, has led to deforestation and a substantial loss of highly biodiverse natural areas. This is examined in depth in chapter 5.

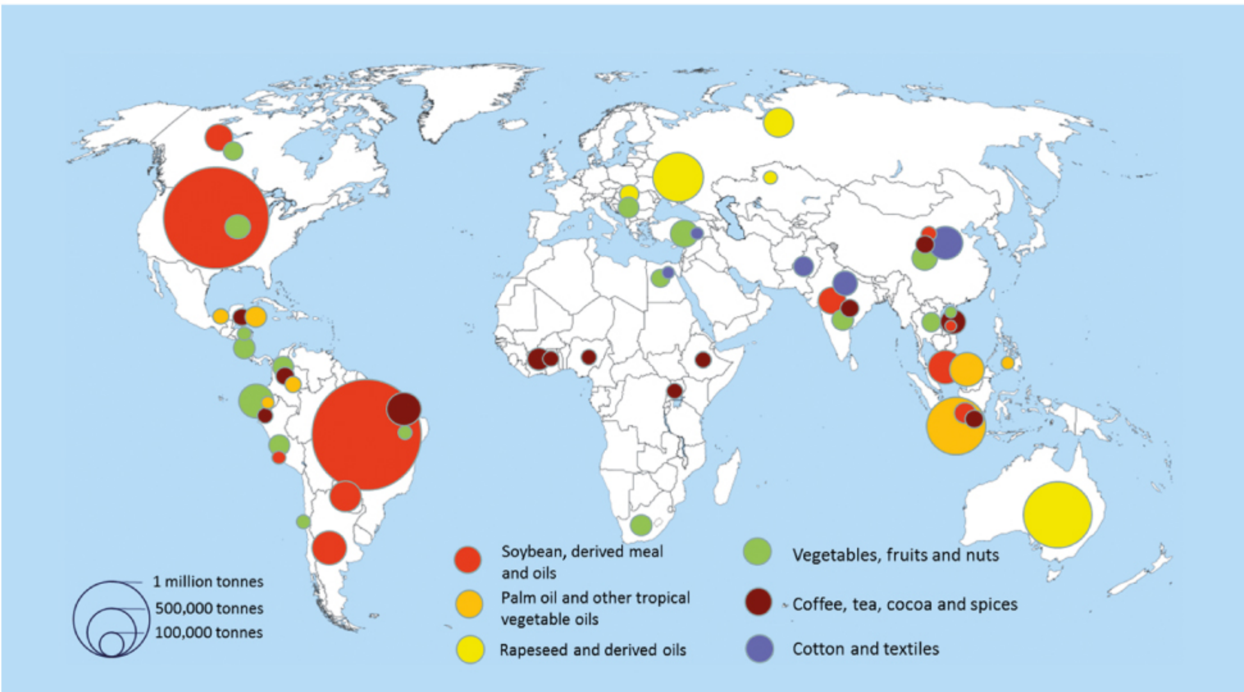


Figure 3: **Origins of agricultural and product derivatives imported into Germany from non-EU countries in 2017;** *Source: Eurostat Comext*

Palm oil is used mainly for food production, but also in cosmetics, detergents and biofuel. The production of palm oil in Indonesia and Malaysia is one of the main drivers of tropical rainforest conversion. At an average annual yield of 3.3 tonnes per hectare, a cultivation area of, approximately 1,200 km^2 is needed to meet German demands. Annual land-use change in Indonesia is estimated at 6.6 percent of the total cultivation area.[11] Consequently, German palm oil consumption is responsible for an average land-use change of 80 km^2 per year, affecting primary forests, in particular, which have some of the highest diversity of vascular plants worldwide.[12]

Similarly, rapeseed imports from Australia and Ukraine are associated with large-scale monoculture production on expanding cropland. While the total agricultural area in Australia has decreased in recent years due to abandoned grasslands, cropland has strongly increased and Australia has doubled its total rapeseed cultivation area over the last 20 years.[13] This goes hand in hand with an increasing share of genetically modified rapeseed in Australia.[14] The herbicide-tolerant monoclones cause further impoverishment of the accompanying flora and genetic diversity.

Tropical fruits, coffee, tea and cotton are grown primarily in large-scale monoculture plantations

Vegetable, fruit and nut imports are highly diverse. The key countries of origin are Ecuador (bananas), Turkey (nuts, raisins, roots and tubers), the US (nuts), China (mainly roots and tubers) and Costa Rica (bananas). Fruits are the second most important agricultural import commodity after oil plant products, with bananas making up 42 percent of all fruit, vegetable and nut imports. The main producing countries for bananas sold in Germany are Ecuador, Costa Rica, Columbia and Peru. The overall cultivation area for bananas in countries exporting to Germany is in decline and bananas will unlikely be a major driver of land-use change. Industrial-scale banana monocultures, however, are often accompanied by the intensive use of pesticides that cause severe damage to biodiversity and ecosystem services. An especially damaging practice is aerial spraying of highly toxic substances such as Oxamyl that is toxic to bees and fish.[15]

The consumption of fruits and vegetables in Germany has remained constant over the past 15 years, although a number of exotic fruits such as avocados have increased in consumption, with forests being cleared specifically for their production.[16] As cultivation often takes place in regions where the climate is not suitable for the water requirements of the crop — for instance avocados in Chile or nuts in California, high-intensive irrigation is being employed, leading to the lowering of groundwater tables.

The main countries of origin for coffee are Brazil, Vietnam and Honduras. Tea is imported predominantly from China and India. The major source of cocoa consumed in Germany is the Ivory Coast. Coffee, tea and cocoa are cultivated primarily in industrial-scale monocultures with detrimental effects on biodiversity. Due to increased pest pressure on monocultures, large-scale plantations are using vast quantities of pesticides, which could be largely avoided by employing mixed cropping practices or agroforestry.[17] The situation is particularly serious in the case of cocoa. Cocoa cultivation has led to the loss of valuable areas in national parks and protected forest areas in the Ivory Coast, the largest producer of cocoa.[18] The global production of tea and coffee is expanding, contributing to land-use change.[19]

Textile imports to Germany come mainly from Asia, China being the key producer, followed by Turkey, India and Pakistan. Since statistical data do not distinguish between different types of textiles, synthetic fibres originating from China are included in the statistics. The share of cotton textiles is estimated at 60 percent. The main producers of cotton consumed in Germany are India, China and Pakistan. Cotton is usually grown in large-scale monocultures. Pesticide use, genetically modified varieties and irrigation have a considerable impact on biodiversity and ecosystem services. These are explored in chapter 4.

3.3 Woody biomass imports: timber from boreal forests, pulp and rubber from the tropics

In 2017, approximately 32 million tonnes of products made from wood, cork, pulp and rubber were imported to Germany, 6.7 million tonnes of which originate from countries outside the EU. Timber and wood products accounted for the largest share (Table 2).

Imported timber originates mainly from northern and eastern European countries

Outside the EU, the main producers of timber and wood manufactures for the German market are Norway, Belarus, Russia and Ukraine (Figure 4). Indonesia and Paraguay also rank among the ten most important countries of origin, but with far smaller shares. Switzerland likewise has a relatively large share of exports to Germany, but this is attributable to Switzerland's position as a transit country in the trade and supply chain.

In Eastern European countries such as Russia, Belarus, Ukraine and Bosnia-Herzegovina, the intensification of forestry has led to large-scale conversions of natural or near-natural forests. Such conversions impact biodiversity immensely, degrading natural forest biotopes. A further problem is clear cutting, a common forest management practice in these countries. This type of harvesting can lead to soil losses and reduces the forests' capacity to store water. Yet very little reliable data exists on these impacts and tangible effects are difficult to gauge.[20] Where sustainable forest practices are in place, the consequences for biodiversity and ecosystem services are comparable to those of forest management in Germany.

The disappearance of natural forests due to increasing industrial development in Russia has been pointed out by various environmental organisations. Today, less than 25 percent of Russian forests remain intact natural forests, unaffected by industrial cutting activities or fragmented by roads and pipelines. The importance of these natural forests in conserving biological diversity and ensuring ecosystem services speaks for itself, particularly in view of their physical dimensions. They account for one third of the total forest area worldwide. However, less than three percent of them are protected.[21]

Woody biomass imports into Germany	Quantity (million tonnes)
Total woody biomass imports	**32**
Woody biomass imports from outside the EU	**6.7**
Timber and wood products	3.8
Pulp	1.9
Natural rubber	1.0

Table 2: **Woody biomass imported into Germany from outside the EU in 2017, by type and quantity;** *Source: Eurostat Comext*

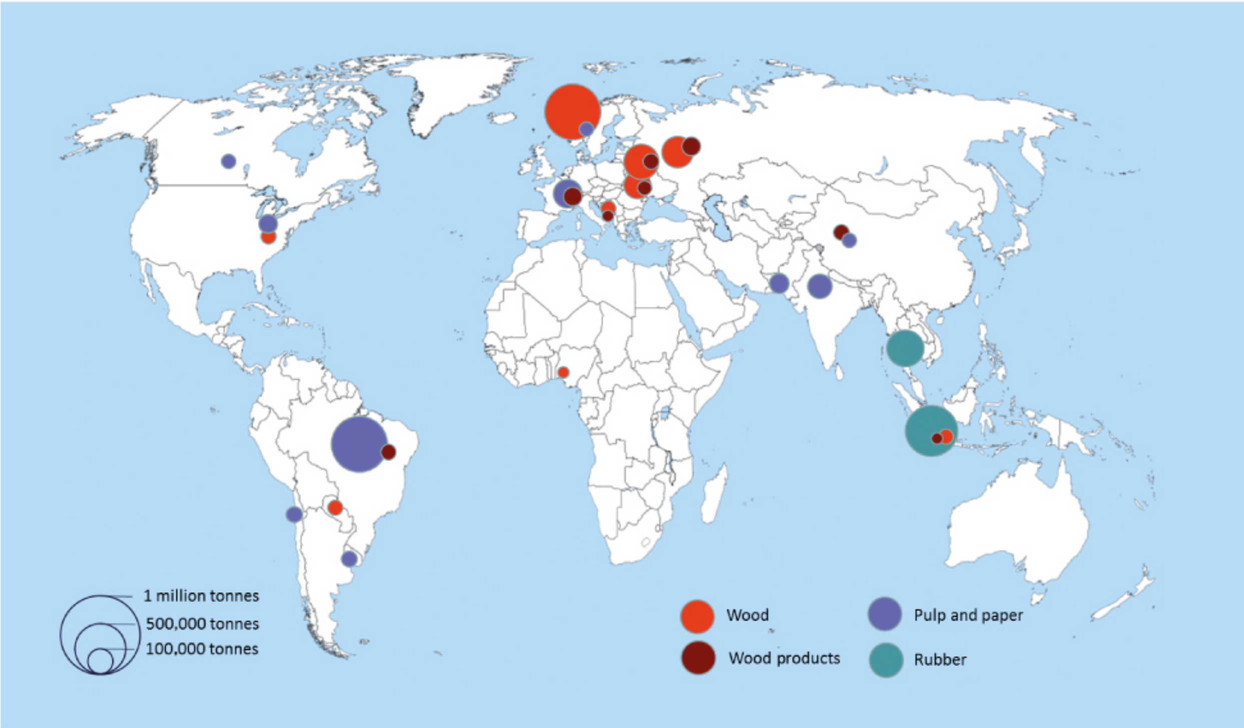


Figure 4: Origins of woody biomass, derived wood products and rubber imported into Germany from non-EU countries in 2017; *Source: Eurostat Comext*

Biodiversity of intensively managed forests is lower than in near-natural forests

In general, there is a significant loss of biodiversity when natural or near-natural forests are converted into managed forests. A comparative analysis of several hundred studies shows how species richness differs in managed and unmanaged forests and tree plantations.[22] When ranked from best to worst practices, selection and retention systems are most beneficial for local species richness, while conventional selective logging and clearcutting ranks worst in temperate and boreal climate zones. In the tropics, reduced impact logging is found to be the best way to manage forests in terms of biodiversity, while timber and fuel wood plantations have the worst ranking. On average, the conversion of natural forest to timber plantations leads to a loss of 40 percent of local species.

Pulp production in Brazil is based on extensive eucalyptus and pine plantations

With its extensive eucalyptus production, Brazil produces considerable amounts of pulp and is the largest exporter of pulp to Germany among non-EU countries. The majority of wood plantations in Brazil are intensive monocultures that have strong negative impacts on biodiversity owing to the high-level toxic chemicals used which cause water and soil pollution.[23] At 7.7 million tonnes per year, Brazil's pulp production displays strong growth.[24] The biggest part of this growth is expected to occur in or adjacent to the Cerrado, a highly biodiverse savannah region covering about one quarter of the country. German demand for pulp is increasing due to rising demand for packaging material resulting from an increase in online shopping.

Production of rubber is concentrated in Thailand and Indonesia

Germany imports one million tonnes of crude rubber and rubber manufactures, primarily in the form of foams. Rubber is produced exclusively in tropical countries, which is why German consumption relies entirely on imports from outside the EU. The major producing and exporting countries for natural rubber are Thailand and Indonesia, which hold a share of 60 percent of global production. Among monoculture tree crop plantations, rubber has been expanding in South-East Asia most rapidly. The current area covered by rubber plantations is equivalent to 57 percent of oil palm plantations. More than two million hectares of rubber plantations have been established over the last decade.[25]

3.4 Metals and minerals: great dependence on Brazil and Canada

In 2017, German imports of metal and mineral products amounted to 113 million tonnes. Approximately one quarter of these imports originate from non-EU countries. Metal ores, predominantly iron, make up the greatest share (Table 3).

Ore extraction changes landscapes drastically, often leaving them in total devastation for a long time

With a total import volume of 29 million tonnes per year, metal ores and metals exceed biomass imports. However, the area requirements for biomass production differ substantially from mining in terms of quantity and quality of land use. For example, the production of one tonne of soy meal requires an average of 0.3 hectares of arable land, while the extraction of one tonne of metal ore requires on average as little as 0.021 hectares.[26] Yet, while areas for agricultural production are repeatedly cultivated, mining activities cause major change in the areas of ore extraction, which are left in devastation for an extended period.

Brazil and Canada among the biggest ore producers

At 10 million tonnes, more than half of the total iron ore imports stem from Brazil and Canada (Figure 5). The most substantial material flow is iron from Brazil. The most important mining region is located in the Serra dos Carajás in the State of Pará, which is rich in forest. Surface mining practices include mountaintop removal which causes large-scale devastation to the landscape, leading to the loss of entire ecosystems.[27]

Germany's main provider of bauxite is Guinea

Ores from non-ferrous metals include bauxite that comes primarily from Guinea, copper from Chile and Mexico, and lead and zinc from Canada and Australia. Mining practices generally

Metal and mineral imports into Germany	Quantity (million tonnes)
Total metal and mineral imports	**113**
Metal and mineral imports from outside the EU	**29**
Iron ore	14.7
Steel and iron	3.7
Aluminium ore	2.3
Copper ore	0.4
Non-ferrous metals (aluminium, copper etc.)	1.3
Metal manufactures	1.9
Minerals	5.1

Table 3: **Metal and mineral products imported into Germany from outside the EU in 2017, by type and quantity;** *Source: Eurostat Comext*

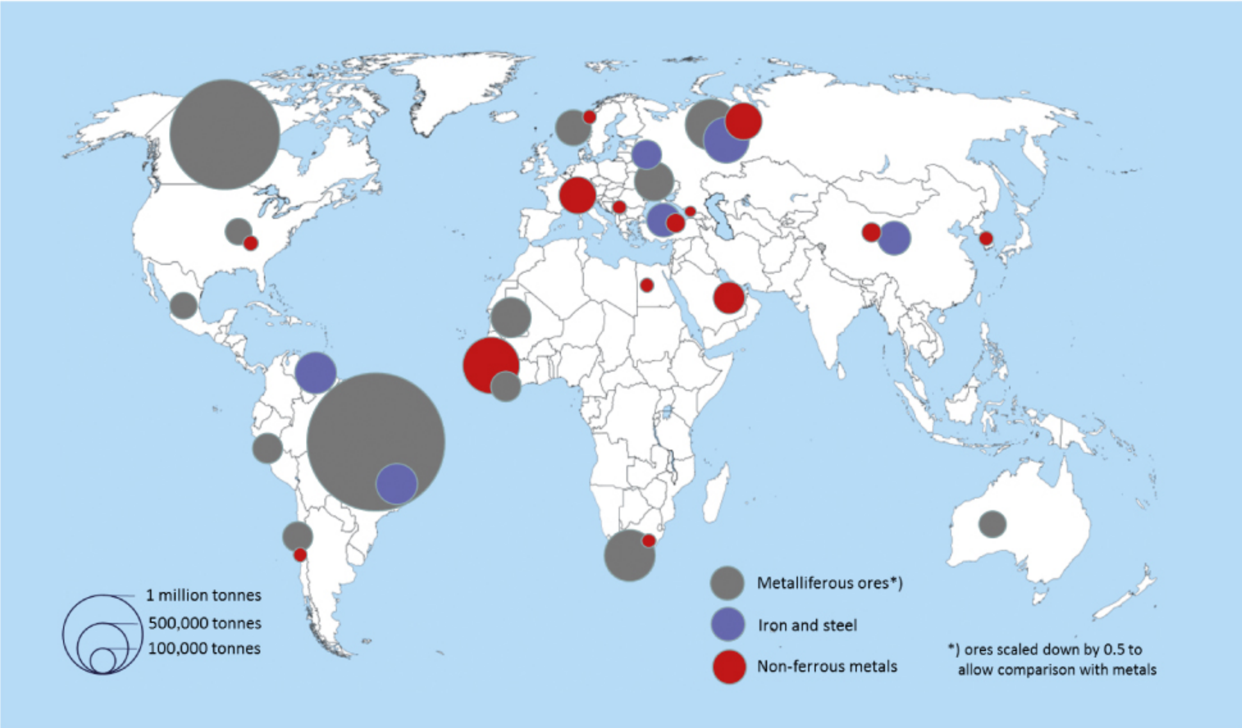


Figure 5: Origins of metal ore and metal products imported into Germany from non-EU countries in 2017; *Source: Eurostat Comext*

lead to the same detrimental environmental effects as iron ore surface mining. The release of toxic effluent is still standard practice. Mining precious metals such as gold is particularly harmful, despite the small mining quantities. Local changes in land use and damage to natural areas are substantial for all of the ore mining practices mentioned.[28]

97 percent of German bauxite (aluminium) imports come from Guinea. Assessments of the environmental impacts find that bauxite mining in Guinea poses a particular threat to the country's northern ecosystems, which are characterised by mangroves and lowland riparian forests in coastal regions, as well as savannah habitats further inland.[29] The affected forests in the region are classified as biodiversity hotspots.

The majority of ore mines are small-scale, but have serious local effects on nature

Apart from aluminium and copper, other non-ferrous metals such as cobalt, nickel or lithium are imported into Germany. These are extracted in much lower quantities, but still have the potential to gravely impact local biodiversity and ecosystem services. These impacts are often very specific and localised. An interesting case in this context is lithium. Despite the present, rather low import volume of 2,800 tonnes per year (including lithium in imported end-user products), very specific impacts on biodiversity and ecosystem services are expected to occur. The complexity of the lithium supply chain and its environmental impacts are explored in depth in chapter 6.

3.5 Import of fossil resources: threats from mining, but even more from climate change

Fossil resources such as petroleum, natural gas and coal comprise the largest import volume into Germany. Of the 287 million tonnes imported in 2017, about 60 percent originate from non-EU countries. Petroleum and natural gas make up the greatest share of imports (Table 4).

Fossil resource imports into Germany	Quantity (million tonnes)
Total fossil resource imports	**287**
Fossil resource imports from outside the EU	**172**
Petroleum	85
Natural gas	68
Coal	19

Table 4: : Fossil resources imported to Germany from outside the EU in 2017, by type and quantity; *Source: Eurostat Comext*

Russia is the main country of origin for all fossil fuels imported into Germany

Besides Russia, crude oil is also imported from Norway, Kazakhstan, Libya and Nigeria (Figure 6).[30] As for coal, Russia is the main producer, followed by the US, Australia, Colombia and Canada. The main supplier of natural gas is likewise Russia.

Biodiversity hotspot in Nigeria impacted by oil extraction

One of the producing countries for petroleum imported to Germany is Nigeria. In the Niger Delta crude oil production is a serious environmental burden for both biodiversity and ecosystem services. The mangrove forests of the Niger Delta are a biodiversity hotspot and the largest continuous ecosystem of its kind in

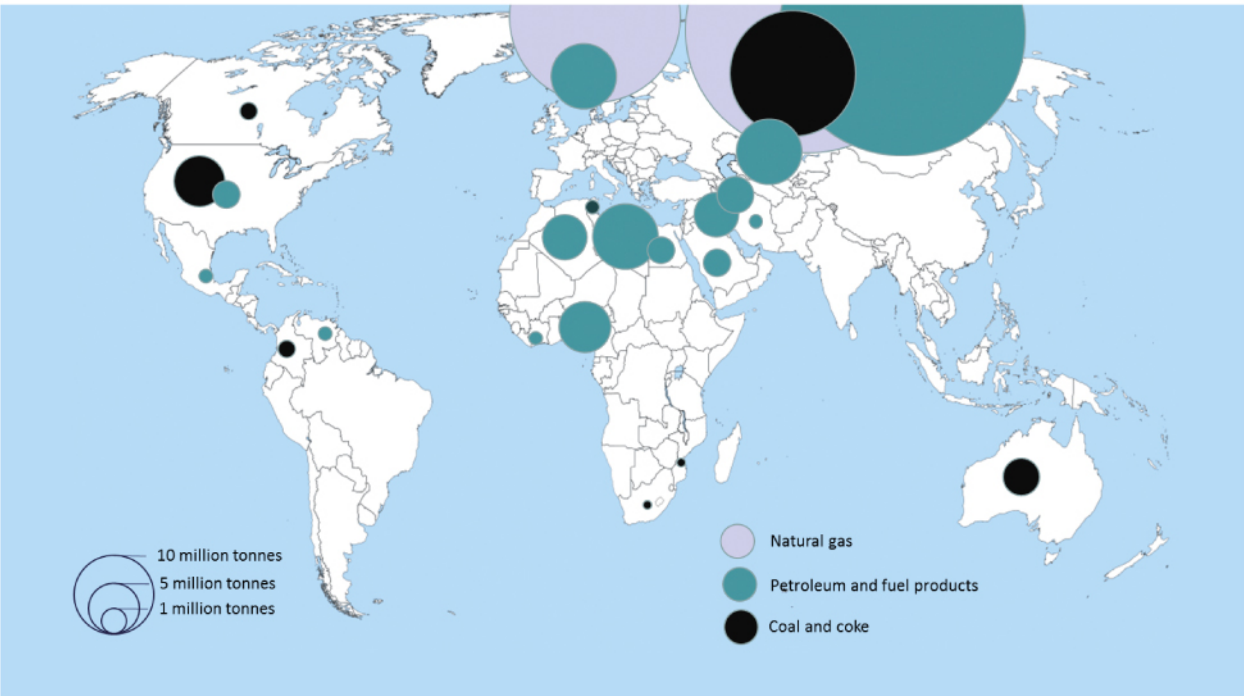


Figure 6: Origins of coal, petroleum and natural gas imported into Germany from non-EU countries in 2017; *Source: Eurostat Comext*

Africa, accounting for three percent of global mangroves.[31] These mangrove forests are the most threatened in West Africa, affected by fragmentation and deforestation caused by indiscriminate logging for oil extraction.[32] Given the accelerating rate of loss, Nigerian mangrove forests are at risk of disappearing within this century.[33]

Unconventional oil extraction can cause major impacts

While Nigeria is a particularly serious example, oil production does generally have a significant impact on ecosystems and biodiversity. This applies not only to oil extraction on land, for example in Russia, and offshore drilling like in Norway, but in particular also to unconventional production methods such as deep sea drilling, fracking or tar sand mining. The Deepwater Horizon disaster that struck BP in 2010, for example, led to the destruction of one of the most valuable ecosystems along the southern coast of the US due to an 800-million-litre oil spill in the ocean. The accident had severe impacts on the avifauna.[34] Tar sands are mined in Canada (Alberta oil sands). A prairie landscape of roughly 70,000 km^2 is at risk of being destroyed including the long-term pollution of water bodies in the area.[35] To date, products from fracking have borne no significant relevance for the German mineral oil market. However, if there are no significant reductions in global crude oil consumption, they may well pave the way to the future of technology in the mineral oil sector.

