United Nations
Convention to Combat Desertification

United for land

FASHION & LAND

Unravelling the Environmental Impact of Fibres

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UN ALLIANCE FOR SUSTAINABLE FASHION

zoï environment network

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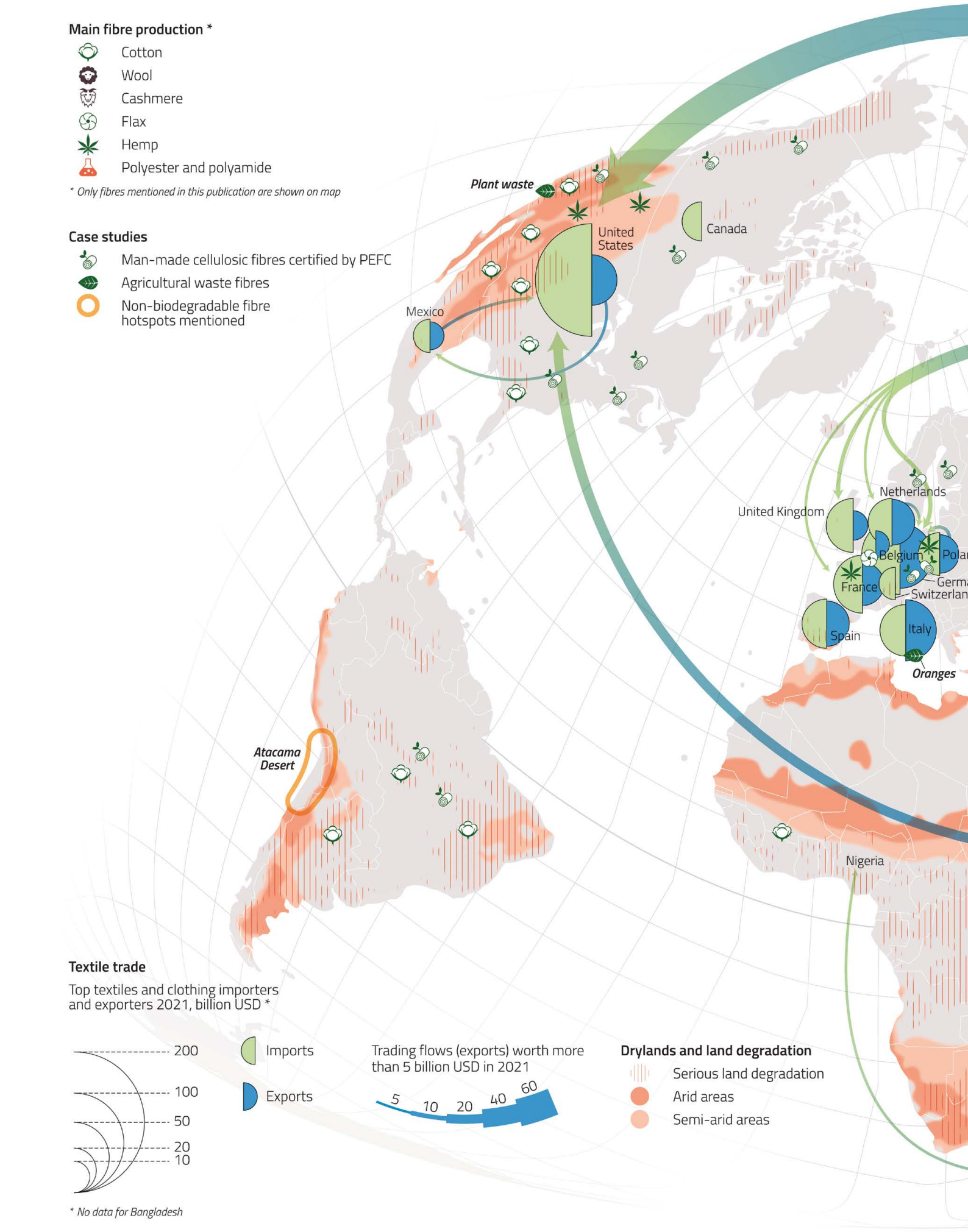
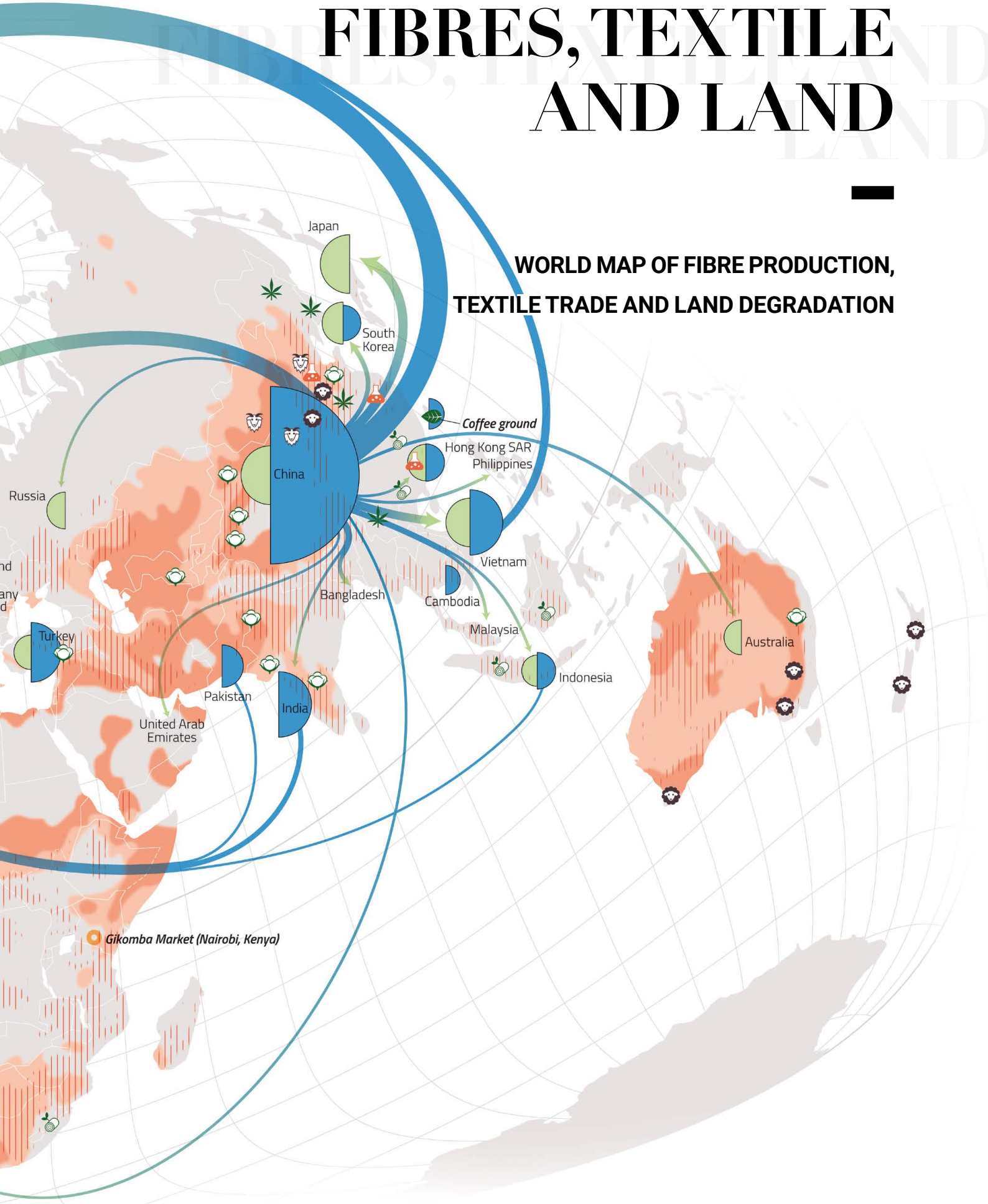