Adverse effects of Russian natural gas on the tundra

The production of natural gas often goes hand in hand with mineral oil drilling, especially in the North Sea. Russia extracts natural gas predominantly on the Yamal Peninsula in the tundra, which is a fragile arctic environment. The fragmentation of formerly undisturbed landscapes such as taiga forests by pipelines and other infrastructure related to the gas and energy industry puts biodiversity at risk. Today, such infrastructure projects require comprehensive environmental impact analyses. The actual loss of biodiversity and ecosystem services caused by the sector is, however, difficult to quantify.

Open pit mining of coal causes devastation to far-reaching landscapes

The extraction of coal also has considerable impacts on natural environments. Some examples: Mountaintop removal mining is carried out in the US, extensive surface mining in open pits is

practiced in Australia and Colombia, degrading ecosystems severely through the devastation of entire landscapes.[36]

Climate change is the largest threat to biodiversity from fossil resources

As severe as the local effects of fossil fuel mining may be, the greatest impact on biodiversity and ecosystem services is caused by the use of fossil fuels, one of the major contributors to greenhouse gas emissions and hence climate change. Climate change is considered to be one of the most relevant drivers of change in nature in the last 50 years.[37]

3.6 Overview of impacts by German consumption on biodiversity and ecosystem services

The impacts of German consumption on global biodiversity and ecosystem services are manifold. But what are the most important areas? By way of illustration, Table 5 contains a summary in the form of a rating scheme. The table considers land use as well as the estimated impact on biodiversity and ecosystem service loss.

Assessing the impacts of consumption on biodiversity and ecosystem services is not an easy task. The significance of ecosystem services often very much depends on local or regional contexts. Although there are many examples of broad and large-scale causal relationships such as the tropical forests of the Amazon that determine rainfall patterns for the entire subcontinent, the relevance of individual ecosystem services is best assessed at the local level. Such an assessment is beyond the scope of this study.

Rather, this study aims to provide a broad assessment of the impact of the cultivation and extraction of key goods and materials on biodiversity and ecosystem services. To provide such an assessment, the impacts of the most important commodities are rated using a four-level colour scheme which covers three aspects: the amount of land occupied for the cultivation or extraction of the product, the estimated level of biodiversity loss and the estimated level of ecosystem service loss. Since the impacts vary widely depending on geographical location as well as on social, environmental and technical conditions, the results should not be seen as universally applicable, but rather as an assessment of large-scale trends.

Commodity	Main consumer goods	Major producing countries (outside the EU)	Annual German import volume in million tonnes	Primary impacts on the environment	Amount of land use	Biodiversity loss	Ecosystem services loss
Soy (beans, meal or oil)	Meat, dairy products, eggs	Brazil, US	5.8	Land conversion; agricultural intensification	🔴	🔴	🔴
Palm oil	Food products, soap, cosmetics, biofuel	Indonesia, Malaysia, Thailand	0.7	Land conversion of forests (peatland)	🔴	🔴	🔴
Rapeseed	Food products, biofuels	Australia, Ukraine Canada	1.4	Land conversion of grasslands; agricultural intensification	🔴	🟠	🟠
Bananas	Fruit	Ecuador, Costa Rica, Columbia, Peru	0.6	Agricultural intensification	🟠	🟠	🟠
Coffee	Beverage	Brazil, Vietnam, Honduras, Indonesia	0.6	Agricultural intensification and expansion	🔴	🟠	🟡
Tea	Beverage	India, China	0.1	Agricultural intensification and expansion	🔴	🟡	🟡
Cacao	Chocolate	Ivory Coast, Ghana	0.5	Agricultural intensification and expansion	🔴	🟠	🟡
Cotton	Clothes	India, China, Pakistan, Turkey	1.0	Agricultural intensification; irrigation	🔴	🔴	🔴
Wood for timber	Construction	Norway, Belarus Russia, Ukraine	2.6	Degradation of forests	🟡	🟡	🟠
Wood manufactures	Manufactures	Russia, China, Belarus, Brazil	1.2	Degradation of forests; installation of plantations	🟡	🟡	🟠
Wood for pulp	Paper, cardboard	Brazil, Switzerland, US, Chile, Uruguay	1.9	Degradation of forests; installation of plantations	🟢	🟠	🔴
Iron (ore) & steel	Construction, cars, machines	Brazil, Canada	14.7 steel and iron ore & 3.7 steel and iron	Land conversion; toxic waste and effluents	🟡	🔴	🔴
Aluminium (ore)	Cars, packaging, electronics	Guinea, Brazil, United Arab Emirates	2.3 aluminium ore & 0.4 aluminium	Land conversion; toxic waste and effluents	🟢	🔴	🔴

Commodity	Main consumer goods	Major producing countries (outside the EU)	Annual German import volume in million tonnes	Primary impacts on the environment	Amount of land use	Biodiversity loss	Ecosystem services loss
Copper (ore)	Electronic devices	Brazil, Canada Russia	0.4 copper ore & 0.03 copper	Land conversion; toxic waste and effluents	● (green)	● (red)	● (red)
Lithium[38]	Batteries	Chile, Argentina	0.003	Land conversion; large-scale evaporation	● (orange)	● (orange)	● (orange)
(Hard) Coal	Energy	Russia, US, Australia, Colombia, Canada	19 including 7 surface mining	Surface mining waste and effluents	● (yellow)	● (red)	● (red)
Petroleum	Energy, petrochemistry	Russia, Norway, Kazakhstan, Libya, Nigeria	85	Fragmentation of undisturbed landscapes, surface mining waste and effluents	● (green)	● (orange)	● (orange)
Natural gas	Energy	Russia, Norway	68	Fragmentation of undisturbed landscapes	● (green)	● (orange)	● (orange)

Legend

Amount of land use – land used to cultivate or extract the product:
● (red) > 500 km^2 ● (orange) 100 – 500 km^2 ● (yellow) 10 – 100 km^2 ● (green) < 10 km^2

Biodiversity or ecosystem services loss – estimated level of concern:
● (red) very high ● (orange) high ● (yellow) medium ● (green) low

Table 5: Impacts of the production of goods and raw materials imported into Germany from outside the EU on biodiversity and ecosystem services in the countries of origin

Evaluation of large-scale trends based on key literature

The ratings in Table 5 are based on a broad review of key literature on the impacts of the individual material flows. Biodiversity loss is deemed to be of *very high concern* when cultivation or extraction occurs in biodiversity hotspots or when key biodiversity areas are affected and land conversion is happening on a large scale, like in the cases of soy, palm oil or iron ore. The ratings *high and medium concern* mean that these aspects were only partially present or in a weaker form. Rapeseed cultivation or hard coal extraction, for example, do not affect key biodiversity areas. The rating *low concern* indicates the absence of any major threats to biodiversity.

Loss of ecosystem services is rated to be of *very high concern* when soil or natural vegetation is eliminated on a large scale, air, soil and/or water bodies are affected, landscapes are fragmented, pollinators are endangered and toxic pollution is present. Lower ratings are given when these aspects are only partially present or in a weaker form. Clearcutting of timber wood, for example, received a *high concern* rating and coffee cultivation a *medium concern* due to its contribution to permanent soil erosion. *Low concern* indicates the absence of any major threats to ecosystem services.

Agricultural production impacts biodiversity and ecosystem services most severely

The analysis shows that agricultural products have the greatest impact on biodiversity and ecosystem services and result in the largest land-use changes. Soybean, palm oil and cotton are rated red across all the criteria. For this reason, cotton and soy were analysed in more depth (chapter 4 and 5). The study confirms the findings of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services not only for agricultural production but also for mining products.

Despite the limited amount of land affected directly (see yellow and green rating for area of land occupied), mining still has a significant impact on biodiversity as a result of emissions of highly toxic pollutants that affect the air, soil and water quality as well as water quantity in terms of availability for nature and people.[39] Particular attention should be paid to iron and steel, which cause large-scale devastation in key biodiversity areas. In view of the large number of different metal ores with very specific environmental impacts, criteria other than absolute quantity were used to select a case study for mining. Instead, the focus was on materials for which demand is expected to increase considerably in the near future. In view of the politically backed increase in e-mobility and the huge demand for battery and storage systems, lithium was selected.

Wood harvesting is one of the three major drivers of land-use change, with logging contributing to an overall reduction of 290 million hectares of native forest cover between 1990 and 2015.[40] German wood consumption has its share in this, albeit comparatively small. Managed forests in major export countries are likely to have lower levels of biodiversity than natural forests but unlike land converted for agricultural purposes, forest ecosystems are at least maintained. However, artificial plantations for the pulp and paper industry – in particular in tropical countries such as Brazil – have more severe environmental impacts.

Impacts from mining (rather than combusting) fossil resources are relatively contained, though examples such as petroleum mining in Nigeria or oils spill accidents demonstrate the severe local and regional biodiversity impacts fossil resource extraction can cause. More severe effects are caused by open pit mining, especially of hard coal. For fossil fuels, the strongest impact on biodiversity and ecosystem services, however, is indirect – through its contribution to climate change caused by greenhouse gas emissions released during combustion.

4 The Case of Cotton – Slow Fashion to Protect Biodiversity and Ecosystem Services

4.1 Cotton trends: global production remains constant

Clothing consumption in industrialised countries is characterised by an era of 'fast fashion'. The majority of clothing is short-lived, inexpensive and sold by large fashion chains. This trend has led to a doubling of clothing consumption since 2000. German consumers purchase an average of 60 items of clothing each year, which they wear only half as long as they did 15 years ago, and many are disposed of within a year of being produced.[41]

A large proportion of these clothes are made partially or entirely of cotton. Although synthetic fibres (mostly polyester) are increasingly popular, cotton is still a key staple for the clothing industry and currently accounts for around 30 percent of all textile fibre consumption.[42] Since growing demand is largely met by a strong increase in synthetic fibres, total global cotton production has remained more or less constant in recent years, at around 25 million tonnes per year.[43] Nearly one million tonnes of which is consumed in Germany – 760,000 tonnes of textiles and 218,000 tonnes of fibres, yarn and fabric. This is equivalent to four percent of total global cotton consumption, even though the German population comprises only around 1.1 percent of the global population.

Clothing makes up 74 percent of cotton fibre use, the rest is used for furniture, vehicle interiors and other textiles. In addition to textile products, cotton plants are used for a variety of other purposes. For example, cotton seeds are used in the production of refined oils, such as margarine, refinery residues are used to produce cosmetics, waterproofing and oil cake, and seed coats are used as livestock feed and fertiliser. This report focuses on cotton for clothing consumption.

4.2 Germany's cotton: every second garment is grown in India, China or Pakistan

The major producers of cotton for consumption in Germany are India, China, Pakistan and Turkey. Together they account for 64 percent of the German cotton supply (Figure 7). It is worth noting that although the US and Brazil are among the major global producers, they are only of minor relevance for Germany.

Domestic textile production in Germany became economically uncompetitive in the second half of the twentieth century and textile production shifted almost entirely abroad. Today, 90 percent of the clothing consumed in Germany is produced elsewhere in the world. Imports of cotton textiles into Germany come mainly from Turkey and Bangladesh. China and India, along with the Netherlands and Pakistan, also supply the German market with cotton textiles (Figure 8). The geographical distances between cotton cultivation and textile production and consumption illustrate the complex supply chains of cotton. They pose a major challenge to controlling environmental standards and other efforts to increase the sustainability of cotton production.

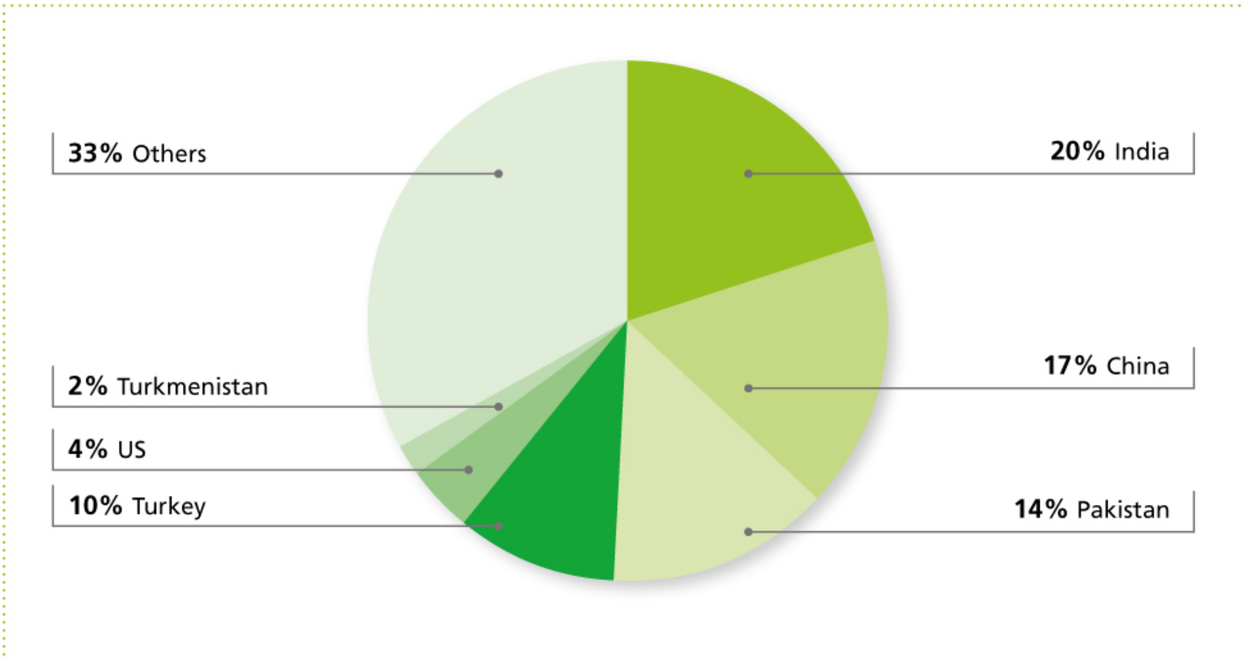


Figure 7: Origins of cotton imports to Germany in 2016; *Source: Eurostat Comext*

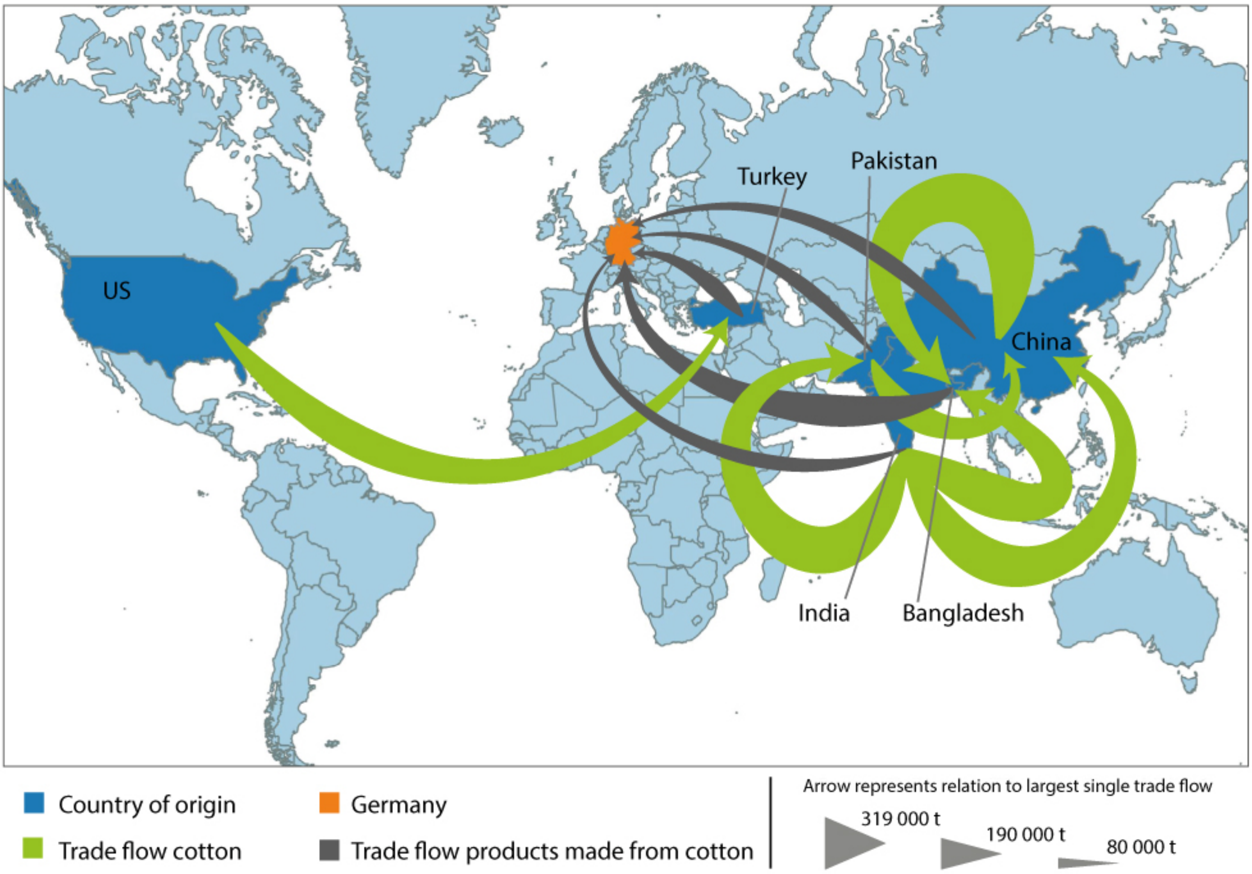


Figure 8: **Trade flows of cotton and cotton products imported into Germany from outside the EU in 2016 (in tonnes);** *Source: Eurostat Comext*

4.3 Consequences of cotton production: drying-up, salination, toxic residues, habitat loss

Cotton is a water-intensive, pest-prone crop, grown primarily in semi-arid, water-scarce regions. Although total global cotton production has remained relatively constant in recent years, its cultivation has multiple negative effects on biodiversity and ecosystem services (Table 6).

Whole regions run dry as demand for water rises

The large-scale irrigation of cotton can interfere with whole aquatic ecosystems. The problem has been analysed for decades. The most well-known example is the loss of 85 percent of the surface of the Aral Sea – formerly the world's fourth-largest lake – due to its tributaries being diverted for cotton production in Kazakhstan and Uzbekistan. This led to the extinction of nearly all native fish and many bird

Commodity	Major producing countries (outside the EU)	Annual German import volume	Amount of land use	Biodiversity loss	Ecosystem services loss
Cotton	India, China, Pakistan, Turkey	1 million tonnes	●	●	●

Table 6: **German cotton imports and impact rating on biodiversity and ecosystem services in producing countries** (for legend of colour rating see Table 5 on page 29)

species. Similarly, in the Indus Delta in Pakistan, cotton production has contributed to substantial reductions in water flows since 75 percent of the water has been diverted for irrigation, including for cotton. Another example is the Punjab area of Pakistan, which is affected by water drainage for cotton irrigation, leading to falling ground water levels and the discharge of saline water and hence a loss of valuable wetland.

Approximately 2,300 million cubic metres of water are required annually to meet German demand for cotton. This is enough water to fill 920,000 Olympic-sized swimming pools. It is important to note that the amounts of water required vary widely between different cultivation sites. Figure 9 shows the volumes required in major cotton-producing countries. They range from very low volumes required for rain-fed cultivation in Brazil to extremely high volumes used for cotton cultivation in Central Asia or Egypt. The global average is 1,820 cubic metres of irrigation water per tonne of cotton. Cotton destined for the German market is produced in irrigation-intense areas and requires an average of 2,280 cubic metres per tonne, more than the global average.[44]

Large-scale irrigation can cause salinisation – the build-up of salts in the soil. This problem affects dry regions, in particular, where evaporation levels are high. The salts degrade soil fertility to the extent that plants can no longer be cultivated there. For instance, around half of the irrigated land in Uzbekistan has suffered severe productivity losses due to salinisation.

Agrochemicals contaminate land, wildlife and water

The widespread use of agrochemicals is a key concern in cotton-producing regions. Cotton cultivation relies heavily on pesticides and other agrochemicals. In 2014, 5.7 percent of global pesticide use was attributed to

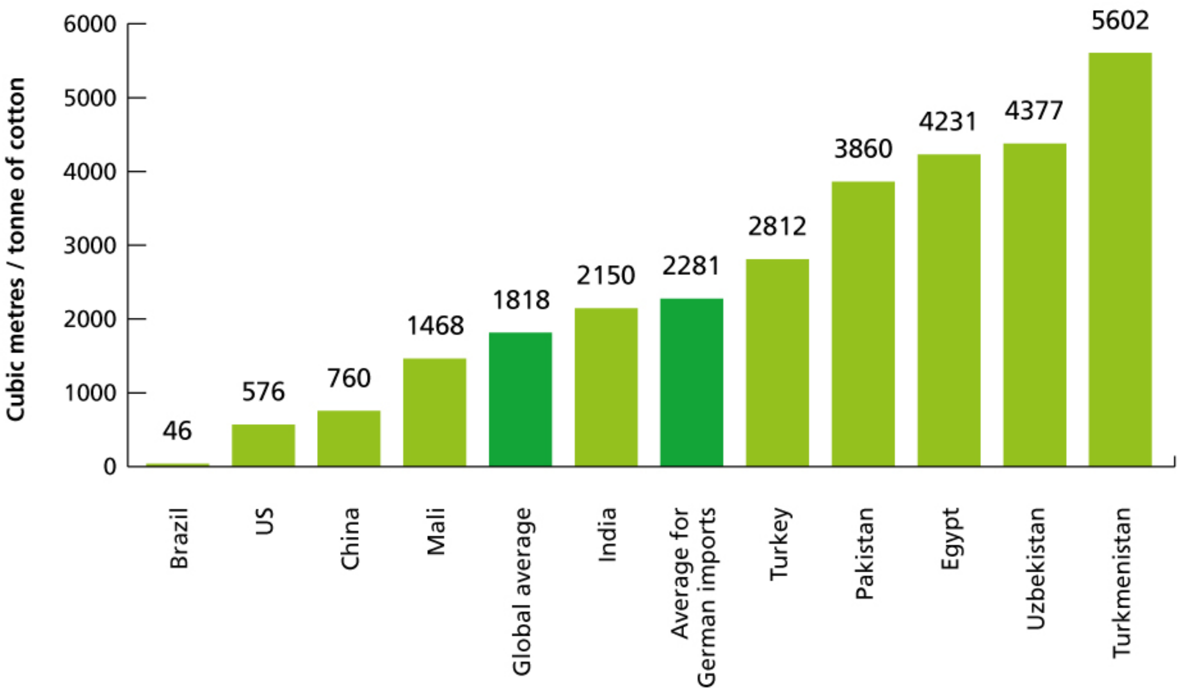


Figure 9: Average irrigation water usage per tonne of cotton production by country
Source: Chapagain et al. (2006), see endnote 44

conventional cotton production, which occupies around 2.3 percent of global agricultural land. Insecticide use for cotton even accounted for 16.1 percent of all global insecticide sales.[45]

Agrochemicals affect biodiversity, directly by immediate toxicity, or indirectly through long-term accumulation in soil and water bodies. While the degree of toxicity of some chemicals is disputed, numerous studies have documented the overall damaging effects of agrochemicals on biodiversity.[46]

Monocultures of genetically modified crops affect biodiversity

Today, more than 80 percent of cottonseeds are genetically modified. Most varieties carry traits for herbicide resistance or produce insecticides against the cotton bollworm, which is a major pest in cotton cultivation. Although pesticide use declined in response to the introduction of genetically modified cotton varieties, the cultivation of these crops in industrial-scale monocultures has led to a growing resistance to pesticides, in recent years.[47] The trend to limit cultivation systems to a single high-performance cultivar may be viewed as the most extreme form of reduction of genetic diversity within a species. As soon as a pest becomes resistant, the entire crop is under threat and growers often resort to heavy pesticide use to avoid crop failures. Monoculture-based production systems and genetically modified varieties may thus reinforce each other. However, the overall effect of pest-resistant crop use on pollinator abundance and diversity is unknown.

Cotton cultivation has led to habitat loss

A large share of land cultivated with cotton has been used for this purpose for many decades. However, some areas, including natural forests, have been converted to cotton cropland in more recent years. Tugay forest in the Amu Darya Basin in Central Asia has, for example, lost 80 percent of its area to cotton production. The forest provides a natural habitat for various flora and fauna, including over 150 different species of bird.

An area of approximately 13,000 square kilometres – nearly the size of the German Federal State of Schleswig-Holstein – is required to satisfy German demand for cotton. Since global cotton production levels remain constant, no significant expansion in the total cultivation area is expected in the near future. However, as soil quality declines, cotton cultivation may shift to other areas and potentially endanger natural habitats.

Textile processing is harmful for people and the environment

In addition to the impacts of primary cotton production, processes such as dyeing and textile finishing lead to further environmental pressures. The textile industry uses around 700 chemical agents and 1,500 different dyes – approximately 250,000 tonnes of dye and four million tonnes of textile auxiliaries, leaches and salts annually. A single T-shirt requires 150 grams of chemicals, many of which are highly toxic. Since environmental and health protections in many manufacturing countries are weak, on average, 20 percent of dyes and 80 percent of auxiliaries are discharged into the sewage system, making their way into rivers.[48]

Compounding these ecological concerns is the negative social impact associated with the cotton and textile industries. Although they provide employment for many local workers, the working conditions on plantations are often poor and pesticides and chemical agents subject them to many health hazards. Workers' rights are routinely violated and child labour is common in the textile industry. Furthermore, water-scarcity due to irrigation can lead to a limited water supply for local populations.[49] The ecological and social impact of the textile industry is serious and must be improved. However, this report concentrates primarily on cotton cultivation.

Key findings

Table 7 summarises the influence of cotton cultivation on biodiversity and ecosystem services worldwide. The rating shows that cotton cultivation severely threatens biodiversity and ecosystem services, primarily through agricultural intensification and large-scale irrigation.

4.4 Mitigating the impact of cotton production – options for action

Current trends in fast fashion have been fuelled by (social) media and advertising. They have led to an overconsumption of (cotton) clothing, posing urgent challenges for the environment. A large-scale shift in production and consumption patterns is needed to mitigate these effects. Options for action include raising consumer awareness, encouraging people to purchase certified organic cotton, promoting the repair, reuse and recycling of cotton textiles and increasing the share of alternative renewable fabrics.

Main drivers	Impact on biodiversity	Impact on ecosystem services
Land conversion	→ Loss of highly biodiverse forests and grasslands → Destruction and changes in habitats threaten species	→ Depletion of permanent soil cover and associated functions → Depletion of carbon storage → Loss of buffering soil functions
Agricultural intensification	→ Reduced biodiversity due to intensive use of agrochemicals, especially pesticides → Decreased agrobiodiversity due to monoculture production → Loss of genetic diversity due to increasing use of genetically modified varieties	→ Contamination of river systems, groundwater and aquifers → Long-term persistence of pollutants in soils, reducing soil function → Reduction of pollinators and associated functions
Irrigation	→ Loss of aquatic habitats due to lake and river drainage	→ Severe changes in the hydrology of entire landscapes leading to water scarcity → Increased salinisation degrades soil fertility

Table 7: Main impacts of cotton cultivation for biodiversity and ecosystem services

4.4.1 Raising awareness for 'slow fashion'

The greatest positive factor for reducing the impact of the textiles sector on ecosystem services and biodiversity would be a reduction of overall cotton and clothing consumption. Encouraging sufficiency lifestyles is vital for achieving sustainability and reducing the amount of clothing consumed. Sufficiency starts with individual lifestyles and promoting slow fashion, where consumers buy fewer items of clothing, but of greater quality and produced under higher ecological standards. The narratives of slow fashion also emphasise the value of clothes by celebrating the art of making them and the people responsible for their production.

Clothing is part of an individual's visible social identity and is often used to express affiliation to social groups. It thus fulfils social functions that should not be dismissed. Individual lifestyles, habits and routines determine what items of clothing are purchased and how they are used. While a relatively large share of consumers are aware of the social impacts of the textile industry, such as poor labour conditions and health hazards, most are unaware of the ecological consequences of the production, use and disposal of apparel. Increasing consumers' awareness of the impacts of the textile industry on ecosystem services and biodiversity, for example through educational programmes and campaigns, is crucial and needs to go hand in hand with other measures.

4.4.2 Increasing the market share of certified organic cotton

The global share of certified organically produced cotton is currently below one percent. Germany has one of the largest markets for organic cotton textiles worldwide, yet the share of certified cotton still remains relatively small. Targets have been set to increase this share. The Partnership for Sustainable Textiles, a multi-stakeholder partnership initiated by the German Federal Ministry for Economic Cooperation and Development (BMZ), aims to increase the share of organic cotton to 20 percent by 2025.[50]

There is a large potential for a shift towards biodiversity-friendly production by promoting organic cotton. Since no hazardous pesticides are used in organic cultivation, it has a positive impact on biodiversity and ecosystem services, protecting pollinators and wildlife and reducing soil and water contamination also in adjacent ecosystems. Crop rotation, which is required in organic cultivation schemes, also enhances biodiversity. Studies show that well-planned crop rotation positively affects the

population densities of various insects, thus minimising pest pressures.[51] Such practices also have positive effects on soil fertility. A continuous supply of organic material improves soil quality and water retention. In addition, organic cotton does not use genetically modified seeds. However, organic cotton cultivation may lead to greater land use since average yield rates per hectare are typically lower than for conventional cotton. Yield differences vary widely from five to 34 percent, depending on site characteristics, climate conditions and management practices.[52] Yet, greater land use is unlikely to outweigh the overall benefits to biodiversity and ecosystem services from organic cotton cultivation.

Promoting independent certification standards is key

Increasing the market share of organic cotton requires ambitious, independent certification standards, taking account of the entire supply chain. The textile industry has long used labelling to increase the transparency of their products, allowing consumers to make informed purchasing decisions. More than one hundred different textile labels have emerged since the 1980s. However, the criteria vary widely and not all labels guarantee high environmental standards along the entire supply chain. Some labels only consider potential health effects related to wearing the final product or are limited to social criteria. In terms of biodiversity and ecosystem services, many labels set standards on the use of agrochemicals, but few consider the biodiversity effects of large-scale cultivation or sustainable irrigation systems. Current certification schemes that set high standards include the Global Organic Textile Standard (GOTS, see box), the EU eco-label and the German Blue Angel eco-label, although no certified products are available yet for the latter. Surveys show that many consumers are overwhelmed by the number of labels. It is, therefore, vital to increase awareness and specifically promote those labels that set high environmental and social standards

Public procurement could be a driver of biodiversity-friendly cotton consumption

Public authorities play an important role in shifting production and consumption patterns. Since they tend to wear out comparatively quickly, textiles are bought regularly and in large quantities, primarily in the form of apparel. German Federal Agencies annually spend around 100 million euros every year on procuring textiles and workwear, and this figure does not include spending by the federal states and municipalities.[53] The considerable economic potential of the public sector has the leverage to increase the share of sustainably produced textiles and hence lessen the impact on biodiversity and ecosystem services. Due to their market power, public administrations have a key role and responsibility as a consumer of textiles.

On the federal level, Germany took the first step in 2015 by pledging to procure 50 percent of its textiles in accordance with ecological and

The Global Organic Textile Standard (GOTS)

The Global Organic Textile Standard (GOTS) is a textile processing standard for organic fibres. It sets ambitious environmental and social standards along the entire supply chain – from cultivation through ecologically and socially responsible manufacturing processes, up to product labelling through independent certification. GOTS has certified facilities in over 60 countries. The standard distinguishes between 'GOTS Organic' textiles, which must contain at least 95 percent certified organic fibres and 'GOTS Made with Organic' textiles, which require a minimum of 70 percent.

www.global-standard.org

social criteria (such as those set by the Blue Angel eco-label, the EU eco-label or the Global Organic Textile Standard), as part of the Sustainability Measures Programme.[54] The task now is to fully implement and expand upon these goals. More ambitious targets and expanding this pledge to include the municipal and federal state level are essential.

4.4.3 Promoting the repair, reuse and recycling of cotton textiles

An item of clothing lasts an average of 3.3 years before it is discarded. The average lifetime of apparel varies between 2.7 years for T-shirts and tops and 4.5 years for coats. Prolonging the use of clothing can have a positive impact, especially if it contributes to an overall reduction of clothing consumption. It is estimated that extending the lifespan of clothing by nine months will reduce negative environmental effects, including water footprints by up to one-third.[55]

Digitalisation and e-commerce have changed the way we purchase clothes. Instead of trying out clothes in person, consumers are increasingly ordering clothes in various sizes to be sent to their homes and returning those that do not fit. This process shortens the lifespan of clothes. In Germany, around 280 million deliveries are returned each year. Around 11 million of these are being directly disposed of for economic reasons.[56] Many of them contain new clothes.

Innovative business models may incentivise clothing reuse

In recent years, several innovative approaches to counter these trends and extend the lifespan of clothes have emerged. These include online subscription models and platforms for exchanging second-hand clothing. One example, the Norwegian company Fjong (see box), gives users the opportunity to lease clothes for everyday wear and special occasions or rent out their own clothes. Similarly, the German Platform Kleiderkreisel allows its more than twenty million users to sell and gift second-hand clothing online. A recent study based on a life-cycle assessment of a cotton T-shirt shows that the use of such platforms can have positive effects on biodiversity and ecosystem services. However, the study warns that due to rebound effects, such platforms do not necessarily reduce overall consumption. The money saved by buying second-hand clothing and the perceived environmental benefits may even increase overall apparel consumption.[57] It is, therefore, important that such approaches are accompanied by cultural change. A broad public discourse is needed in order to generate awareness about the environmental impact of our textile consumption and facilitate a shift towards placing greater value on individual products.

Incentivising repair to prolong textile use

Promoting the repair of clothes may contribute to their longevity, especially since repair

Renting your clothes – the example of Fjong

Fjong is a web-based sharing platform that provides access to clothes for sharing and renting. The aim of the initiative is to prolong the lifetime of garments, making sure they are used until they are worn out – thereby reducing the need to buy something new. Fjong's goal is to make it easier to rent than to buy. The platform allows customers to browse through an extensive range of outfits, and book them for the time periods needed. Clothes can be picked up at a showroom or delivered to the customer's home. After use, customers return the item and Fjong ensures it is cleaned and maintained in an environmentally-friendly manner. The platform gained more than 40,000 users and became economically profitable within two years. The inventory is mostly based on clothes owned by private people, professional designers, brands and retailers. The rental revenue is split equally between Fjong and the clothing owner.

www.fjong.co

services are currently rarely used. Surveys show that half of all Germans have never used a repair service for clothes and only one in seven Germans uses such services regularly.[58] Studies also reveal that there would be a significantly greater willingness to use such services, if they were cheaper.[59] The EU Commission's Circular Economy Action Plan recommends economic incentives, such as fiscal reforms, to encourage clothing maintenance and reuse.[60]

Sweden, for example, has recently aimed to increase the use of repair services by reducing the sales tax on such services from 25 to 12 percent. In addition, Swedish citizens may offset repair costs of up to 2,600 euros from their taxes. Other EU Member States have introduced similar measures, however, there is no data on the effectiveness of such measures. They are likely to be comparatively small, given that the majority of clothing is disposed of due to a change in the owners' taste, size or needs and only around five percent due to wear and tear.[61] Nevertheless, in Sweden, media coverage of the changes in tax legislation contributed to national debates on sustainable consumption.

Fibre-to-fibre recycling faces technological limitations

Around one quarter of used clothing collected in Germany is recycled.[62] However, the majority of recycled fibres are not used to manufacture new clothing, but are down-cycled as they are shredded and processed into cleaning rags or insulating and filling materials. Fibre-to-fibre conversion, which is the processing of dissembling the fabric while preserving the original fibres, which are then reused, is less common. Since the fibre length is reduced during this process, virgin fibres are typically of higher quality.[63] To create usable recycled yarns, large quantities of new fibres have to be added. Hence, new products usually make up a relatively small percentage of recycled fibres. Another issue for the recycling industry is that many clothes today are fibre blends. This makes recycling challenging, since different types of fibres first need to be separated. Although high quality recycling is viable in general, the costs exceed those of cotton production, making recycling not always a cost-effective option.

In terms of biodiversity and ecosystem services, supporting circular economy approaches and increasing the recycling rates of cotton is highly favourable, as it can contribute to a reduction in raw material production.

4.4.4 Promoting clothes from alternative renewable fibres

Textiles based on renewable raw materials, such as hemp or linen from flax plants provide alternatives to cotton that may help ease pressure on the environment. Compared to conventionally grown cotton, hemp and linen require significantly less water. They also need fewer pesticides and can easily be cultivated in the European climate. Their annual fibre yield per hectare is around twice as high as the global average yield of cotton, reducing land use pressures (Table 8).[64] As a result, hemp and flax are thus considered more biodiversity-friendly than cotton.[65] The energy required to produce these fibres is also considerably less. Other renewable fibres, such as bamboo, also have advantages, but rely on heavy chemical processes resulting in an additional negative environmental impact.

Fibre	Cotton	Hemp	Flax (Linen)
Climatic requirements	Subtropical climates	Mild climates, humid atmosphere	Maritime, temperate climates
Main growing areas	India, China, US, Brazil, Pakistan	Europe (e.g. Netherlands, France)	China and Europe (e.g. France, Belgium)
Irrigation	Irrigation of 73 percent of cotton producing areas	Almost no irrigation required	Almost no irrigation required
Water usage	3,000 to 7,000 litres per kilogramme of fibre[69]	2,100 litres per kilogramme of fibre[70]	1,900 litres per kilogramme of fibre[71]
Application of agrochemicals	Approximately one kilogramme per hectare[72]	No agrochemicals required[73]	Small amounts of herbicides are used[74]
Average global fibre yield	790 kilogrammes per hectare[75]	2,000 kilogrammes per hectare (range from 400-7,500)[76]	1,100 kilogrammes per hectare[77]

Table 8: **Characteristics, growing requirements and average yields of cotton, hemp and flax**

Hemp and linen: biodiversity-friendly alternatives to cotton

Hemp was one of the most important fibres in the textile industry in the 17th and 18th centuries and was still widely used in the first half of the 20th century.[66] However, cultivating hemp was prohibited in Europe from 1961 to 1992, due to its use as a recreational drug. Current regulations in Germany allow hemp cultivation with psychoactive component levels of less than 0.2 percent. (Narcotic hemp has psychoactive components of eight to ten percent or more.) Industrial hemp, however, is frequently confused with narcotic hemp and consequently has an image problem. With a market share of only around 0.3 percent, the relevance of hemp for the fashion industry today is relatively small, but increasing. In the EU, the cultivation area of hemp has quadrupled since 2011, and now comprises around 33,000 hectares.[67] The main producers are France, the Netherlands and Lithuania. The area used for hemp cultivation in Germany is 2,148 hectares and, therefore, comparatively small.[68] However, due to its modest climatic requirements, hemp has the potential to grow in any European country.

The main barriers for hemp as a textile fibre are the lack of efficient processing technologies and the inferior wearing comfort of the final product. The hemp processing industry has never caught up from the 30 years of standstill in research and technical developments and processing technologies cannot currently compete with those of cotton.

Flax is the oldest of all plant fibres. It played a major role in textile raw material production well into the 19th century, when more than 200,000 hectares where cultivated in Germany alone. At the start of the 20th century, it was almost completely replaced by cotton and later also by synthetic fibres. In recent years, however, ecological fashion labels, in particular, have taken up the material again, often blending it with other materials to ensure wearing comfort. More than half of global flax production comes from Europe, primarily France, Belgium and the Netherlands.

To increase the competitiveness of alternative renewable fibres, investments in processing technologies are needed and consumer awareness for the ecological advantages of such fibres needs to be prioritised.

Synthetic fibres may cause microplastic pollution

Synthetic fibres, such as polyester and polyamide, are not sustainable alternatives to cotton. In recent years, it has become apparent that the fibres break during washing and after repeated wear. There is concern that these microparticles end up in the oceans and our food chains. Such microplastic pollution is harmful for the aquatic life that inevitably digests them – from zooplankton and small fish to sharks and whales. The production of synthetics also requires large amounts of fossil resources. Synthetic fibres do not, therefore, represent a sustainable alternative to natural materials.

4.5 Key takeaways

By far the most effective way to conserve biodiversity and ecosystem services is to reduce overall clothing consumption. The amount of cotton textiles consumed per capita has a vital overall impact. Every item of clothing bought and discarded shortly thereafter – and in the worst case, never even worn – negatively impacts the environment. Extending the lifespan of clothing by buying second-hand clothes, repairing or upcycling them, can reduce the impact on biodiversity and ecosystem services, especially if it decreases overall consumption.

Increasing the market share of certified organic cotton by promoting labels with high ecological and social standards and setting public procurement quotas may help shift production in a more sustainable direction. Promoting alternative natural fibres such as hemp or linen may also contribute towards conserving biodiversity and ecosystem services. From an environmental perspective, synthetic fibres are not recommended.

Measures for advancing sustainable cotton consumption include:

- Promoting a culture of slow fashion and launching campaigns and educational materials that focus specifically on the ecological impacts of the textile sector by identifying target-group specific narratives
- Fostering independent standards such as the Global Organic Textile Standard (GOTS), the EU eco-label or the Blue Angel eco-label to increase the market share of certified organic cotton
- Setting ambitious public procurement targets for organic and recycled fibres at all levels of government
- Supporting the development of innovative start-ups and initiatives that aim to increase resource efficiency, for example, through upcycling, renting and sharing concepts
- Incentivising the reuse and repair of clothing, for example, through fiscal incentives
- Increasing awareness for clothing made with sustainably produced renewable raw materials, such as hemp or flax from legal, sustainable and, where possible, local production
- Supporting research and development into processing technologies for hemp and flax as textile fibres
- Supporting international multi-stakeholder sustainability initiatives in the cotton and textile sector, such as the Partnership for Sustainable Textiles, and encouraging task forces or working groups to be set up to specifically focus on biodiversity and ecosystem services

5 The Case of Soy – Sustainable Meat Consumption for the Conservation of Biodiversity Hotspots

5.1 Soy trends: global production has tripled in the last two decades

Soy is one of the most important agricultural commodities worldwide and production is steadily growing. Since the 1990s, the global share of land cultivated with soybeans has more than tripled. In 2017, 126 million hectares were cultivated with soy worldwide.[78] This is an area around 3.5 times the size of Germany.

Meat and dairy consumption is the largest driver for soy cultivation

For the German market, soy is by far the largest agricultural import from outside the EU. Most soybeans are processed into 80 percent soybean meal or flour and around 20 percent soybean oil. The meal is rich in protein and almost exclusively used as livestock feed. Its high share of completely digestible protein makes it a key ingredient in animal nutrition and around

80 percent of German demand for soy comes from the livestock industry.[79] Around half of this share is used for poultry feed, 28 percent for pig feed and 21 percent for cattle.[80]

Average global meat consumption is currently around 34 kilogrammes per capita.[81] Forecasts estimate an increase in global meat consumption of 16 percent between 2016 and 2025.[82] At 59.7 kilogrammes per capita, meat consumption in Germany is significantly above the global average and has nearly doubled since the 1950s.[83] These high levels of meat and dairy consumption explain the large quantity of soy imports into Germany.

Around six percent of global soy production is used directly for human consumption, for example as tofu or soy milk. In addition, soybeans are used as oil or as additives in processed food and industrial processes and account for around 15 percent of the global soy harvest.[84] Soybean oil is also used in the production of biofuel and biodiesel.

5.2 Brazil and the US supply 80 percent of Germany's soy

Germany's annual demand for soy is 5.8 million tonnes. As can be seen in Figures 10 and 11, the largest shares are imported from Brazil (41 percent) and the US (33 percent). Although Argentina is the third largest soy producer worldwide and one of the world's largest producers of soy biodiesel, imports from Argentina only play a minor role in Germany.

Approximately 3.1 million tonnes of soy imports to Germany come in the form of meal. Soy meal is a by-product of soybean oil production and used to produce compound feed, of which Germany is Europe's largest producer. Although some of the compound feed and livestock is exported to other European countries, it is estimated that 2.35 million tonnes of soy remain in the German livestock feed market.