Map produced by Zoï Environment Network, November 2024
Source: World Bank; U. S. Department of Agriculture, Foreign Agricultural Service; FAO; European Commission, Joint Research Centre; Alliance for European Flax-Linen & Hemp; Textile Exchange; PEFC (Programme for the Endorsement of Forest Certification)

FIBRES, TEXTILE AND LAND

WORLD MAP OF FIBRE PRODUCTION, TEXTILE TRADE AND LAND DEGRADATION



World map showing the connections between fibre production, land degradation and the international textile trade: while trade and manufacturing is concentrated on the Asia-Europe-North Africa axis, fibre production and land degradation is global.

LETTER FROM THE EDITOR

Dear Reader,

You are holding in your hands the publication *Fashion & Land: Unravelling the Environmental Impact of Fibres* produced by the United Nations Convention to Combat Desertification (UNCCD).

You may wonder what a UN treaty to combat desertification, land degradation and drought signed by 196 countries and the European Union has to do with something seemingly as remote — and, for some, as trivial — as fashion.

The simple answer is that our clothes come from the land. And, more often than not, they return to the land.

In recent years, an increasing level of attention has been given to fashion's environmental record, particularly this trillion-dollar industry's contribution to climate change.

This is a much-needed reckoning; however, we should look beyond the number of tons of carbon emitted during the making, wearing and discarding of our clothes.

We must consider the varied and often overlooked impacts of fashion on landscapes and wildlife, waterways and forests, and more.

And we must not forget the people who call these landscapes home — farmers, herders, Indigenous and local communities — who are at the start (and often at the very bottom) of many global fashion value chains.

This pioneering publication explores the role of the fashion industry in driving environmental change, particularly in relation to land.