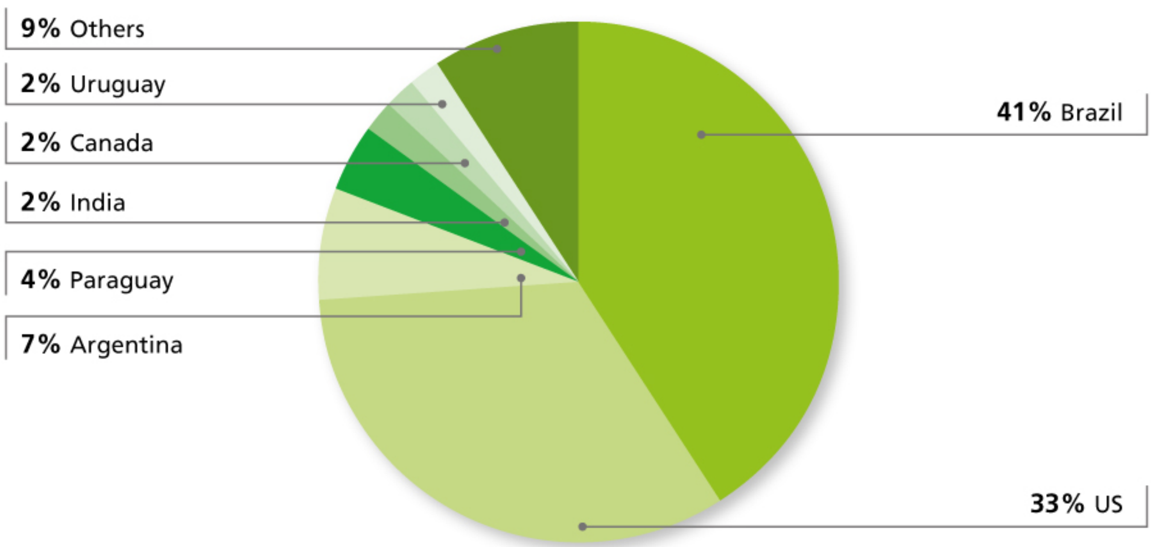


Figure 10: Origins of soy imported to Germany in 2016; *Source: Eurostat Comext*

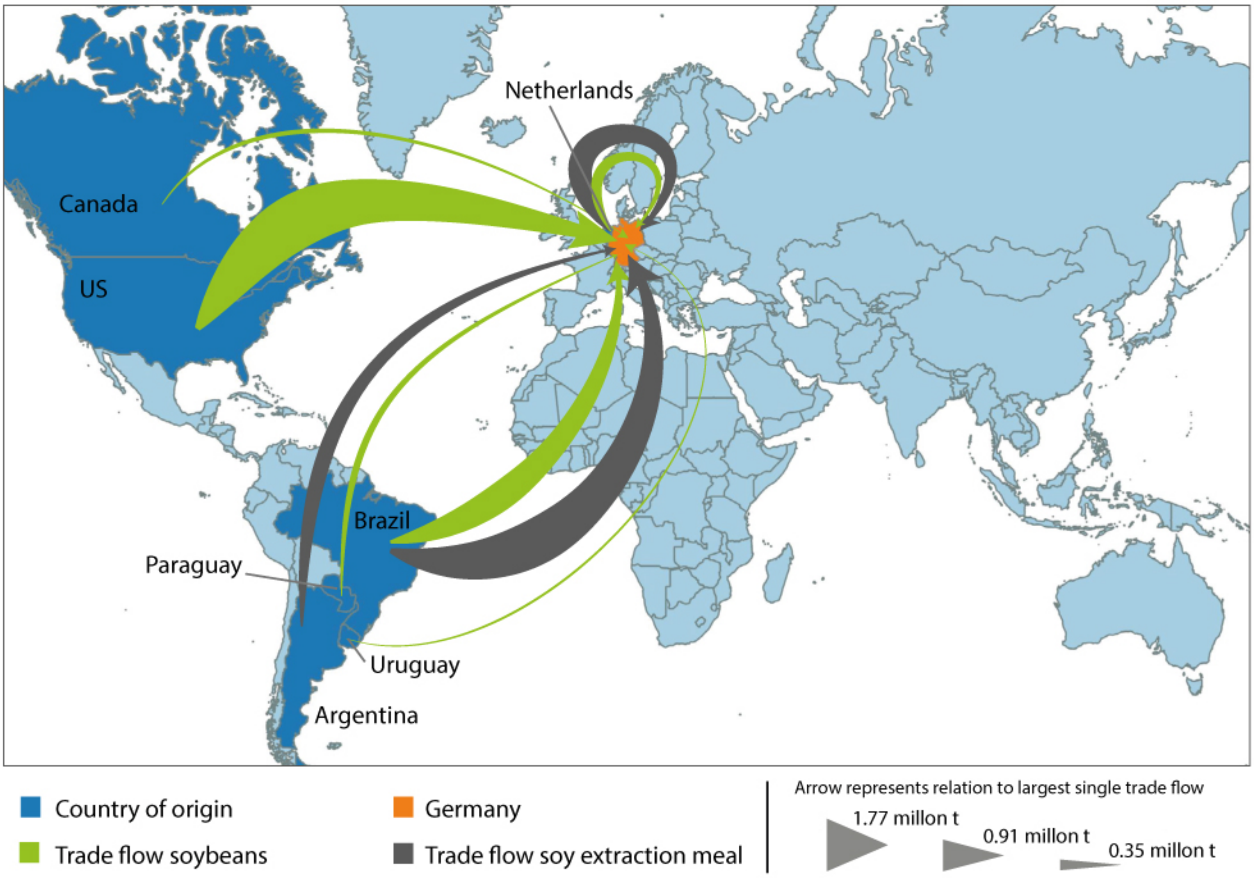


Figure 11: Trade flows of soybeans and soy meals imported to Germany in 2016 (in tonnes); *Source: Eurostat Comext*

5.3 Impacts of soy: biodiversity loss from deforestation and monocultures

Soy cultivation is expanding rapidly. It is often grown in monoculture plantations in highly biodiverse regions. There are a number of negative impacts on biodiversity and ecosystem services caused by soy cultivation (Table 9).

Deforestation and land conversion threaten biodiversity hotspots

To meet rising global demand for meat, more and more land has been converted to cultivate soy within the past 20 years, while the yield per hectare has stayed more or less constant. Between 2007 and 2017, the area used for global soy cultivation increased by 37 percent

Commodity	Major producing countries (outside the EU)	Annual German import volume	Amount of land use	Biodiversity loss	Ecosystem services loss
Soy (beans, meal and oil)	Brazil, US, Argentina	5.8 million tonnes	●	●	●

Table 9: German soy imports and impact rating on biodiversity and ecosystem services in producing countries (for legend of colour rating see Table 5 on page 29)

from 92 to 126 million hectares. In Brazil alone, there has been a 2.4-fold increase in soy cultivation since 2000 (Figure 12), with a cultivation area of 34,700 million hectares in 2018. This is roughly equivalent to the size of Germany.

More than two million hectares of land are needed to meet total German soy imports, which is equivalent to around half the size of Switzerland.[85] Agricultural land conversion is one of the main reasons for global biodiversity loss.[86] In South America, the expansion of farmland for soybeans leads to deforestation and the destruction of highly biodiverse areas. Paraguay and Argentina currently have the largest deforestation rates of one to two percent annually. Brazil loses 984,000 hectares of forest annually, which is the highest total area of deforestation per year anywhere in the world.[87]

These developments put areas with especially high levels of biodiversity, such as the Cerrado and the Amazonas region, under pressure. The Cerrado is one of the largest savannahs in South America and is home to around five percent of the world's species. By 2012, it was reported that only 20 percent of the Cerrado was still an intact biotope.[88] Production increasingly shifted to the Cerrado when a moratorium on deforestation for soy cultivation came into force in the Amazonas region in 2006.[89] In 2017, a coalition of non-governmental organisations and industry representatives launched a Cerrado Manifesto with the aim of protecting the region.[90] So far, only small parts of the Cerrado are under legal protection and a rise in land conversion has been observed since 2015.[91]

In the US, the expansion of soy cultivation has placed a great deal of pressure on native grasslands, including the prairies.[92] Since 2000, soy acreage has increased by 20 percent to 36 million hectares in 2017. The amount of prairieland converted to agricultural land between 2008 and 2012 was four times greater than between 1993 and 2008. Soy was the main crop planted on this newly converted land.[93] The native grasslands of the US are home to many pollinators and endangered bird species and are among the most threatened environments in the whole country.[94] Vulnerable species that can only be found in these ecosystems are endangered and some are at risk of extinction.

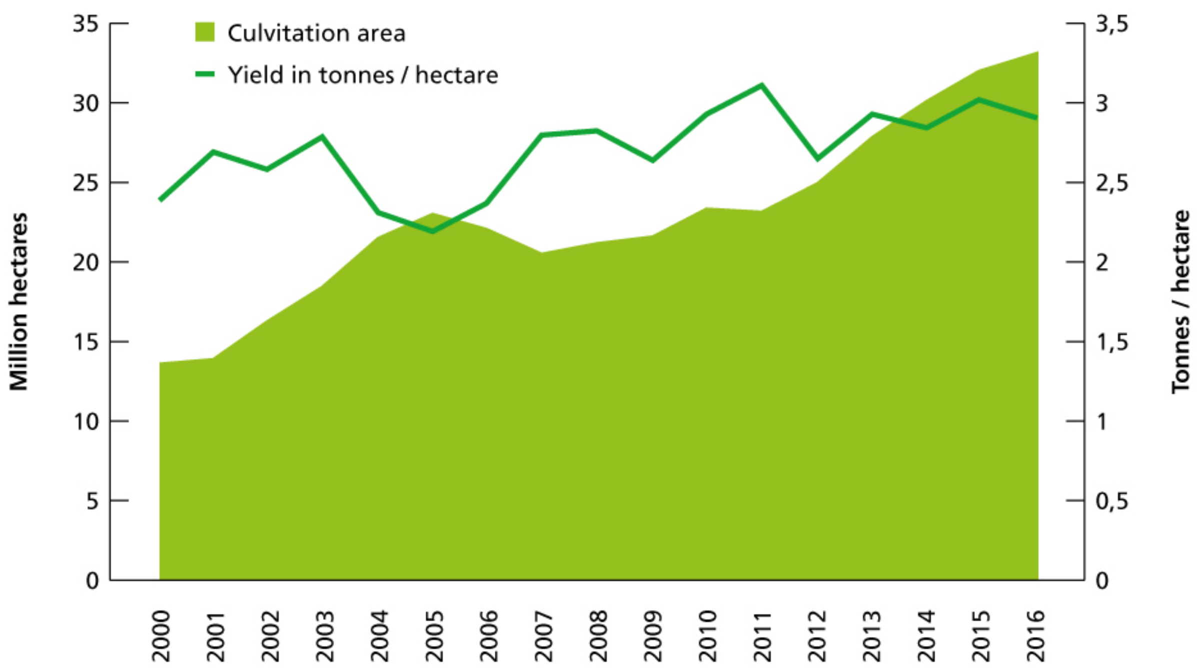


Figure 12: Development of cropland for soy and yields in Brazil. *Source: FAOSTAT*

Intense insecticide and herbicide use threatens pollinators and water bodies

A staggering 83 percent of the soy cultivated worldwide is genetically modified. This includes 90 percent of Brazilian, 94 percent of US American and 100 percent of Argentinean soy. Most of these crops are resistant to herbicides which allows for the widespread use of glyphosate (see box). Additionally, soy is treated with other herbicides to combat weeds that are already resistant to glyphosate as well as insecticides such as neonicotinoids.[95] Many of those chemicals are either banned in the EU or their environmental toxicity is heavily debated.[96] They are particularly harmful to insects, especially pollinators, and also aquatic organisms due to long-term accumulation in water bodies. Agricultural intensification and intensive pesticide use are among the main drivers of biodiversity loss.[97]

Expanding soy monoculture degrades soil functions and reduces biodiversity

Soy monocultures have a strong negative impact on soil quality and soil functions. Since soy plants do not have deep roots, repeated cultivation leads to soil densification. This affects the water and gas balance of the soil and has an impact on microorganisms caused by the accumulation of chemical residues. Moreover, intense agricultural practices without sufficient crop rotation deplete the soil of nutrients. By converting former grassland, savannahs, wetlands and (tropical) forests into farmland, soil erosion increases and carbon storage functions are lost. Monoculture cultivation also affects biodiversity directly. By limiting cultivation to a few genetically modified soy varieties, the genetic diversity of the fields is reduced and this affects the resistance of agricultural systems to pests and climate change.[98]

The use of pesticides and genetically modified cultivars

In 1996, the then US American company Monsanto succeeded in incorporating a bacterial gene into soybeans which allows plants produce a specific enzyme that makes them resistant to treatment with the herbicide glyphosate. Since then, so-called Roundup-ready soybeans, corn, rapeseed, sugar beet and cotton have been cultivated commercially, mainly in the US, Argentina, Brazil and Canada. In 2016, 185 million hectares were cultivated with genetically modified plants.

Today, 95 percent of genetically modified soy and nearly 80 percent of other genetically modified plants are herbicide-resistant, mainly to glyphosate.[99] Due to intensive use, more and more glyphosate-resistant weed species are emerging. Rising costs for controlling adapted weeds has led to a levelling off of the original advantages of the cultivation of genetically modified soy.[100] The amount of glyphosate used per hectare has more than doubled in recent years. For example, in 2012, soybeans in Brazil were treated with three times more pesticide than in 2000, whereas productivity only increased by 9.5 percent over the same period.[101] Similar observations were made in the US, where the freshwater-ecotoxicity of soybean cultivation tripled between 2002 and 2012 due to pesticide use.[102]

To enhance the effectiveness of glyphosate, additives such as polyethoxylated tallow amine are added.[103] This chemical is considered highly toxic and is no longer used in glyphosate on the German market.[104] Similarly, the use of paraquat and 2,4 dichlorophenoxyacetic acid increased in response to the increasingly glyphosate-resistant weeds.[105] A range of insecticides are also used, for example endosulfan, which is prohibited in the EU because of its toxic effects.[106] Similarly, in the US, the advantages of genetically modified crops have appeared to diminish due to invasive insect species, against which a multitude of insecticides like chlorpyrifos or lambda-cyhalothrin are used.[107]

The application of chemicals results in heightened freshwater toxicity, which is harmful to aquatic fauna and soil microorganisms. Not only does it threaten pollinators and decrease biodiversity, some of these chemicals are also proven to have adverse health effects on humans. Paraquat, in particular, has been criticised repeatedly for its poisonous effects on human health.

Key findings

Table 10 summarises the impacts of soy cultivation on biodiversity and ecosystem services. The rating shows that soy cultivation severely threatens biodiversity and ecosystem services, primarily through land conversion and agricultural intensification.

5.4 Reducing impact of soy consumption – options for action

To alleviate the pressure of extensive soy farming on biodiversity and ecosystem services, it is crucial to reduce the high levels of meat and dairy consumption. An increase in the share of sustainably produced soy and a shift towards locally and sustainably cultivated protein sources could also help. The following section considers various options for action.

5.4.1 Reducing meat consumption through promoting low-meat and vegetarian diets

Different food products have different impacts on biodiversity and ecosystem services. Plant-based diets usually have a much lower impact than food from animals. Their production usually causes lower carbon dioxide (CO_2) emissions and has less of an impact on biodiversity and ecosystem services. For example, soy consumed directly, for instance in the form of tofu, requires up to 32 times less land than is required for the production of beef.[108] Reducing meat and dairy consumption in industrialised nations to sustainable levels will be crucial, not only to meet climate change targets, but also to conserve biodiversity and ecosystem services.

Reduced meat consumption also has positive public health benefits. The German Nutrition Society recommends a weekly consumption of 300 to 600 grams.[109] The German average, however, is currently above one kilogramme. Reducing meat consumption is thus beneficial to the health of both the planet and people.

However, consumers are largely unaware of the consequences of their diet choices and the amount of soy they indirectly consume in the form of meat and other livestock products.[110] Dietary practices depend on our habits and daily routines and are ingrained in cultural practices. They are part of our lifestyles and individual preferences. This makes influencing food consumption patterns difficult. Consumer campaigns and educational efforts, nudging approaches, public procurement and economic incentives can provide starting points.

Public canteens and public procurement can set an example

Offering attractive vegetarian options in public canteens and catering, can contribute to a shift in perception and a more widespread

Main drivers	Impact on biodiversity	Impact on ecosystem services
Land conversion	→ Loss of highly biodiverse natural ecosystems, primarily forest, savannahs and grasslands → Destroyed and changing habitats threaten species	→ Depletion of permanent soil cover and associated functions → Depletion of carbon storage → Loss of buffering soil functions → Change in local climate regulation → Change in regional water cycles
Agricultural intensification	→ Reduction of biodiversity due to intensive use of agrochemicals, especially pesticides → Decreased agrobiodiversity due to monoculture production → Loss of genetic diversity due to increasing use of genetically modified varieties	→ Contamination of river systems, groundwater and aquifers → Long-term presence of pollutants in soils, reducing soil function → Reduction of pollinators and associated functions

Table 10: **Main impacts of soy cultivation on biodiversity and ecosystem services**

acceptance of low-meat diets. Schools, day-care centres, hospitals, care homes and staff cafeterias in the public sector provide meals to millions of people every day. Several countries have introduced meet-free days, such as the Donderdag-Veggietag in Belgium, Lundi Vert in France or the Meat Free Monday in the United Kingdom. Similar proposals in Germany have stirred controversy and some people perceived them as a restriction of personal freedom. Nevertheless, canteens can set examples by shifting their menus towards high quality, healthy low-meat (for example smaller meat portions) and vegetarian options.[111] Procurement guidelines and training for cooks and kitchen staff on how to prepare low and no-meat meals and sourcing sustainable products are key here.

Nudging, or influencing decision-making and behaviour through indirect suggestion and positive reinforcements, is also used successfully in canteens. For example, changing the order of menus or placing vegetarian options in a more prominent position can lead to shifts in behaviour.[112]

Consumer campaigns and educational efforts

A number of consumer campaigns have been launched by civil society actors, such as the Hidden Soy Campaign by the World Wildlife Fund.[113] The aim of such campaigns is to inform consumers of the negative implications of a particular choice and show alternatives. Although such campaigns are important, research shows that they are slow to change consumer behaviour. This can partially be explained by a phenomenon known as the value-action gap, which is the mismatch between an individual's values and their actual consumption behaviour. Although arguments for more sustainable options are often accepted, understood and valued, actual decisions are often driven by economic reasons and unconscious patterns, such as habits and situational circumstances.[114] Nevertheless, the secondary effects of information tools, such as changes in social norms and provoking larger public debates, are crucial.

Financial incentives have the potential to shift consumption

Financial incentives can help shift behavioural patterns, but must be designed so as not to harm disadvantaged groups. The introduction of subsidies for healthy meat-free food choices is only likely to be effective if subsidies are relatively high. In Germany, abolishing the current reduction in sales tax for meat, which is set at seven percent, rather than 19 percent, would lead to a decrease in meat consumption. Framing such a shift as an ecological duty or an animal welfare duty rather than a meat tax would be key to increasing acceptance. The biggest challenge in designing such incentives is how to make them socially equitable.

There are only a few precedents for government interventions aimed at promoting vegetarian diets. However, considerable efforts to dissuade the public from consuming sugar, alcohol or other unhealthy products have been made in the past.[115] Successful examples, such as the introduction of a tax on sugary beverages in the Californian city of Berkeley, which effectively reduced their consumption, might provide learning opportunities.

The overarching aim of such policies must be to build a coherent policy framework to enable, incentivise and empower consumers to choose sustainable food options and reduce their overall meat consumption.

5.4.2 Increasing transparency along the supply chain

Increasing transparency along the value chain is key to raising consumer awareness of the environmental aspects of food and facilitating informed decision-making. In the case of soy, labels on products that contain no genetically modified products have emerged, such as the ProTerra certification or the 'Ohne GenTechnik' label from the Association Food without Genetic Engineering (see box).

In the EU, it is mandatory to label genetically modified food. However, animal products fed with genetically modified feed do not fall under this legislation.[116] Yet, German consumers have a strong preference for products that have not been genetically modified. Recent surveys show that 93 percent of German customers demand labels for genetically modified feed in animal products while 79 percent would even favour a ban on all genetically modified organisms in agriculture.[117] Promoting such labels to increase transparency along the supply chain is thus likely to lead to a shift in consumption and production patterns. In recent years, a number of German supermarket chains such as Lidl, Aldi and Kaufland have voluntarily committed to supply up to 100 percent of their meat and dairy products free of genetically modified feed. Such voluntary efforts are crucial first steps.

'Ohne GenTechnik' Label

'Ohne GenTechnik' (translates as: without genetic engineering) is a label introduced in 2009 by the Association Food without Genetic Engineering. It certifies that animals have not been fed with genetically modified soy for a certain period prior to slaughter. The length of this period varies from ten weeks for poultry to twelve months for beef. The label is increasingly popular. In 2018, products worth 98 billion euros were sold under this label, which is an increase of 41 percent over 2017.

Ohne GenTechnik

www.ohnegentechnik.org

ProTerra Certification

The ProTerra Foundation is a non-profit organisation that aims to secure the supply of ingredients for feed and food that are sustainably produced, fully traceable and non-genetically modified. It certifies non-genetically modified soy and sets social and environmental standards.

ProTerra FOUNDATION

www.proterrafoundation.org

Mandatory labelling or a complete ban on genetically modified soy would be even more effective in shifting consumption and production patterns. Switzerland has set an example here, by establishing a voluntary import moratorium for genetically modified animal feed in 2007, which has led to the complete phasing out of genetically modified feed.

5.4.3 Supporting European organic soy cultivation

Germany's growing soy cultivation is located mainly in the country's southern regions where climate conditions are more favourable.[118] With an area of 24,100 hectares, Germany is able to cover around one percent of its soy demand. One fifth of the soy cultivated in Germany is organic.[119] In total, around 10,000 tonnes of organic soybeans are harvested annually on approximately 4,500 hectares.[120] Soy cultivation is also increasing in many other EU states such as Italy, France, Romania and Austria. In 2017, a total of 2.7 million tonnes of soy was harvested in the EU.[121]

Domestic soy cultivation is growing

Although the total area used for soy cultivation increased by a quarter from 2017 to 2018 and fivefold since 2012, the potential for domestic soy cultivation is far from exhausted. An area of around 780,000 hectares, mainly located in southern Germany, is assumed to be suitable for soy production. In general, areas suitable for grain maize are usually also suitable for soy. Current breeding efforts aimed at developing early-ripening varieties, which are especially suited to Germany's climate conditions, may further increase the potential cultivation area.[122] Non-profit organisations such as Danube Soya (see box) are looking to shore up political support for increasing European soy production.

Theoretically, if all suitable areas were cultivated, it is estimated that up to two million tonnes of soy could be produced annually. This would cover 30 percent of current German demand. When taking into account real life restraints, enlarging the cultivation area of soy up to 100,000 hectares by 2030 is considered feasible.[123] Cultivating organic soy is currently around twice as costly as conventional soy, but leads to higher average profits than those of many other organic protein crops, such as winter wheat or field beans.[124]

Is shifting to European soy production an alternative?

As outlined above, the majority of soy imported by Germany is associated with unsustainable cultivation practices that heavily impact biodiversity and ecosystem services and pose social and health burdens on the local population of producing countries. In contrast to soy production in Brazil, production in Europe is less likely to affect biodiversity hotspot

Danube Soya: supporting European soy cultivation

Danube Soya is an international non-profit organisation, committed to supporting the sustainable development of European soy cultivation, in particular in the Danube region. The organisation promotes the breeding, cultivation, marketing and processing of a regional protein supply that is free of genetically modified soy. Danube Soya is calling for regional soybeans and other legumes to meet half of European demand for feed protein by 2025. Its more than 280 members include representatives from the food and agricultural trade sector, the livestock feed industry, oil mills and numerous processors as well as associations and non-governmental organisations. Danube Soya also provides a certification standard for regional soy. Organic certification is also available.

areas and environmental standards and regulations are higher. However, greater demand for European and genetically non-modified soy threatens to cause negative ecological effects. Soy monocultures have recently emerged in some parts of south-eastern Europe, so ensuring sustainable cultivation systems and practices is, therefore, key.

Shifting towards domestic and European soy production would substitute imports from Brazil or the US, but not necessarily contribute to improving the situation in producer countries, as highly demanding markets, primarily China, further expand with growing demand for meat. Brazil, for example, exports only around ten percent of its total soy exports to Europe and 80 percent to China. In order to reduce the impact in producer countries, more needs to be done to support sustainably produced soy, as promoted by for example the Round Table on Responsible Soy (see box).

Some European countries, like the Netherlands and Switzerland, have already progressed substantially to assure most soy imports are sustainably produced. A reliable market helps to encourage producers to adopt environmentally and socially responsible practices, despite the higher costs of production and the absence of a price premium. With the Amsterdam Declaration 'Towards Eliminating Deforestation from Agricultural Commodity Chains with European countries' signed in 2015, seven European countries including Germany committed to supporting private sector and public initiatives and promoting policy coordination to halt deforestation caused by agricultural products traded with European countries. A multilateral instrument is to be welcomed, yet its scope is limited. A greater impact could be achieved if it were extended to the global level.

5.4.4 Diversifying protein sources for feed

Diversifying protein sources for feed can also contribute to protecting the environment. Soy in animal feed is required to provide a particular combination of amino acids. Those amino acids form the basis of proteins that are the main meat-producing constituent of livestock nutrition. Soy is currently used as the main source of protein in feed, but could, at least in

Round Table on Responsible Soy

The Round Table on Responsible Soy (RTRS), established in 2006, is an association that promotes the responsible production, processing and trading of soy on a global scale. Members include representatives of the soy value chain and civil society organisations. Based on a set of principles and criteria, the Round Table created a globally applicable certification standard to assure socially equitable, environmentally sound and economically feasible soy production.

Since its establishment, the Round Table has continuously extended its services. Today, it provides a trading platform as well as alternative certification schemes, including group certifications for smallholders.

The current volume of responsibly produced soy is 2.1 million tonnes per year. This represents only 0.6 percent of global soy production, with Europe being its major market. Yet, some production regions have substantially increased their share of responsibly produced soy. The Brazilian Federal State of Maranhão, for example, produces 30 percent of its soy responsibly. This shows that scaling-up is feasible whilst retaining positive environmental effects with regard to water use efficiency, soil conservation etc.

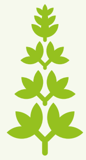
www.responsiblesoy.org

part, be substituted by other protein sources such as peas, beans, lupines, sunflower cake or clover (see box).

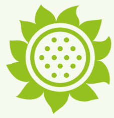
Examples of alternative protein sources

Peas

Beans



Lupines



Sunflower cake

Clover

Different livestock species need different amino acids. The feasibility of replacing soy with other protein crops thus varies. Cattle are traditionally fed on grass and produce their own amino acids. However, animals bred for the dairy industry are dependent on supplementary feeding with protein-rich concentrated feed. Pigs and poultry can show signs of malnutrition when the combination of proteins is not well balanced.[125] The substitution potential for soy in protein feed is estimated to be between 35 and 51 percent for poultry and between 35 and 65 percent for pigs.[126]

A variety of legumes benefit local ecosystem and biodiversity

The cultivation of legumes, such as clovers, lupines and fava beans can have various beneficial effects on local biodiversity and ecosystem services. In contrast with other plants, legumes can actively absorb atmospheric nitrogen and convert it into valuable amino acids required for human and animal nutrition. As part of crop rotations, legumes can contribute to species diversification and reduce the need for synthetic nitrogen fertilisers.[127] Grain legumes also contribute to the build-up of high-quality organic matter, facilitate soil nutrient circulation and water retention, and benefit pollinating insects.[128] Furthermore, their cultivation causes lower CO_2 emission, due to lower nitrogen fertiliser requirements. Overall, legumes are considered to have great potential in contributing to sustainable agriculture.[129]

European legume cultivation has declined

The cultivation of protein crops in Europe has declined sharply over the past two decades. Duty-free imports of protein crops and oilseeds, low prices for mineral fertilisers, increasing use of maize as feed and limited economic incentives, have all made the cultivation of legumes unattractive for farmers. As a result, cultivation of legumes declined in Germany and across Europe.[130] At present, legumes are of secondary importance for the protein supply in Germany and are mostly only relevant as part of organic animal feed. In 2018, 188,000 hectares were cultivated with grain legumes and 262,000 hectares with small seeded fodder legumes, such as clover and alfalfa.[131] A yield of 537,000 tonnes of legumes was used as animal feed.[132] That is equivalent to around ten percent of Germany's soy imports.

With the signing of the European Soy Declaration in July 2017, 15 member states, including Germany, have committed to growing more protein crops in their countries. The German Protein Crop Strategy adopted in 2016 aims to expand crop rotations in Germany and Europe and, in particular, increase the cultivation of legumes. The strategy is aimed at reducing the competitive disadvantages of domestic protein crops, closing research gaps and implementing measures in practice. An annual budget of around six million euros has been allocated for these activities. However, as the only European member state to have opted out of coupled payments under the Common Agricultural Policy, Germany misses out on a key mechanism to support domestic legume cultivation. Many other European member states have chosen to financially support domestic legume cultivation through coupled payments. France, for example, provides subsidies for the cultivation of green fodder legumes, grain legumes and soy of between 105 and 120 euros per hectare.[133]

5.5 Key takeaways

In the case of soy, by far the most effective way to conserve biodiversity and ecosystem services is a large-scale shift in consumption towards low-meat and vegetarian diets. Since Germany's demand for soy is primarily driven by the livestock sector, a decrease in the consumption of meat and dairy products could ease the ecological pressures soy cultivation places on highly biodiverse areas. Increasing transparency along the value chain can also contribute to more sustainable consumption patterns. Furthermore, supporting the European and domestic cultivation of diverse protein-rich legumes, such as lupines, beans or peas could provide a partial substitute to soy as feed. Increasing domestic soy cultivation can also contribute to reducing the global environmental impact of soy consumption, if high standards of sustainability are imposed on cultivation. Information, communication and raising awareness are crucial to all these aspects.

Measures for reducing the impact of soy production include:

- Developing concrete information, fiscal and regulatory measures to enable consumers to reduce meat consumption and choose sustainable food options
- Developing target-group specific campaigns, educational materials and narratives focused on the impact of meat and dairy consumption on biodiversity and ecosystem services
- Promoting independent certification standards such as Ohne Gentechnik, Danube Soya and ProTerra to foster transparency along the value chain and increase the market share of sustainably produced and non-genetically modified soy
- Increasing the share of diverse local protein sources in animal feed by incentivising and supporting the breeding, cultivation, marketing and processing of domestic organic protein crops
- Supporting international multi-stakeholder sustainability initiatives in the soy industry that promote sustainable production processes along the value chain, such as the Round Table on Responsible Soy

6 The Case of Lithium – Sustainable Mobility and the Plight of the Flamingo

6.1 Lithium trends: global demand is rising drastically due to electric cars

Lithium is a chemical element that constitutes a key component in batteries for cell phones, laptops, hybrid and electric cars, as well as grid storage. Global consumption of the alkali metal has increased drastically in recent years, almost doubling between 2008 and 2016. Although, compared to other minerals and metals, relatively small quantities are extracted, lithium plays a crucial role in the production of lithium-ion batteries. At 39 percent, batteries make up the largest and fastest growing share of global lithium consumption.[134] As well as being used in batteries, lithium is also required to manufacture ceramics, glass, polymers and lubricants.[135]

The e-mobility sector has, in recent years, overtaken the information and communication sector for global lithium demand and has since become the most important driver.[136] With climate change mitigation policies set on promoting e-mobility, demand for lithium is expected to increase further in the near future. The United Nations, for example, actively promotes e-mobility as a mitigation policy, with the declared aim of increasing the share of battery-electric vehicles in cities to at least 30 percent globally by 2050.[137] Transitions in the global transport sector required to meet the climate change goal of a temperature rise of no more than two degrees Celsius would imply an increase in the number of electric vehicles of 1,430 percent between 2015 and 2030, and an additional 230 percent increase between 2030 and 2050.[138]

Germany's e-mobility transition requires large amounts of lithium

E-mobility is a key component of both Germany's energy and mobility transition. The German government aims to increase the number of battery-electric vehicles on Germany's roads to six million (of a total 47.1 million cars currently registered in Germany) by 2030.[139] A variety of policies promoting e-mobility have been implemented in recent years in order to reach this goal (Table 11).

German demand for lithium-ion batteries is high, partly due to these transitions. The country claims a share of 13.6 percent of the world market for lithium-ion batteries. In 2016 alone, Germany imported approximately 35,000 tonnes of lithium-ion batteries with an average lithium content of 8 percent, resulting in 2,800 tonnes of lithium.[140]

At 65 percent of total imports, portable applications are currently still responsible for the largest share of lithium-ion batteries in Germany. The share of battery imports for electric vehicles comes to 30 percent.[141] However, due to increasing demand, it is highly likely that the e-mobility sector will soon be responsible for the largest share of German lithium consumption. As of January 2019, only 83,200 electric vehicles were registered in Germany.[142] If the goal of six million battery-electric vehicles by 2030 is met, demand for lithium-ion batteries will drastically increase in the coming years.

A battery-electric vehicle requires an average of 6.73 kilogrammes of lithium. To meet the target of six million battery-electric vehicles, 40,000 tonnes of lithium would be required by 2030. Assuming a linear increase, this comes to a total of 3,000 tonnes of lithium per year for e-mobility alone. This equates to a quarter of the current production in Chile, which is the main country of origin for German lithium imports.[143] If global demand for lithium outside of Germany does not further increase in the coming years, future German demand could hypothetically be met from resources presently available. However, given that industrialised countries worldwide are pushing for a larger share of e-mobility, it is evident that considerable increases in global lithium extraction are needed to satisfy demand.

It remains uncertain as to whether technological developments will lead to a substitution of lithium by other substances such as magnesium-sulphur or hydrogen in the future. As things currently stand, lithium is likely to remain an essential component of efficient battery systems for the foreseeable future.

Purchase premiums	Purchase premiums of up to 4,000 euros are available to buyers of new electric vehicles with the total funding set at 1.2 billion euros
Charging infrastructure	300 million euros were made available by a federal funding programme to accelerate the expansion of charging infrastructure
Tax exemption	The Traffic Tax Amendment Act exempts new electric passenger vehicles from the motor vehicle tax
Electric public transport	The procurement of electric buses for public transport is supported with up to 80 percent of additional investment costs
Research & development	2.2 billion euros were allocated for research and development through the government's e-mobility programme since 2009

Table 11: Measures implemented by the German Federal Government to promote e-mobility

6.2 Nearly 100 percent of lithium imported to Germany originates from Chile

Lithium is primarily imported into Germany in the form of products such as batteries. The main countries of origin are South Korea, Japan and China, where the batteries are manufactured (Figure 13). However, 99 percent of Germany lithium is sourced in Chile. Argentina, which forms the so-called lithium triangle with Bolivia and Chile, is in second place supplying one percent. Figure 14 presents an overview of the most important trade flows of lithium for battery manufacture from the respective countries of origin.

Chile holds 32 percent of global lithium reserves, followed by Bolivia with 24 percent, China with 15 percent and Argentina with eleven percent of global reserves.[144] In 2016, 40 percent of global lithium was sourced from the Salar de Atacama in Chile, the third-largest salt flat in the world.[145] Other sources of lithium also include the Salar del Hombre Muerto in Argentina and the Salar de Uyuni in Bolivia, the largest salt flat in the world.

In contrast to the large reserves that exist in the lithium triangle, Australia holds only four

percent of global lithium reserves, but sources lithium quantities comparable to those in Chile. Australian lithium is primarily sourced from the mineral spodumene through hard rock mining. It is used for domestic aluminium production and not exported for battery manufacture. The following focuses, therefore, on the sourcing of lithium from salt flats.

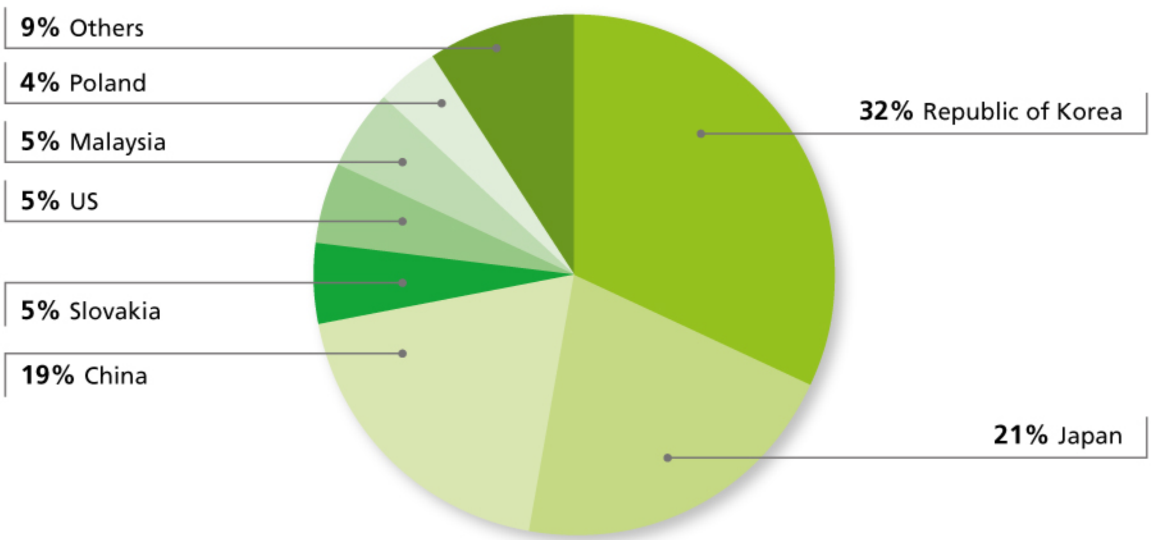


Figure 13: **Origins of lithium-ion batteries imported to Germany in 2016;** *Source: Eurostat Comext*

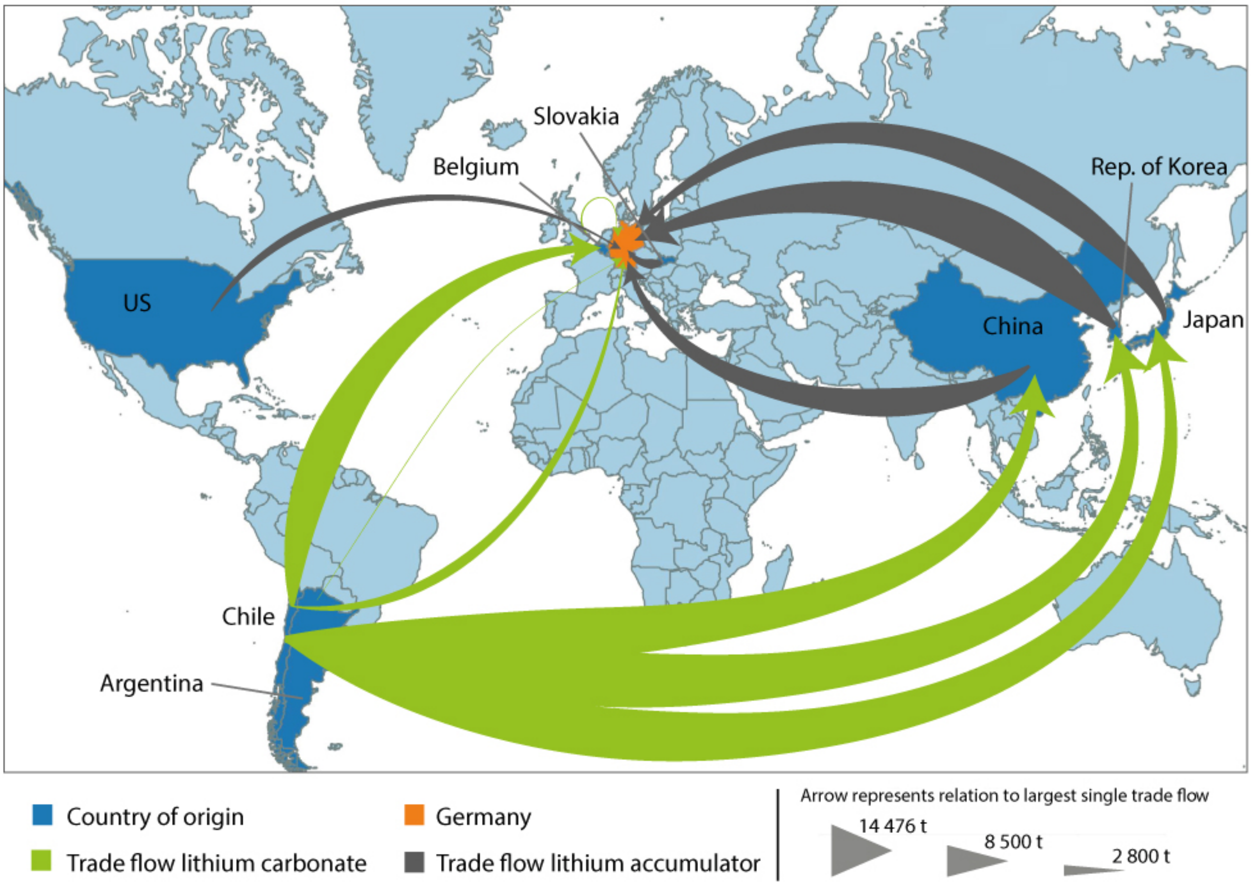


Figure 14: Trade flows of lithium for battery production and lithium batteries imported to Germany in 2016 (in tonnes); *Source: Eurostat Comext*

6.3 Impacts of lithium mining: loss of unique Salar habitats, threats to indigenous communities

Salt flats in the Andes Mountains are the primary source of lithium for battery production. Lithium is extracted from brine in the salt flats or Salars. During the process, brine is pumped to the surface via boreholes and stored in evaporation pools to concentrate the solution.[146] Despite the comparably low volume of trade and the regional scope of lithium mining, this extraction method is known to have a number of effects on biodiversity and ecosystem services that are highly concerning for all three criteria (Table 12).

Commodity	Major producing countries (outside the EU)	Annual German import volume	Amount of land use	Biodiversity loss	Ecosystem services loss
Lithium	Chile, Argentina	2,800 tonnes	●	●	●

Table 12: German lithium imports and impact rating on biodiversity and ecosystem services in producing countries (for legend of colour rating see Table 5 on page 29)

Rare and unique extreme habitats are lost due to changes in land use

In terms of surface cover, approximately one quarter of the total area of 3,000 square kilometres of the Salar de Atacama are already covered with lithium extraction facilities.[147] As a result, a substantial proportion of this rare and unique extreme habitat has already been lost. If German demand increases to six million lithium battery-powered cars by 2030, lithium extraction facilities covering around 185 square kilometres would be needed in order to meet German demand.

Despite the hostility of highly concentrated brines, these areas are home to so-called extremophiles which have adapted well to conditions in these environments. Hundreds of species of microorganisms live in the concentrated brine of the Salar de Atacama and would all be severely threatened by further exploitation of the Salar surfaces.[148]

The Salar region's water tables are depleting irreversibly

Salars are located in arid climate zones and isolated valleys that are poorly connected to glacial discharge. As a consequence of brine evaporation for lithium exploitation, water tables in the aquifers are lowered. This water loss is irreversible and may lead to changes in the habitat and desertification of the lakeshore environment. Brackish lagoons with open water around the main lake edges are particularly vulnerable and in need of protection.[149]

Approximately 50,000 tonnes of lithium compounds (including around 12,000 tonnes of pure lithium) were extracted in the Salar the Atacama in 2016.[150] Extraction processes of this magnitude require the evaporation of six percent of the brine. This equates to the evaporation of approximately 33 million cubic metres or 2,700 cubic metres of water per ton of lithium. If six million battery-electric cars were to be driven on German roads by 2030, 1.1 billion cubic metres of water would need to be evaporated for lithium extraction to meet German consumption alone.

Endemic flamingo species are endangered

The annual sustainability reports of the Sociedad Química y Minera de Chile – the leading company for sourcing lithium in the lithium triangle – regularly monitor the populations of endangered species in the area. Keystone species for nature conservation efforts include three types of flamingo that are endemic and only breed in the lagoon habitat around the salt flats, which explains their conservation status as 'vulnerable'.[151] The designated conservation areas harbour a number of additional highly specialised or endemic species classified as endangered.

Current data on annual flamingo populations do not yet indicate a decline.[152] However, extraction rates are advancing rapidly. Some studies estimate that the lithium reserves in Chile will last for another 30 years before depletion, assuming constant mining rates.[153] Following this scenario, a complete degradation of the Salars is likely to damage the local ecosystem permanently.

The Salar de Uyuni in Bolivia contains extended lithium deposits, though its quantities have not yet been thoroughly assessed.[154] However, increased mining efforts are expected to be associated with effects similar to those documented in the Salar de Atacama.[155]

Indirect environmental impact and threats to indigenous communities

Increasing mining activities in scarcely populated regions can also lead to an indirect environmental impact from additional infrastructure and an increase in population due to mining activities. They include increases in changed land use and area conversion due to the growing population and rising water consumption, which further compounds water scarcity and pollution.

In addition to these ecological concerns, lithium mining causes a range of social impacts. Large-scale lithium sourcing threatens the livelihood of various local and indigenous communities. In the region around the Salar de Uyuni in Bolivia, indigenous communities have relied on salt harvesting, llama and alpaca herding and the production of quinoa grains for decades.[156] It is unclear how these activities will be affected if lithium sourcing continues to expand at its currently estimated rate.

In addition to lithium, the manufacture of lithium-ion batteries requires a number of other materials such as cobalt, nickel, manganese and phosphorus. The extraction of these materials is also associated with a slew of social and environmental impacts. Cobalt and nickel are primarily mined in emerging economies and developing countries. The labour conditions in these countries are often highly problematic. Child labour, for example, is a widespread problem in the Democratic Republic of the Congo, a major exporter of cobalt. Cobalt and nickel mining also lead to serious health problems for workers.[157] These particular impacts are not explored further here, yet they are of great significance to lithium-ion battery production.

In contrast to the mining of raw materials needed for battery production, the manufacture of lithium-based products only has a minor environmental impact, as documented in life-cycle assessments.[158]

Key findings

Table 13 summarises the impact of lithium production from brine on biodiversity and ecosystem services.

Driver	Impact on biodiversity	Impact on ecosystem services
Covering vast areas with evaporation ponds	→ Loss of and changes in highly specialised habitats → Reduction of diversity and threat of extinction of endemic species such as flamingos	→ Reduced aesthetic value of unique landscapes → Loss of or radical changes to open water zones (lagoons)
Evaporating brine from Salars	→ Potential loss of open water zones, threatening endemic species and many microorganisms	→ Lowering of water tables leads to changes in the hydrological structure of the valley → Negative impacts on peripheral ecosystems (arid and specialised systems)

Table 13: Main impacts of lithium production on biodiversity and ecosystem services, using the Salar de Atacama in Chile as an example

6.4 Slowing the increasing demand for lithium – options for action

The transport sector accounts for nearly 20 percent of global greenhouse gas emissions and is, therefore, one of the main causes of climate change, which in turn is an important driver of biodiversity and ecosystem service loss. Over the past 25 years, the sector's overall CO_2 emissions have remained virtually constant, as efficiency gains have been offset by an increase in transport volumes. To achieve the national climate protection targets in Germany, transport would have to make a significant contribution to reducing emissions in the future. A drastic increase in e-mobility is key in addressing these concerns, given the technology's emissions-related saving potentials. However, the impact of e-mobility on biodiversity and ecosystem services cannot be ignored, as outlined above in the case of lithium.

Developing strategies and implementing policies for a mobility transition away from individual motorised transport is therefore vital and needs to be given the highest priority. However, since it is unlikely that society will no longer be reliant on cars and other forms of motorised transport in the near future due to path dependencies, current infrastructures and mobility needs, the objective of a modern transport and environmental policy must be to make society's mobility as environmentally-friendly as possible. E-mobility represents an important pillar within this overall mobility transition, yet policymakers need to identify options for limiting the environmental impact linked to raw material extraction.

Contrasting the cases of cotton and soy with lithium, consumers cannot choose between different batteries with varying degrees of sustainability. As a result, it is comparably more difficult to exert a direct influence on raw material extraction processes. Nevertheless, consumers do have a choice, given that they can opt for alternatives to individual motorised transport, such as using public transport.

6.4.1 Promoting public and non-motorised transport

The most effective way to reduce the ecological pressures caused by lithium extraction is a mobility transition away from individualised modes of transport, such as cars, and towards public transport and non-motorised modes of transport, such as cycling. Avoiding raw material extraction in the first place leaves ecosystems intact. Encouraging an overall reduction in the number of cars will have to be the highest priority in order to conserve biodiversity and ecosystem services.

A mobility transition of this kind has a range of other positive effects. Individual motorised transport places considerable burdens on the environment and poses increased risks to human health. These include noise, air pollution and emissions, reduced urban quality of life, accidents, use of space, land sealing and others. These external costs must be borne by society as a whole and are often distributed unfairly.

In contrast, cycling and pedestrian traffic causes no emissions or noise, lowers accident risks, requires less investment in infrastructure and makes a significant contribution to health prevention, thereby reducing medical costs. Similarly, public transport reduces environmental and social externalities. A recent study in Germany showed that if these factors were taken into account, the overall cost of driving a car would be three times higher than that of using public transport. However, since 2000, ticket prices for buses and trains in Germany have increased by nearly 80 percent, whereas the costs for purchasing and maintaining a car only rose by 36 percent.[159]

Policy makers have many options to facilitate a mobility transition. These include measures such as free public transport, investment in cycling infrastructure, introducing congestion charges or car-free Sundays, traffic-calming zones, cargo-bicycle lending schemes, promoting car-sharing and many others (also see box). Each of these measures comes with advantages and disadvantages which need to be assessed in local contexts.

Free public transport: the example of Tallinn

In 2013, Tallinn became the world's first capital to offer all its registered residents free use of public buses, trams and trains. This led to a ten percent increase in bus and tram use, while train use more than doubled. Free public transport has been shown to attract cyclists more than car drivers. Nevertheless, an eight percent decrease in car use has also been observed. Estonia as a whole has declared its ambition to become the first country with free public transport nationwide. Buses in 11 of its 15 counties are now free of charge.

Collecting a congestion charge: London shows the way

In 2003, London implemented a congestion charge to tackle air pollution and congestion. There is currently a charge of 11.50 pounds sterling to drive a vehicle within the charging zone on weekdays between 7am and 6pm. Residents receive a discount of 90 percent and those registered disabled may drive in the zone free of charge. Emergency services, motorcycles, taxis and minicabs are exempt. As a result, the number of private cars in the charging zone fell by 39 percent between 2002 and 2014. Bus use increased by 37 percent. Congestion and accidents decreased significantly. The charge brings an annual net revenue of over 150 million pounds sterling, which is used to subsidise discounted tickets on public transport and investments in infrastructure.

6.4.2 Recycling lithium-ion batteries

In order to meet the increasing global demand for lithium while simultaneously protecting biodiversity and ecosystem services worldwide, building an efficient recycling infrastructure for lithium-ion batteries is essential. The benefits of incentivising recycling are twofold. Firstly, the demand for virgin lithium imports could potentially be reduced without slowing down battery production. As a result, the environmental impact of our lithium consumption would decrease. Secondly, a functioning recycling infrastructure could mitigate temporary bottlenecks. To reduce the demand for virgin material and mitigate the risk of disruptions along the supply chain, developing a domestic lithium supply from recycling is likely to become increasingly important in the long-term.[160]

Global recycling rate of lithium is below one percent

Due to low raw material prices, recycling is currently not cost-efficient. Extracting lithium from salt brines is almost three times cheaper than recycling it.[161] As a result, in 2017, only around three percent of all lithium-ion batteries worldwide were recycled.[162] Furthermore, only the economically valuable components such as nickel and cobalt contained in these batteries are usually recovered.[163] The global recycling rate of lithium from lithium-ion batteries is still well below one percent.

The development of lithium prices in recent years makes it unlikely that recycling will become economically viable any time soon. While global prices of battery grade lithium carbonate increased from 1,590 US dollars per tonne in 2002 to 16,500 US dollars in 2017, they fell again to around 11,500 US dollars per tonne in February 2019.[164] While a superficial look at the sharp rise in global demand for lithium might lead to the assumption that prices will continue to rise in the future, access to new extraction areas and an increase in supply may lower prices again.

It is currently difficult to predict whether and when lithium recycling will become cost-efficient. However, technological progress might lower the future costs of recovering the raw material from lithium-ion batteries substantially. As such, recycling could become an economically feasible method for decreasing imports in the medium to long term.

Recycling infrastructure and standardised procedures required

Since there is currently little economic incentive to recycle lithium, there are only a handful of companies worldwide engaged in the process. An important prerequisite for battery recycling is establishing an effective collection system. In addition, there are, as yet, no standardised procedures for pre-treating lithium-ion batteries, i.e. removing the casings, circuit protection modules and temperature safety vents as well as other materials surrounding the cells.[165]

Revising European and German battery regulations may incentivise lithium recycling

The European Battery Directive and associated German Batteries Act, implemented in 2009, regulate the recycling of batteries in Germany. A revision of these regulations could incentivise the recycling of lithium.

The European Battery Directive categorises vehicle batteries as industrial batteries and sets the recycling target for end-of-life batteries at 45 percent. However, the directive does not set a collection target specifically for lithium-ion batteries.[166] According to the German Batteries Act, lithium-ion batteries count as 'others' and the minimum recovery target is set at 50 percent. Since current regulations only stipulate overall collection targets and do not specify what types of raw material need to be recovered, recycling companies focus primarily on those materials that are easy to recover. Lithium is most often disregarded entirely.

The European Battery Directive is currently being evaluated. Besides higher overall recycling rates, it is likely to set specific targets for recycling lithium.[167] Studies assume that a recycling rate of 80 percent is feasible.[168]

Closing material cycles is challenging due to insufficient recycling quality

Efficient recycling processes have various prerequisites. Firstly, information about the load capacity and material components of the batteries needs to be transparent. Secondly, domestic infrastructure and recycling technology must be put in place and ensure high environmental and recycling standards. Thirdly, the technological processes for recovering raw materials need to yield high-quality materials.

In particular, the quality of recycled materials has proven challenging. Even though the estimated recovery rates possible for lithium are relatively high, the quality of the recycled product does not currently meet the requirements of battery production. Therefore, the reuse of recycled lithium in the manufacture of new electric vehicle batteries has, to date, only been successful in part. Recycled lithium carbonate is currently used in other industries such as the ceramic industry. Increasing the quality of secondary lithium carbonate is, therefore, a major challenge for battery recycling.[169]

If technological progress in the recycling industry allows for secondary lithium to be used for new batteries (closed-loop recycling), this will meet a significant share of the demand for lithium.[170] If this is not possible, the supply of secondary lithium (open-loop recycling) will quickly outgrow demand for lithium in other sectors and result in an oversupply.

Research and development of recycling technology is crucial

Research and development of recycling technologies that aims to produce high quality secondary lithium is key in addressing the challenges outlined above. If technological advancements are successful, recycling targets specific to lithium-ion batteries need to be set through regulation and battery configurations standardised. This could allow the recycling of lithium to become a major pillar in Germany's e-mobility strategy and thereby decrease the negative environmental impact of lithium consumption in the field of mobility.

6.4.3 Promoting the research and development of lithium alternatives

In recent years, numerous studies have contrasted estimates of rising global demand for lithium with data on lithium reserves and resources. Although most of these studies do not see a danger of premature depletion in the coming decades, it nevertheless remains unclear how long global reserves will last. To consider alternatives to lithium constitutes a necessary precaution. In this process, particular focus should be placed on researching the ecological impact of alternatives to lithium-ion batteries, given that most negative effects on biodiversity and ecosystem services are related to the sourcing of these raw materials. Currently, the most widely discussed alternatives to lithium-ion batteries are fuel cells and magnesium-sulphur batteries.

Fuel cell-powered electric vehicles

Fuel cells are likely to play an important role in the global energy transition. Estimations predict a global annual production rate of 18 million fuel cell-based vehicles by 2050.[171] Similar to conventional combustion engines, fuel cells generate electricity through chemical reactions. Compared to conventional engines, fuel cells are more efficient. The most attractive fuel for fuel cells is hydrogen. As a result, any reference to fuel cells in the following section, specifically refers to hydrogen fuel cells. Similar to battery-powered electric vehicles, fuel cell vehicles do not emit any pollutants and are, therefore, classified as zero-emission vehicles. From an ecological point of view, this constitutes the main benefit of this technology. In addition, compared to lithium-ion batteries, the process of manufacturing fuel cells has fewer negative consequences on biodiversity and ecosystem services.

The specific energy of an energy source – defined as the available energy per kilogramme – is generally considered an important technological criterion for evaluating advantages and disadvantages. Compared to battery-powered vehicles, the specific energy of fuel cell vehicles is around five to 20 times higher.[172] This represents a considerable technological advantage, leading to much shorter fuelling times of around three minutes compared to seven hours for the standard charging process of a lithium-ion based Tesla, for example. Fuel cells are also much lighter.[173] The range of a fuel cell-powered vehicle is 400 to 500 kilometres per fuelling which is similar to the most advanced lithium-powered vehicles.

A major technological hurdle for fuel cell-powered vehicles is the fact that the fuel it uses is not an energy source by itself, but a secondary energy, i.e. an energy carrier.[174] As hydrogen is not naturally available in combustible form, a primary energy source is needed to produce it. Hydrogen is currently produced by reforming natural gas, using 90 percent fossil fuels. Hence, greenhouse gases are emitted in the production of hydrogen, denying fuel cells – at their current level of technological advancement – the label of a green energy source.

High costs are also a barrier in the manufacture of fuel cells. The technology is currently only economically competitive in a few highly specialised applications. Furthermore, there is only a limited charging infrastructure, to date. In July 2019, only 71 hydrogen filling stations were available in Germany.[175] By comparison, there were around 15,000 standard filling stations and 9,000 charging stations for battery-powered electric vehicles.

Magnesium-sulphur batteries

Another option currently being discussed is a rechargeable magnesium-sulphur battery.[176] Due to its potential high-energy density, its safety features and low cost, this type of battery is considered a promising candidate for future battery generations.[177] In theory, the specific energy of magnesium-sulphur batteries is far higher than that of lithium-ion batteries. However, in practical applications they are still performing approximately the same. Nevertheless, research on this type of battery is still in its early stages.

Key obstacles include the price of raw materials and the small number of charging cycles. A lithium-ion battery can undergo approximately ten times as many recharges as a magnesium-sulphur battery before it has to be replaced. Increasing the number of charging cycles in a magnesium-sulphur battery's overall lifetime is one of the major technological challenges in the development of this alternative.

The environmental impact of the production of magnesium-sulphur batteries on biodiversity and ecosystem services has not yet been fully assessed. Magnesium is one of the most abundant elements on the planet. It occurs naturally, though only in combination with other elements, mainly in the form of carbonates and chlorides. Elemental sulphur occurs in almost all the world's active volcanic regions. Global reserves are estimated at around 5,000 gigatonnes, making any form of depletion practically impossible. Environmental concerns associated with the mining and processing of magnesium include CO_2 emissions and the potential for acidification.[178]

A change towards a large-scale use of magnesium-sulphur batteries is currently unlikely. More research is needed to provide a better assessment of the long-term prospects of this technology.

6.4.4 Sourcing lithium locally

Lithium reserves are not only found in South America and Australia, but also in Europe. The largest European lithium deposit is located in the German Ore Mountains close to the Czech Republic-Germany border. Non-governmental organisations and mining companies estimate the deposit contains around 96,000 tonnes of lithium.[179] In recent years, greater attention has been given to the possibility of sourcing lithium locally from these deposits. In 2017, permits for hard rock mining in the region were awarded to Deutsche Lithium GmbH. Mining is expected to begin in 2020. The company estimates that the resources available in the Ore Mountains are sufficient to produce around ten million battery electric vehicles.

Impact of sourcing lithium locally on biodiversity unclear

As with deposits in Australia, lithium in the Ore Mountains is found in the form of spodumene minerals requiring hard rock mining for its extraction. Its environmental impact is inconclusive.

On the one hand, sourcing lithium locally could hypothetically suppress demand for imported virgin lithium. The mining of lithium from hard rock is considered by some as a potentially more sustainable alternative to the hydro-chemical sourcing method employed in the lithium triangle, given that it bypasses the problems of evaporating salt brine areas.[180] As a result, it might prevent the irreversible loss of water in arid regions. Furthermore, given Germany's high monitoring standards, sourcing lithium locally might allow the negative environmental consequences on biodiversity and ecosystem services associated with hard rock mining to be kept in check.[181]

On the other hand, the mining of spodumene deposits comes with its own negative effects, which depend on the specific locality. There are currently no data available on the possible impact of lithium mining on biodiversity and ecosystem services in the Ore Mountains region. Further research is needed to assess these effects. It is known, however, that spodumene deposit mining in general causes CO_2 emissions, the accumulation of mining waste and potential erosion, and the silting up of lakes and waterways.

Before large-scale sourcing in the Ore Mountains begins in earnest, the ecological disadvantages of spodumene deposit mining need to be contrasted with those of brine deposit mining. Without further research, sourcing lithium locally cannot be considered a more sustainable alternative.

6.5 Key takeaways

Due to the strategic importance that e-mobility plays as part of the overall mobility transition in many industrialised countries, a sharp increase in global lithium demand and, as a result, a negative impact on biodiversity and ecosystem services in the producing countries are to be expected. Consequently, the most effective way to reduce the environmental impact of mobility is to reduce the amount of cars – and not only change the type of energy that powers their engines. There is a fundamental need to raise awareness for the fact that almost every kind of consumption dependent on raw materials has an ecological impact. This also holds true in the context of mobility. Investing in the necessary infrastructure and incentivising public and non-motorised transport options is, therefore, the highest priority.

Since mobility is a key requirement of social and economic development in modern industrial societies and that motorised transport is unlikely to be made redundant in the near future, decreasing the ecological impact of raw material sourcing is crucial. The example of lithium shows that closing material cycles is of key importance here. Assuming successful technological developments in recycling processes, the recovery of lithium from used batteries would need to become mandatory and legally binding, even in the absence of economic incentives. Recycling alone, however, is unlikely to meet European and German demand for lithium. It will require more investment in research to explore alternative extraction techniques and battery technologies.

Measures for reducing the anticipated impact of lithium production:

- → Promoting public and non-motorised transport, particularly in urban areas, for example by introducing free public transport or congestion charges
- → Promoting public and non-motorised transport by developing target-group specific information campaigns, educational material and narratives that include the impact of e-mobility on biodiversity and ecosystem services
- → Supporting research and development into improving recycling technologies for lithium-ion batteries and setting up the necessary infrastructure for battery collection and pre-treatment
- → Revising the existing legal framework for battery recycling to include raw material-specific collection targets
- → Exploring the advantages and disadvantages of alternatives to lithium-ion batteries such as fuel cells and magnesium-sulphur batteries

7 Pathways to Sustainable Consumption

Changes in ecosystems caused by human activity have occurred more rapidly over the past 50 years than at any other point in human history. The severe biodiversity loss observed in connection with such changes constitutes one of the planetary boundaries that, according to the Stockholm Resilience Centre, humanity has already transgressed.[182] Consumption in industrialised countries like Germany is a key driver of these changes.

To provide insights into these developments, this study has

- analysed the global material flows of raw materials into Germany,
- assessed the impact of the production or extraction of cotton, soy and lithium on biodiversity and ecosystem services and
- considered measures for action to promote sustainable consumption patterns that support the conservation of biodiversity and ecosystem services.

7.1 Cotton, soy and lithium: what do they all have in common?

The analysis of global raw material streams shows that consumption in industrialised countries like Germany requires imports from almost every region of the world. Raw material production or extraction often has a significant impact on biodiversity and ecosystem services in the countries of origin. Since these effects are often highly localised and can be better recorded if analyses focus on specific goods, the study has explored three specific examples: cotton for clothing in the textile sector, soy as feed in the food sector and lithium for batteries in the mobility sector.

Using case studies as examples helps to demonstrate the complex relationship between consumption in industrialised countries and its global impact on the environment. Nevertheless, case studies can only provide us with a hint of the magnitude of the overall impacts of consumption. Further analysis is needed to understand the overall impact of German consumption.

Increasing demand for e-mobility, the culture of fast fashion and the high demand for meat all have far-reaching effects on biodiversity and ecosystem services worldwide. While the three cases pertain to different fields of consumption, their major effects on biodiversity and ecosystem services are comparable in some regards:

- **Loss of habitat:** this is often the result of change in land use as production sites expand to meet increasing demands. Land-use change is the most important global driver of biodiversity loss and has a major impact in all three examples.
- **Pollution of water and soil:** this is linked to industrial agricultural processes and is primarily caused by agrochemicals, as well as chemical agents used in processing. It is a major consequence of cultivating both cotton and soy.
- **Loss of (fresh) water resources:** irrigation and resource extraction processes often require enormous amounts of water. Loss of (fresh) water resources is a central impact of the extraction of lithium from brine as well as the irrigation of cotton crops.

7.2 General observations of this study

Based on the analysis of the impact of German consumption on biodiversity and ecosystem services worldwide, a number of general observations can be made:

Biodiversity, ecosystem services and climate change need to be considered together

Climate change and biodiversity are two sides of the same coin. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, global warming is the third largest factor driving species extinction, after land-use change and the exploitation of organisms. A temperature increase of 1.5 to 2 degrees Celsius would degrade habitats and significantly affect the world's terrestrial species.[183] At the same time, certain species are known to play key roles in the functioning and maintenance of ecosystems. Their existence is a prerequisite for the earth's capacity to absorb CO_2.

Although the interdependencies between climate change and biodiversity and ecosystems were not a focus of this study, a holistic approach to sustainable consumption needs to take into account both the impact on biodiversity and ecosystem services, as well as on the climate. Many – but not all – efforts to protect biodiversity and ecosystem services also mitigate climate change and many efforts to mitigate climate change also protect biodiversity and ecosystem services. Reduced meat consumption, for example, not only reduces land-use pressures and pollution caused by soy cultivation but, would also contribute to climate change mitigation, as livestock has been linked to approximately 15 percent of global greenhouse gas emissions.[184]

However, as the example of lithium shows, climate change mitigation policies can lead to conflicts of interest and may have negative consequences for biodiversity or ecosystem services or vice versa. In these cases, the severity of the impact needs to be carefully contrasted. Contextualising the findings of this study with current climate change policies will not only allow for such trade-offs to be identified, but also for strategies to be developed that are capable of addressing the pressing environmental issues of our time in an integrated manner.

The negative impact of consumption in industrialised countries are unjustly distributed

The negative consequences of consumption in industrialised countries on biodiversity and ecosystem services elsewhere in the world are unjustly distributed. Ecosystem services are the benefits nature provides for humans. If these benefits are reduced, the quality of life drops. Many of the goods and raw materials consumed in Germany come from countries in the Global South. Consequently, the losses of biodiversity and ecosystem services linked to our consumption patterns negatively impact the well-being of others – primarily those living in the countries that provide us with resources and commodities. Thus, analysing the ways in which environmental and socioeconomic systems are telecoupled over large distances is key to understanding the responsibility consumers in the Global North bear for environmental loss in the Global South and worldwide inequalities.

The full social impact of raw material production and extraction is not part of the scope of this study. However, in many contexts the provision of raw materials and goods to be consumed in industrialised countries comes with serious social implications in the countries of production. For instance, the limited labour rights of workers in the textile industries or health implications for farmers from pesticide use can severely diminish quality of life. Successfully addressing social and ecological challenges in an integrated manner presupposes the involvement of all relevant stakeholder groups.[185] Multi-stakeholder platforms such as the One Planet Network are of particular importance here, since they have the potential to bring together public authorities, producer organisations, non-governmental organisations and consumer associations.

The effects of consumption on biodiversity and ecosystem service are complex and multi-facetted

The effects of our consumption on biodiversity and ecosystem services are highly diverse and global supply chains of imported goods are highly complex. Direct causal relationships between consumption and global ecological consequences are difficult to establish, based on available data.

Only by studying in-depth the impact of individual raw material and goods, can we gain profound insights into how consumption in industrialised countries is driving global loss of biodiversity and ecosystem services. Yet, even in the case studies presented here, it has only been possible to outline certain key effects. Secondary effects and other impacts along the supply chain, such as cultural ecosystem services (e.g. aesthetic appreciation or recreational value), could not be taken into account here. Further research is required to shed light on the multi-facetted interconnections and interdependencies between the ecological and social repercussions. Furthermore, while this report focuses on the impact on natural environments abroad, the protection of domestic ecosystems should not be neglected, in order to sustain our quality of life in the long term.

It is also important to note that the emergence of more sustainable consumption patterns in countries such as Germany might be offset by developments in other regions of the world. In the case of soy, for example, China is currently responsible for nearly two-thirds of imports on the international market and demand is expected to grow even further in the coming years.[186] This does not mean that efforts to shift consumption in a more sustainable direction are futile. On the contrary, it underlines the necessity for decision-makers in national governments to attempt to address the issues of biodiversity loss and the destruction of ecosystem services on a transnational level. Best practice examples need to be shared and promising approaches tested. This further emphasises the importance of global initiatives, such as the One Planet Network.

Promoting sustainability: what the supply and the demand sides can do

Consumption and production systems are inherently linked. On the one hand, a change in consumption patterns towards sustainability can have pull-effects on the supply side and ultimately change production processes. On the other hand, producers and marketers can actively generate demand for more sustainable products through push-effects on the supply side. Strategic marketing that influences trends and fashions plays an important role, especially in countries with significant purchasing power. An increase in availability and strategic subsidies on sustainable goods in industrialised countries can lead to changes in consumption patterns on the demand side.

Biodiversity and ecosystem services are directly impacted through raw material production, extraction and processing. Ultimately, this is where substantial changes have to take place in order to protect the environment. Yet, shifts away from harmful processes can also occur if consumers in industrialised countries demand such changes and change their consumption patterns accordingly.

To initiate changes on the demand side, consumption-oriented policies in industrialised countries need to focus on providing sufficient information for sustainable purchasing choices, but also on setting up consistent regulations. It is important to note that providing information alone is not sufficient to change consumption. Everyday consumption practices are strongly driven by habit, social and cultural contexts and institutional configurations.[187] Substantial changes in consumer lifestyles thus require not only on policies that aim to make sustainable consumption easier, but also on policies that make unsustainable consumption difficult and inconvenient.[188]

7.3 Recommended actions to enhance sustainable consumption

7.3.1 Promoting consumer information and communication

In addition to shoring up standards and regulations, providing consumers with useful information and improved communication are important tools for influencing consumption patterns. As outlined above, consumption practices that are beneficial to biodiversity and ecosystem services often help mitigate climate change as well. Where this is the case, narratives on climate change need to be expanded to include the biodiversity and ecosystem services aspects. The deforestation of the Amazonian rainforest is one such example. It is popular due to its biodiversity and is also known as the 'Lungs of the Earth', referring to its capability of absorbing around two billion tonnes of CO_2 per year.

In some cases, it can be advantageous to develop independent biodiversity-specific narratives. Biodiversity is an abstract concept for many consumers. Identifying narratives that are tangible and easy to understand and circulating these through innovative formats such as storytelling is crucial. Campaigns and information materials developed by governments and non-governmental organisations must be target-group specific and useful in practice, for example by recommending specific actions consumers can take in their day-to-day lives. Information campaigns have a better chance of changing consumption behaviour if the recipients emotionally identify with the species impacted. For instance, a recent petition for a referendum on biodiversity in the federal state of Bavaria showed that bees serve as an excellent communication example.[189]

7.3.2 Promoting sufficiency-oriented lifestyles

Reducing overall consumption levels would have the greatest effect in terms of protecting biodiversity and ecosystem services, as well as mitigating climate change. Sufficiency-oriented lifestyles need, therefore, to be mainstreamed and promoted more seriously by decision-makers. Sufficiency is sometimes regarded as a voluntary lifestyle choice associated with sacrifice or restriction. Yet, sufficiency narratives also address the question as to whether a steady accumulation of consumer goods actually increases our well-being and ask what materials and goods are really necessary for good quality of life. This requires a broader societal discourse and markets, infrastructures and policies that support a mainstreaming of sufficiency lifestyles.[190]

Steps towards sufficient lifestyles vary in scope. Some only require minor behavioural changes, such as borrowing tools from a friend or neighbour, rather than purchasing new ones. Others can have a greater impact on daily life, like choosing not to own a car but instead use public transport and car-sharing options. Sufficiency begins with specific habits and can go as far as changes in lifestyle and economic structures.[191] Nevertheless, sufficiency-oriented lifestyles require not only consumer awareness, but also infrastructure that conveniently enables consumers to easily integrate the necessary changes into their day-to-day lives.

7.3.3 Using public procurement as leverage to promoting biodiversity-friendly consumption

Public procurement can act as a crucial lever in promoting sustainable products. The public sector can lead by example and use its economic power to increase demand for sustainable products. This requires the development and systematic implementation of biodiversity criteria across all fields of procurement as determined by the German Sustainability Measures Programme in 2015.

7.3.4 Increasing transparency along the supply chain and internalising environmental costs where possible

Greater transparency along global supply chains, for example through labelling schemes, is the key to enabling consumers to make informed decisions and incentivising producers and manufactures to set high ecological standards. Biodiversity criteria are often not considered in labelling schemes and need to be strengthened. This requires biodiversity-specific indicators that consider the effects along the entire supply chain, including raw material production for the relevant product groups and harmonising these criteria across international and national labelling systems. Internalising environmental costs where possible is desirable in order to steer consumption choices toward biodiversity-friendly options.

7.3.5 Supporting international stakeholder initiatives on biodiversity and ecosystem services

Consumption-oriented policies in industrialised countries must go hand in hand with supply-side changes. International stakeholder forums on sustainability, such as the Round Table on Responsible Soy or the Partnership for Sustainable Textiles, can set industry goals, exchange best practices and facilitate communication and coordination along the entire supply chain. Such initiatives and forums should receive further support from national governments and international actors. Nevertheless, biodiversity and ecosystem services need to be more thoroughly integrated into the agendas of these various initiatives and forums.

7.3.6 Evaluating and consider existing alternative materials or commodities

More sustainable substitute raw materials or commodities are often available, sometimes even readily. For example, for clothing, fibres such as hemp or flax could provide more sustainable alternatives to cotton and synthetics.

In the case of soy, increasing the share of locally grown protein sources, such as legumes in livestock feed, could reduce the impact on biodiversity and ecosystem services. In the case of lithium, both fuel cells and magnesium-sulphur batteries might power a mobility transition that is less harmful to biodiversity and ecosystem services than our current lithium-driven transition. More research is needed to fully evaluate the impact and implementation potential of these alternatives and stimulate technical and institutional innovations for alternative products with appropriate incentives.

7.3.7 Closing key material cycles

In some instances, raw materials can be recovered through recycling. This could diminish the need for further resource extraction and reduce the impact on biodiversity and ecosystem services. The cases of cotton and lithium demonstrate this potential. In both cases, recycled products do not yet meet the quality standards required for closed-loop recycling, meaning further research is required to avoid any unintended consequences such as an oversupply of inferior raw materials. Closing material cycles of raw materials needs to be part of a larger circular economy-oriented framework.

Table 14 provides a summary of the recommendations developed in this study and specifies which stakeholders need to actively implement them. Short-term policies – such as reviewing public procurement guidelines – need to be implemented as soon as possible. However, in order to address the issues at hand comprehensively and systemically, these policies need to be part of a larger, medium to long-term societal and cultural transformation: towards sustainable diets, slow fashion and mobility concepts that are less dependent on individual, motorised transportation. A first key step is to fully integrate the effects on biodiversity and ecosystem services into our consumption-related analyses and policies.

Table 14: Policy recommendations for fostering sustainable consumption and which stakeholders need to take action

	Activity	Federal government	Local government	Non-governmental organisations
General	Encouraging sufficiency-oriented lifestyles with **consumer-specific information** that addresses the impact of consumption on biodiversity and ecosystem services	☒	☒	☒
	Using **public procurement** as leverage to promote goods and services that have a low impact on biodiversity and ecosystem services	☒	☒	☐
	Increasing transparency along the supply chain to facilitate sustainable purchasing decisions, for example by promoting ambitious labelling that sets high standards for biodiversity protection	☒	☒	☒
	Encouraging **upcycling and sharing practices** to decrease overall raw material consumption	☒	☒	☒
	Supporting sector-specific **international stakeholder initiatives** on biodiversity and ecosystem services to promote sustainable consumption and production processes	☒	☐	☒
	Promoting **research and development** into identifying and evaluating **alternative** raw materials that may have less of an impact on biodiversity and ecosystem services than current raw materials	☒	☐	☐
	Closing key material cycles by means of **recycling**, where technologically feasible	☒	☒	☐

	Activity	Federal govern-ment	Local govern-ment	Non-govern-mental organisations
Cotton-specific	Increasing the market share of certified organic cotton (e.g. Global Organic Textile Standard), for example by setting **public procurement quotas**	☒	☒	☐
	Supporting the development of **innovative start-ups** and initiatives that aim to increase efficient clothing use, for example with apparel upcycling, renting and sharing concepts	☒	☒	☐
	Incentivising the reuse and repair of clothing, for example with fiscal incentives such as tax breaks and by raising awareness	☒	☐	☒
	Increasing the share of sustainably produced renewable raw materials, such as **hemp or flax** by raising awareness and supporting research and development into processing technologies	☒	☐	☒
	Supporting **international multi-stakeholder sustainability initiatives**, such as the Partnership for Sustainable Textiles to promote sustainable production processes along the value chain	☒	☐	☒
	Promoting a culture of slow fashion, for example with **campaigns** and educational material focused on the ecological impact of the textile sector	☒	☒	☒
Soy-specific	Developing specific measures to enable and empower consumers to **reduce meat consumption** and choose sustainable food options by providing information and implementing fiscal and regulatory measures	☒	☒	☒
	Increasing the share of diverse local protein sources in animal feed by incentivising and supporting the breeding, cultivation, marketing and processing of local organic protein crops	☒	☐	☐
	Promoting **independent certification standards** (e.g. Danube Soya or ProTerra) to foster transparency along the value chain and increase the market share of sustainably produced and non-genetically modified soy	☒	☒	☒
	Developing **campaigns** and educational material focused on the environmental impact of meat and dairy consumption	☒	☒	☒
	Supporting **international multi-stakeholder sustainability initiatives** to promote sustainable production processes along the value chain	☒	☐	☒
Lithium-specific	Revising the existing **legal framework** for battery recycling at the European level to include lithium-specific collection targets	☒	☐	☐
	Setting up the necessary **infrastructure for lithium-ion battery collection**	☒	☒	☐
	Supporting **research and development** into improving the recycling process of lithium-ion batteries and alternative technologies, such as fuel cell and magnesium-sulphur batteries	☒	☐	☐
	Promoting **public and non-motorised transport** particularly in urban areas, for example by introducing free public transport or congestion charges	☒	☒	☐
	Developing **campaigns** and educational material specifically focused on the impact of e-mobility on biodiversity and ecosystem services	☒	☒	☒

The findings of the present study link to a variety of current debates such as discussions surrounding the Post 2020 Framework of the Convention on Biological Diversity. The fifteenth Conference of the Parties (COP) in 2020 is expected to update the convention's strategic plan and lay down the framework for the next decade. The findings of this report emphasise the need for explicitly addressing consumption-specific issues as part of this strategic plan.

Similarly, the present study provides insights for the One Planet Network of the United Nations – in particular the Sustainable Food Systems and the Consumer Information Programmes. This report shows that transnational multi-stakeholder approaches, such as the one taken by the One Planet Network are indispensable for addressing the complex and multi-faceted nature of the relationships between consumption and biodiversity and ecosystem services. Given the far-reaching trade-offs between environmental and social sustainability, it is clear that only holistic and integrative approaches to solving these issues have a chance of success. The findings of this report can provide guidance to the work of such initiatives.

7.4 Visions for sustainable consumption in 2050

What would a society look like that actively promoted sustainable consumption for the conservation of biodiversity and ecosystem services worldwide? What measures would need to be implemented in the short, medium and long terms for such a transition to be achieved? Based on the findings, this study outlines four visions (Figure 15) to be implemented by 2050 that present potential concepts for achieving sustainable consumption in industrialised countries like Germany. The four visions are not meant to act as alternatives, but as complementing trajectories that have the potential to substantially lessen the impact of consumption in industrial countries on biodiversity and ecosystem services in other parts of the world. These visions seek to provide inspiration for the kind of future we could strive for in order to conserve resources and natural environments for future generations.

Sufficiency-Oriented Lifestyles 2050

Industrialised countries have become a global role model for promoting sufficiency-oriented lifestyles in all areas of consumption. Information campaigns and educational measures have led to greater awareness among consumers of the links between consumption, biodiversity, ecosystem services and climate change. Public discourse is focused on the good life and non-materialistic pursuits, such as social relations or artistic expression. Basic consumption needs are met in an ecologically sustainable, highly localised and socially equitable manner.

Circular Economy 2050

The economy is restructured in a predominantly circular fashion that reduces pressures on biodiversity and ecosystem services worldwide. Resource inputs and waste production, CO_2 emissions and energy leakage are minimised by slowing, closing and narrowing energy and material loops. There has been investment into the improvement of recycling technologies and infrastructures. The closing of key material cycles is common practice and legally binding. Consumers are aware of recycling and repair options, which are readily accessible.

Sustainable Supply Chains 2050

Sustainability along the entire supply chains of consumed goods and services is actively promoted to conserve biodiversity and ecosystem services worldwide. Changes in production are facilitated through multi-stakeholder partnerships, direct investment and technology transfers. The ecological and social impact of products is transparent to consumers with compulsory labelling across sectors. Public procurement guidelines set high ecological and social standards for all goods and services purchased. High demand for sustainably produced products has shifted production processes.

Sustainable Alternatives 2050

The consumption of raw materials and products deemed particularly harmful for biodiversity and ecosystem services worldwide is significantly reduced or phased out. Alternatives are scaled up and investment in research and development creates new product options. The internalisation of external environmental and social costs makes the consumption of unsustainable products the more costly option. Economic and non-monetary incentives encourage consumers to opt for the most sustainable product choices and consumption patterns have shifted significantly.

Figure 15: **Visions for sustainable consumption in 2050**

List of Figures

List of Tables

List of Abbreviations

10YFP	10-Year Framework for Sustainable Consumption and Production
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMZ	Federal Ministry for Economic Cooperation and Development
BfN	Federal Agency for Nature Conservation
CO_2	Carbon Dioxide
COP	Conference of the Parties
EU	European Union
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
SCP	Sustainable Consumption and Production
TEEB	The Economics of Ecosystems and Biodiversity

Endnotes

1 IPBES [Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services] (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat, Bonn, Germany, page 5.

2 IPBES (2019), page 14. See endnote 1.

3 IPBES (2019), page 17. See endnote 1.

4 Liu, J. Q., Hull, V., Batistella, M., DeFries, R., Dietz, T., Fu, F., Herte, T. W., Izaurralde, R. C., Lambin, S., Li, S., Martinelli, L. A., McConnell, W., Moran, E. F., Naylor, R., Ouyang, Z., Polenske, K. R., Reenberg, A., de Miranda Rocha, G., Simmons, C. S., Verburg, P. H., Vitousek, P. M., Zhang, F. & Zhu, C. (2013). Framing sustainability in a telecoupled world. Ecology and Society 18(2), page 26.

5 Lenzen, M., Moran, D., Kanemoto, K., Foran, B., Lobefaro, L. & Geschke, A. (2012). International trade drives biodiversity threats in developing nations. Nature, 486(7401), page 109; TEEB [The Economics of Ecosystems and Biodiversity] (2010). Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB.

6 Statistisches Bundesamt (2018). Einkommen, Konsum und Lebensbedingungen. www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Einkommen-Konsum-Lebensbedingungen/Konsumausgaben-Lebenshaltungskosten/_inhalt.html

7 BMUB/ UBA [Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit/ Umweltbundesamt] (2019). Umweltbewusstsein in Deutschland 2018: Ergebnisse einer repräsentativen Bevölkerungsumfrage. Berlin, Dessau-Roßlau.

8 BMUB/ BfN [Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit/ Bundesamt für Naturschutz] (2018). Naturbewusstsein 2017: Bevölkerungsumfrage zu Natur und biologischer Vielfalt. Berlin, Bonn.

9 Spangenberg, J.H. (2007). Integrated scenarios for assessing biodiversity risks. Sustainable Development 15, page 343–356; Wilting, H. C., Schipper, A. M., Bakkenes, M., Meijer, J. R. & Huijbregts, M. A. J. (2017). Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis. Environ. Sci. Technol. 51, page 3298–3306.

10 IPBES (2019), page 5. See endnote 1.

11 FAO [Food and Agricultural Organization] (2014). Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Indonesia. Environment and Natural Resources Management Working Paper 60. Rome.

12 WWF [World Wide Fund For Nature] Indonesia. (2012). Tesso Nilo NP and Social Development – WWF Indonesia Riau Program.

13 Thackway, R. (2018). Land Use in Australia – Past, Present, and Future. Australian National University.

14 Brookes, G. & Barfoot, P. (2018). GM crops: Global socio-economic and environmental impacts 1996–2016. PG Econocmics Ltd., UK.

15 Humbert, F. & Braßel, F. (2016). Süße Früchte, bittere Wahrheit – Die Mitverantwortung deutscher Supermärkte für menschenunwürdige Zustände in der Ananas- und Bananenproduktion in Costa Rica und Ecuador. Oxfam Deutschland.

16 Statista (2019). Konsum von Obst in Deutschland in den Jahren 1990/91 bis 2015/16. https://de.statista.com/statistik/daten/studie/29107/umfrage/verbrauchsmenge-von-obst-in-deutschland/

17 Krishnan, S. (2017). Sustainable coffee production. In Oxford Research Encyclopedia of Environmental Science.

18 Bitty, E. A., Bi, S. G., Bene, J. C. K., Kouassi, P. K. & McGraw, W. S. (2015). Cocoa farming and primate extirpation inside Cote d'Ivoire's protected areas. Tropical Conservation Science, 8(1), page 95–113.

19 Statista (2019). Coffee production worldwide from 2003/04 to 2017/18. www.statista.com/statistics/263311/worldwide-production-of-coffee/

20 Hennenberg, K., Wiegmann, K., Herrera, R., Hünecke, K., Fritsche, U., Timpe, C., Marggraff, V., Schümann, K. Luick, R. & Krismann, A. (2012). Umsetzung der Biodiversitätsziele bei der nachhaltigen Bioenergienutzung.

21 Greenpeace (2017). Eye of the Taiga – how industry's claimed ‚sustainable forestry' in Russia is destroying the great northern forest. Amsterdam.

22 Chaudhary, A., Burivalova, Z., Koh, L. P. & Hellweg, S. (2016). Impact of Forest Management on Species Richness: Global Meta-Analysis and Economic Trade-Offs. Scientific Reports, 6, page 1–10.

23 EEPN [European Environmental Paper Network] (2015). Mapping Pulp Mill Expansion. Risks and Recommendations.

24 van der Mark, M. & Haggith, M. (2017). Expansion of the Brazilian pulp industry – Impacts and risks. Environmental Paper Network. Discussion Document 3.

25 Warren-Thomas, E., Dolman, P. M. & Edwards, D. P. (2015). Increasing demand for natural rubber necessitates a robust sustainability initiative to mitigate impacts on tropical biodiversity. Conservation Letters, 8(4), page 230–241.

26 Biograce. (n.d.). www.biograce.net; Econinvent. Life Cycle Inventory Database (n.d.). www.ecoinvent.org

27 Dehoust, G., Vogt, R. & Priester, M. (2017). Erörterung ökologischer Grenzen der Primärrohstoffgewinnung und Entwicklung einer Methode zur Bewertung der ökologischen Rohstoffverfügbarkeit zur Weiterentwicklung des Kritikalitätskonzeptes (ÖkoRess I). UBA Texte 87/2017.

28 Dehoust et al. (2017). See endnote 27.

29 Rüttinger, L., Treimer, R., Tloess, G. & Griesto, L., (2016). Umwelt- und Sozialauswirkungen der Bauxitgewinnung und -weiterverarbeitung in der Boké und Kindia-Region, Guinea; Berlin: adelphi.

30 The statistical data also include petroleum products defined as simply processed fuels (e.g. petrol, lubricants) and raw chemicals (e.g. naphtha, aromatics).

31 UNEP [United Nations Environment Programme] (2007). Mangroves of Western and Central Africa. UNEP-Regional Seas Programme/UNEP-WCMC.

32 Oyebade, B. A., Emerhi, E. A. & Ekeke, B. A. (2010). Quantitative review and distribution status of mangrove forest species in West Africa. African Research Review, 4(2).

33 Polidoro, B. A., Carpenter, K. E., Collins L., Duke, N. C., Ellison, A. M., Ellison, J. C., Farnsworth, E. J., Fernando, E. S., Kathiresan, K., Koedam, N. E., Livingstone, S. R., Miyagi, T., Moore, G. E., Nam, V. N., Ong, J. E., Primavera, J. H., Salmo III, S. G., Sanciangco, J. C., Sukardjo, S., Wang, Y. & Yong, J. W. H. (2010). The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern. PLoS ONE 5(4): e10095.

34 U.S. Fish and Wildlife Service (2011). Bird Impact Data and Consolidate Wildlife Reports. www.fws.gov/home/dhoilspill/collectionreports.html

35 Leahy, S. (2019, April 11). This is the world's most destructive oil operation – and it's growing. National Geopraphic. www.nationalgeographic.com/environment/2019/04/alberta-canadas-tar-sands-is-growing-but-indigenous-people-fight-back/

36 Copeland, C. & Resources, Science, and Industry Division. (2013). Mountaintop mining: Background on current controversies. Library of Congress, Congressional Research Service; Dehoust et al. (2017). See endnote 27.

37 IPBES (2019), page 18. See endnote 1.

38 Lithium is not imported as a metal, but as a final product (battery). It is included here due to its relevance in the context of the case study in chapter 6.

39 IPBES (2019), page 17. See endnote 1.

40 IPBES (2019), page 17. See endnote 1.

41 Remy, N., Speelman, E. & Swartz, S. (2016). Style that's sustainable: A new fast-fashion formula. McKinsey. www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/style-thats-sustainable-a-new-fast-fashion-formula; Korolkow, J. (2015). Konsum, Bedarf und Wiederverwendung von Bekleidungen und Textilien in Deutschland. Fachverband Textilrecycling. Bonn.

42 Textile Exchange (2016). Prefered Fiber Market Report 2016.

43 Gesamtverband der deutschen Textil- und Modeindustrie e. V. (2017). Die deutsche Textil- und Modeindustrie in Zahlen. Berlin

44 Chapagain, A. K., Hoekstra, A. Y., Savenije, H. H. & Gautam, R. (2006). The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Ecological economics, 60(1), page 186–203.

45 Ferrigno, S., Guadagnini, R. & Tyrell, K. (2017). Is cotton conquering its chemical addiction – A review of pesticide use in global cotton production. Pesticide Action Network UK; FAO ICAC [Food and Agriculture Organization – International Cotton Advisory Committee] (2015). Measuring sustainability in cotton farming systems. Towards a Guidance Framework. Rome.

46 IPBES (2019), page 30. See endnote 1.

47 Maxwell, B. D., Ryan, M. R. & Smith, R. G. (2012). Navigating a Critical Juncture for Sustainable Weed Management. BioScience 62, page 75–84; Tabashnik, B.E., Carrière, Y. (2017). Surge in insect resistance to transgenic crops and prospects for sustainability. Nat Biotechnol 35, page 926–935.

48 Schaus K. (2013). Gutachten Nachhaltige Kleidung – im Auftrag der Bundestagsfraktion Bündnis 90/Die Grünen. Konstanz.

49 Ergon Associates Ltd. (2008). Literature Review and Research Evaluation relating to Social Impacts of Global Cotton Production for ICAC Expert Panel on Social, Environmental and Economic Performance of Cotton (SEEP).

50 Bündnis für nachhaltige Textilien (2017, November 24). Bündnis für nachhaltige Textilien tritt 2018 in neue Phase: Verbindliche Ziele für alle Mitglieder und stärkere Internationalisierung. www.textilbuendnis.com/neue-phase-verbindliche-ziele-fuer-alle-mitglieder-und-staerkere-internationalisierung/

51 Tiemann, L. K., Grandy, A. S., Atkinson E. E., Marin-Spiotta, E. & McDaniel, M. D. (2015). Crop rotational diversity enhances belowground communities and functions in an agroecosystem. Ecology Letters, 18(8), page 761–771.

52 Seufert, V., Ramankutty, N. & Foley, J. A. (2012). Comparing the yields of organic and conventional agriculture. Nature, 485(7397), page 229.

53 Müller, R., Teufel, J., Stratmann, B., Moch, K., Oldenburg, C., Mangold, M., Zietlow, B. & Stechmesser, K. (2018). Leitfaden für eine nachhaltige Textilbeschaffung der Bundesverwaltung.

54 Bündnis für nachhaltige Textilien (2017). Roadmap 2017: Bundesregierung Deutschland.

55 WRAP [The Waste and Resources Action Programme] (2017). Valuing Our Clothes: the cost of UK Fashion.

56 Otto-Friedrich-Universität Bamberg (2019, April 26). Retourentacho 2018/2019 ausgewertet. Retourenforschung. www.retourenforschung.de/info-retourentacho2019-ausgewertet.html

57 Ludmann, S. (2019). Ökologische Betrachtung des Peer-to-Peer Sharing. In: Behrendt S., Henseling C. & Scholl G. (eds) Digitale Kultur des Teilens. Wiesbaden.

58 Greenpeace (2015). Wegwerfware Kleidung. Repräsentative Greenpeace-Umfrage zu Kaufverhalten, Tragedauer und der Entsorgung von Mode. Hamburg.

59 RREUSE [The Reuse and Recycling EU Social Enterprises network] (2017). Reduced taxation to support re use and repair.

60 European Comission (2015). Closing the loop – An EU action plan for the Circular Economy. Brussels.

61 WRAP (2017). See endnote 55.

62 Remy et al. (2016). See endnote 41.

63 Sandin, G. & Peters, G. M. (2018). Environmental impact of textile reuse and recycling – A review. Journal of Cleaner Production 184, page 353–365.

64 Carus, M., Gahle, C. Pendarovski, C., Vogt, D., Ortmann, S., Grotenhermen, F., Breuer, T. & Schmidt, C. (2008). Studie zur Markt- und Konkurrenzsituation – Werkstoffen (Deutschland und EU). Gülzower Fachgespräche, Band 26. Gülzow.

65 Montford, S. & Small, E. (1999). Measuring harm and benefit: The biodiversity friendliness of Cannabis sativa. Global biodiversity 8(4), page 2–13.

66 Decorte, T. (2011). Fibre hemp and marihuana: assessing the differences between distinct varieties. Geneva Centre for the democratic control of armed forces, International Police Executive Symposium. Working Paper No. 38.

67 Carus, M. (2017). The European Hemp Industry: Cultivation, processing and applications for fibres, shivs, seeds and flowers. Euopean Industrial Hemp Association.

68 Bundesinformationszentrum Landwirtschaft (2017). Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten der Bundesrepublik Deutschland.

69 FAO [Food and Agricultural Organization] (2015). Measuring Sustainability in Cotton Farming Systems – Towards a Guidance Framework.

70 Averink, J. (2015). Global Water Footprint of Industrial Hemp Textile. University of Twente, Netherlands.

71 URS Infrastructure and Environment UK Limited (2012). Review of Data on Embodied Water in Clothing, Summary Report.

72 FAO (2015). See endnote 69.

73 Fachagentur nachwachsende Rohstoffe (2008). Studie zur Markt- und Konkurrenzsituation bei Naturfasern und Naturfaser-Werkstoffen (Deutschland und Europa).

74 Fachagentur nachwachsende Rohstoffe (2008). See endnote 73.

75 FAO (2015). See endnote 69.

76 Averink (2015). See endnote 70.

77 Fachagentur nachwachsende Rohstoffe (2008). See endnote 73.

78 OECD (2019). Crop production (Soy). https://doi.org/10.1787/49a4e677-en

79 WWF [World Wide Fund For Nature] (2016, April 21). Soja: Wunderbohne mit riskanten Nebenwirkungen. www.wwf.de/themen-projekte/landwirtschaft/produkte-aus-der-landwirtschaft/soja/soja-wunderbohne-mit-riskanten-nebenwirkungen/

80 Beste, A. & Boeddinghaus, R. (2011). Artenvielfalt statt Sojawahn. Der Eiweißmangel in der EU: Wie lässt sich das seit langem bestehende Problem lösen? Eine Studie im Auftrag von Martin Häusling, MDEP.

81 OECD (2019). See endnote 78.

82 OECD (2016). Meat. In OECD-FAO Agricultural Outlook 2016-2025. Paris.

83 Statistisches Bundesamt (2008). Vom Erzeuger zum Verbraucher. Fleischversorgung in Deutschland; BLE [Bundesanstalt für Landwirtschaft und Ernährung] (2018). Bericht zur Markt- und Versorgungslage Fleisch 2018.

84 WWF [World Wide Fund For Nature] (2014). The Growth of Soy: Impacts and Solutions.

85 WWF (2014). See endnote 84.

86 IPBES (2019), page 5. See endnote 1.

87 Then, C., Miyazaki, J., Bauer-Panskus, A. & Reichert, T. (2018). Gentechnik-Soja in Südamerika: Flächenverbrauch, Pestizideinsatz und die Folgen für die globalen Ziele für nachhaltige Entwicklung.

88 WWF [World Wide Fund For Nature] (2012). Factsheet: Cerrado – Birthplace of the waters.

89 Dou, Y., da Silva, R. F. B., Yang, H. & Liu, J. (2018). Spillover effect offsets the conservation effort in the Amazon. Journal of Geographical Sciences, 28(11), page 1715–1732.

90 WWF [World Wide Fund For Nature] (2018, January 25). Sixty-one meat and soybean purchasing companies in Brazil have committed to combating deforestation in the Cerrado. www.wwf.org.br/informacoes/english/?65083/Sixty-one-companies-in-Brazil-have-committed-to-combating-deforestation-in-the-Cerrado

91 WWF (2018, January 25). See endnote 90. Then et al. (2018). See endnote 87.

92 Wright, C. & Wimberley, M. (2013). Recent land-use change in the Western Corn Belt threatens grassland and wetlands. PNAS 110 (10), page 4134–4139; Mogren, C. L., Rand, T. A., Fausti, S. W. & Lundgren, J. G. (2016). The effects of crop intensification on the diversity of native pollinator communities. Environmental entomology, 45(4), page 865–872; Johnston, C. A. (2014). Agricultural expansion: land use shell game in the US Northern Plains. Landscape ecology, 29(1), page 81–95.

93 Lark, T. J., Larson, B., Schelly, I., Batish, S. & Gibbs, H. K. (2019). Accelerated Conversion of Native Prairie to Cropland in Minnesota. Environmental Conservation 46, page 155–162.

94 U.S. Fish and Wildlife Services (2019, March 5). Saving our native prairies: A landscape conservation approach. www.fws.gov/midwest/news/nativeprairies.html; Samson, F., Knopf, F., Ostlie, W. (2004). Great Plains Ecosystems: Past, Present, Future. U.S. Geological Survey.

95 Then et al. (2018). See endnote 87.

96 Then et al. (2018). See endnote 87.

97 Schütte, G., Eckerstorfer, M., Rastelli, V., Reichenbecher, W., Restrepo-Vassalli, S., Ruohonen-Lehto, M. & Mertens, M. (2017). Herbicide resistance and biodiversity: agronomic and environmental aspects of genetically modified herbicide-resistant plants. Environmental Sciences Europe, 29(1), page 5.

98 James, C. (2015). Global Status of Commercialized Biotech/GM Crops: 2015. ISAAA Brief, No. 51. Ithaca, New York; IPBES (2019), page 15. See endnote 1.

99 Umweltinstitut München (n.d.). Glyphosat. www.umweltinstitut.org/themen/landwirtschaft/pestizide/glyphosat.html

100 Yang, Y. & Suh, S. (2015). Changes in environmental impacts of major crops in the US. Environmental Research Letters, 10(9), 094016; Then et al. (2018). See endnote 87.

101 Almeida, V. E. S. D., Friedrich, K., Tygel, A. F., Melgarejo, L. & Carneiro, F. F. (2017). Use of genetically modified crops and pesticides in Brazil: growing hazards. Ciencia & Saude Coletiva, 22, page 3333–3339.

102 Yang & Suh (2015). See endnote 100.

103 Then et al. (2018). See endnote 87.

104 Deutscher Bundestag (2016, February 8). Glyphosat ohne Tallowamine. www.bundestag.de/presse/hib/201602/405750-405750

105 Then et al. (2018). See endnote 87.

106 Then et al. (2018). See endnote 87.

107 Yang & Suh (2015). See endnote 100.

108 Machovina, B., Feeley, K. J. & Ripple, W. J. (2015). Biodiversity conservation: The key is reducing meat consumption. Science of the Total Environment, 536, page 419–431.

109 DGE [Deutsche Gesellschaft für Ernährung] (2017). Vollwertig essen und trinken nach den 10 Regeln der DGE.

110 Heinrich Böll Stiftung (2018). Fleischatlas 2018 – Daten und Fakten über Tiere als Nahrungsmittel. Berlin.

111 de Boer, J., Schösler, H. & Aiking, H. (2014). “Meatless days” or “less but better”? Exploring strategies to adapt Western meat consumption to health and sustainability challenges. Appetite, 76, page 120–128.

112 Just, D. R. & Wansink, B. (2009). Smarter lunchrooms: using behavioral economics to improve meal selection. Choices, 24(3), page 1–7.

113 WWF [World Wide Fund For Nature] (2019). The hidden world of soy. http://hiddensoy.panda.org/

114 Wellesley, L., Froggatt, A. & Happer, C. (2015). Changing climate, changing diets: Pathways to lower meat consumption. Chatham House Report. The Royal Institute of International Affairs.

115 Wellesley et al. (2015). See endnote 114.

116 Peter, G., Krug, O., Bendiek, J. & Stolz, A. (2014). Mögliche Auswirkungen einer Ausweitung der Gentechnik-Kennzeichnungspflicht auf Lebensmittel tierischen Ursprungs. Thünen-Institut für Marktanalyse. Braunschweig.

117 Deutscher Bundestag (2018). Angebot und Nachfrage von Lebensmitteln tierischen Ursprungs, die ohne gentechnisch veränderte Pflanzen erzeugt wurden. Wissenschaftliche Dienste, No. WD 5-3000-136/18; BMUB/ BfN (2018). See endnote 8.

118 LfL [Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten] (2018, September 20). Rekord-Anbaufläche für Soja in Deutschland. www.lfl.bayern.de/verschiedenes/presse/pms/2018/199833/index.php

119 BLE [Bundesanstalt für Landwirtschaft und Ernährung] (2018, December 17). Sechs Gründe, warum der heimische (Bio-)Sojaanbau weiter zunehmen wird. Informationsportal Ökolandbau. www.oekolandbau.de/landwirtschaft/betrieb/marketing/maerkte/sechs-gruende-warum-der-heimische-bio-sojaanbau-weiter-zunehmen-wird/

120 BLE (2018, December 17). See endnote 119; Calculated with an average yield of 2.5 tonnes per hectare.

121 OECD (2019). See endnote 78.

122 BLE [Bundesanstalt für Landwirtschaft und Ernährung] (2015, May 29). Sojaanbau in Deutschland – welche Sorten eignen sich? Informationsportal Ökolandbau www.oekolandbau.de/landwirtschaft/pflanze/spezieller-pflanzenbau/koernerleguminosen/sojabohnen/sojaanbau-sortenwahl/

123 BLE (2015, May 29). See endnote 122.

124 BLE (2015, May 29). See endnote 122.

125 AbL [Arbeitsgemeinschaft bäuerliche Landwirtschaft e.V.] (2012). Gentechnikfreie Fütterung – und es geht doch!

126 WWF (2016). See endnote 78.

127 Reckling, M., Bergkvist, G., Watson, C. A., Stoddard, F. L., Zander, P. M., Walker, R. L., Pristeri, A., Toncea, I. & Bachinger, J. (2016). Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in plant science, 7, page 669.

128 Bues, A., Preissel, S., Reckling, M., Zander, P., Kuhlman, T., Topp, K., Watson, C., Lindström, K., Stoddard, F. L. & Murphy-Bokern, D. (2013). The environmental role of protein crops in the new common agricultural policy (No. 2012-067). European Parliament. Brussels.

129 Stagnari, F., Maggio, A., Galieni, A. & Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: an overview. Chemical and Biological Technologies in Agriculture, 4(1), page 2.

130 BUND [Bund für Umwelt und Naturschutz] (2019). Soja-Report. Wie kann die Eiweißpflanzenstrategie der EU auf nachhaltige und agrarökologische Weise angekurbelt werden? Berlin.

131 BMEL [Bundesministerium für Ernährung und Landwirtschaft] (2018). Landwirtschaft verstehen. Fakten und Hintergründe. Berlin.

132 BMEL (2018). See endnote 131.

133 Häusling, M. (2018). Wege aus der Eiweißlücke - Stand und Perspektiven der Eiweißversorgung in der EU. Kritischer Agrarbericht 2018.

134 U.S. Geological Survey (2017). Mineral Commodity Summaries 2017. Reston.

135 Statista (2019). Anteil der weltweiten Verwendung von Lithium zur Herstellung von verschiedenen Produkten. https://de.statista.com/statistik/daten/studie/159921/umfrage/verwendungszwecke-von-lithium-auf-dem-weltmarkt/

136 Pennell, K. (2018, March 26). Gibt es genug Lithium um den Bedarf zu decken? Energy BrainBlog. https://blog.energybrainpool.com/gibt-es-genug-lithium-um-den-bedarf-fuer-batterien-zu-decken/

137 United Nations Human Settlements Programme (2014). Transport Action Plan. Urban Electric Mobility Initiative. Nairobi.

138 Öko-Institut (2017). Strategien für die nachhaltige Rohstoffversorgung der Elektromobilität. Synthesepapier zum Rohstoffbedarf für Batterien und Brennstoffzellen. Studie im Auftrag von Agora Verkehrswende.

139 Federal Government Germany (2011). Regierungsprogramm Elektromobilität. Statista (2019). Anzahl der gemeldeten Pkw in Deutschland in den Jahren 1960 bis 2019 (Bestand in 1.000). https://de.statista.com/statistik/daten/studie/12131/umfrage/pkw-bestand-in-deutschland/

140 Schmidt, M. (2017). Rohstoffrisikobewertung – Lithium. DERA Rohstoffinformationen Nr. 33. Berlin.

141 Schmidt (2017). See endnote 140.

142 Statista (2019). Anzahl der Elektroautos in Deutschland von 2006 bis 2019. https://de.statista.com/statistik/daten/studie/265995/umfrage/anzahl-der-elektroautos-in-deutschland/

143 Schmidt (2017). See endnote 140.

144 Ronggua, C., Juan, G., Liwen, Y., Huy, D. & Liedtke, M. (2016). Supply and demand of Lithium and Gallium. Information Center of Ministry of Land and Resources & Federal Institute for Geoscience and Natural Resources.

145 Ronggua et al. (2016). See endnote 144.

146 Schmidt (2017). See endnote 140.

147 Dehoust et al. (2017). See endnote 27.

148 Cubillos, C. F., Aguilar, P., Grágeda, M. & Dorador, C. (2018). Microbial Communities From the World's Largest Lithium Reserve, Salar de Atacama, Chile: Life at High LiCl Concentrations. Journal of Geophysical Research: Biogeosciences, 123(12), page 3668–3681.

149 SQM [Sociedad Química y Minera de Chile] (2017). Sustainability Report. Santiago, Chile.

150 SQM (2017). See endnote 149.

151 SQM (2017). See endnote 149.

152 SQM (2017). See endnote 149.

153 Wanger, T. C. (2011). The Lithium future – resources, recycling, and the environment. Conservation Letters, 4(3), page 202–206.

154 Schmidt (2017). See endnote 140.

155 Aguilar-Fernandez, R. (2009). Estimating the Opportunity Cost of Lithium extraction in the Salar de Uyuni, Bolivia. Master Project, Duke University.

156 Schüler, D., Dolega, P. & Degreif, S. (2018). European Policy Brief - Social, economic and environmental challenges in primary lithium and cobalt sourcing for the rapidly increasing electric mobility sector. Strategic Dialogue on Sustainable Raw Materials for Europe (STRADE) No. 06/ 2018.

157 Pöyhönen, P. & Simola, E. (2007). Connecting Components, Dividing Communities. Tin production for consumer electronics in the DR Kongo and Indonesia. FinnWatch.

158 BMUB/UBA [Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit/ Umweltbundesamt] (2016). Weiterentwicklung und vertiefte Analyse der Umweltbilanz von Elektrofahrzeugen. Berlin/ Dessau-Roßlau.

159 Sommer, C., Gorges, T., Leonhäuser, D. & Schmitt, V. (2015). NRVP – Kostenvergleich zwischen Radverkehr, Fußverkehr, Kfz-Verkehr und ÖPNV anhand von kommunalen Haushalten. Universität Kassel.

160 Ziemann, S., Müller, D., Schebek, L. & Weil, M. (2018). Modeling the potential impact of lithium recycling from EV batteries on lithium demand: A dynamic MFA approach, Resources, Conservation & Recycling 133, page 76–85.

161 Ziemann et al. (2018). See endnote 160.

162 Schmidt (2017). See endnote 140.

163 Dewulf, J., Van der Vorst, G., Denturck, K., Van Langenhove, H., Ghyoot, W., Tytgat, J. & Vandeputte, K. (2010). Recycling rechargeable lithium ion batteries: Critical analysis of natural resource savings. Resources, Conservation and Recycling, 54(4), page 229–234.

164 Statista (2019). Durchschnittlicher Preis von Lithiumcarbonat weltweit in den Jahren von 2002 bis 2018, https://de.statista.com/statistik/daten/studie/979746/umfrage/durchschnittlicher-preis-von-lithium-weltweit/; Roskill (2019). Lithium. Outlook to 2028. 16th Edition.

165 Sonoc, A., Jeswiet, J. & Soo, V. K. (2015). Opportunities to improve recycling of automotive lithium ion batteries. Procedia cIRP, 29, page 752–757.

166 Schüler, D. Dolega, P. & Degreif, S. (2018). See endnote 156.

167 Öko-Institut (2017). See endnote 138.

168 Ziemann et al. (2018). See endnote 160.

169 Ziemann et al. (2018). See endnote 160.

170 Ziemann et al. (2018). See endnote 160.

171 Öko-Institut (2017). See endnote 138.

172 Wishart, J. (n.d.), Fuel Cells vs. Batteries in the automotive sector. Intertek.

173 Ligen, Y., Vrubel, H. & Girault, H. (2018). Mobility from renewable electricity: infrastructure comparison for battery and hydrogen fuel cell vehicles. World Electric Vehicle Journal, 9(1), page 3.

174 Upadhyaya, J. Peters, R. W. & Fouad, F. H. (2004). Environmental Impact of Fuel Cell Technology for Electric Power Generation: An Overview and Case Studies. University of Alabama.

175 H2 Mobility Deutschland (2019). https://h2.live/

176 Breuer, R. (2018, October 15). Wie Wissenschaftler die Batterien der Zukunft entwickeln. Süddeutsche Zeitung Online. www.sueddeutsche.de/digital/batterien-weg-vom-lithium-1.4169140

177 Zhao-Karger, Z. & Fichtner, M. (2017). Magnesium-sulfur battery: its beginning and recent progress. MRS Communications, 7(4), page 770–784.

178 Gao, F., Nie, Z. R., Wang, Z. H., Gong, X. Z. & Zuo, T. Y. (2008). Assessing environmental impact of magnesium production using Pidgeon process in China. Transactions of Nonferrous Metals Society of China, 18(3), page 749–754.

179 Zacharakis, Zacharias (2017, November 22). Der Berg erwacht. Zeit Online. www.zeit.de/wirtschaft/2017-11/lithium-rohstoff-batterien-elektroautos-erzgebirge

180 Kavanagh, L., Keohane, J., Cabellos, G. G., Lloyd, A. & Cleary, J. (2018). Global Lithium Sources–Industrial Use and Future in the Electric Vehicle Industry: A Review. Resources, 7(3): page 57.

181 Mitteldeutscher Rundfunk (2018, November 22). Pläne für Lithium-Abbau nehmen Gestalt an. MDR Aktuell. www.mdr.de/nachrichten/vermischtes/lithium-abbau-im-erzgebirge-nimmt-gestalt-an100.html

182 Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B. & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223).

183 IPBES (2019), page 8. See endnote 1.

184 Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. (2013). Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO). Rome.

185 IES [Institute for European Studies], SIFO [Oslo Metropolitan University], IÖW [Institute for Ecological Economy Research] (2008) Policy instruments to promote sustainable consumption. Brussels/Heidelberg/Oslo.

186 West, C. D., Green, J. M. & Croft, S. (2018). Trase Yearbook 2018: Sustainability in forest-risk supply chains: Spotlight on Brazilian Soy. Research Report. Stockholm Environment Institute.

187 IES, SIFO & IÖW (2008). See endnote 185.

188 IES, SIFO & IÖW (2008). See endnote 185.

189 Janker, K. (2019, February 10). Ein besseres Symboltier als die Biene gibt es nicht. Süddeutsche Zeitung Online. www.sueddeutsche.de/kultur/volksbegehren-artenschutz-ein-besseres-symboltier-als-die-biene-gibt-es-nicht-1.4322040

190 Heyen, D., Fischer, C., Barth, R., Brunn, C., Grießhammer, R., Keimeyer, F. & Wolff, F. (2013). When less is more. Sufficiency – Need and options for policy action, Working Paper.

191 Heyen et al. (2013). See endnote 190.

www.bfn.de