By focusing on the virtues and challenges of selected fibres, many of which we are likely to wear every day, it underscores the crucial importance of fibre choice in reducing the industry's land footprint and promoting more sustainable production and consumption patterns. At the same time, this publication also highlights solutions that can be found in how various fibres are produced, used and disposed of, and the role of enabling policies and innovative approaches.

Cotton, for instance, requires vast resources and can be a significant contributor to soil and freshwater depletion, while wool production such as cashmere is linked to overgrazing and desertification. There are, however, notable multistakeholder initiatives seeking to reduce these impacts and prioritize long-term sustainability of supply chains.

Wood-based textiles could inadvertently result in deforestation, while synthetic fibres represent a major source of microplastic pollution. Voluntary certification schemes and stricter regulations all play a role in avoiding such collateral damage.

Despite the promising potential of alternative materials, such as agricultural waste fibres, they remain a niche product and have yet to gain significant market traction. We need strong policy incentives and market signals to promote innovation and entrepreneurship in support of healthy land.

By focusing on fashion's impact on land, we can promote more sustainable practices that protect the environment, conserve biodiversity, generate sustainable livelihoods, and ensure that land remains productive for generations to come.

We hope that this publication inspires government and business decision-makers, as well as all of us fashion lovers and consumers, to create a more sustainable and land-friendly fashion industry.

The answer to "who are you wearing" is unequivocal: land.

Xenya Scanlon

UNCCD Chief of Communications,
External Relations and Partnerships

THE IMPACT OF FASHION ON LAND – AN INTRODUCTION

"By 2030, the fashion industry is expected to use 35% more land – much of it to grow materials for cheap and throwaway fashion. But we can choose that shirt or those jeans more carefully. Those choices do not diminish our quality of life. On the contrary, they improve it."[1]

Ibrahim Thiaw

UNCCD Executive Secretary

Fashion is a constantly growing and evolving industry – it thrives and relies on creativity and innovation to propel itself forward. At the same time, it has a serious environmental impact.

The clothing industry is a big polluter. It is also one of the least regulated business sectors, with complex supply chains and not much transparency.[2] The scale of the industry, the rise of "fast fashion" and its voracious appetite for natural resources are placing significant pressure on the environment.

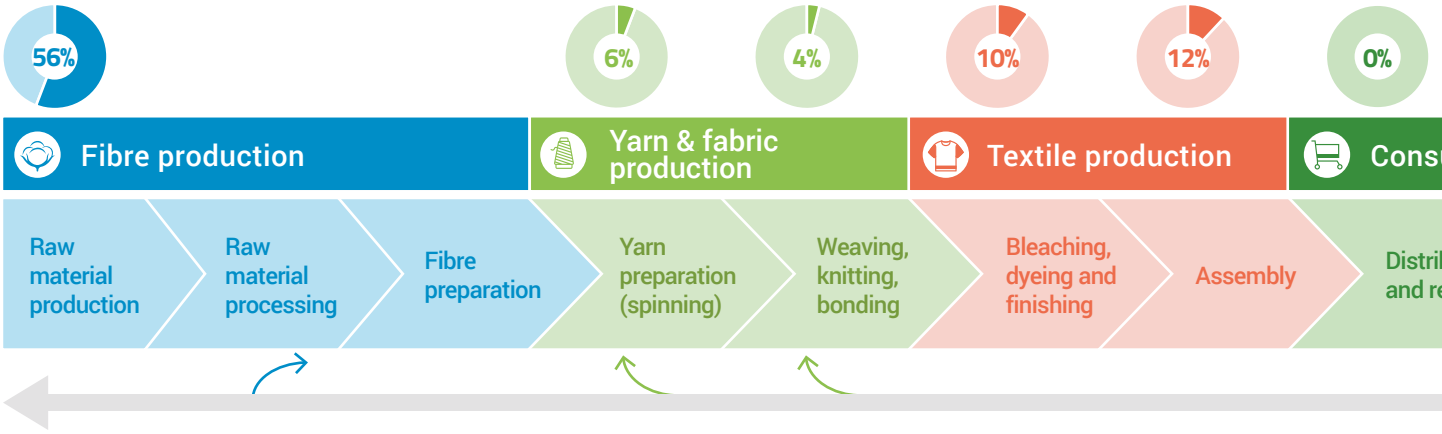
While the carbon and water footprints of fashion are well documented, there is a question that should be asked as well:

What is its impact on land?

This often-overlooked aspect determines **how sustainable** our **clothes actually are** or can be.

In terms of land use, the footprint of the global apparel value chain comes mainly from the production of fibre.[3]

LAND USE IMPACT ACROSS THE GLOBAL APPAREL VALUE CHAIN



Source: Redrawn from UNEP (2020). Sustainability and Circularity in the Textile Value Chain: Global Stocktaking. https://wedocs.unep.org/20.500.11822/34184

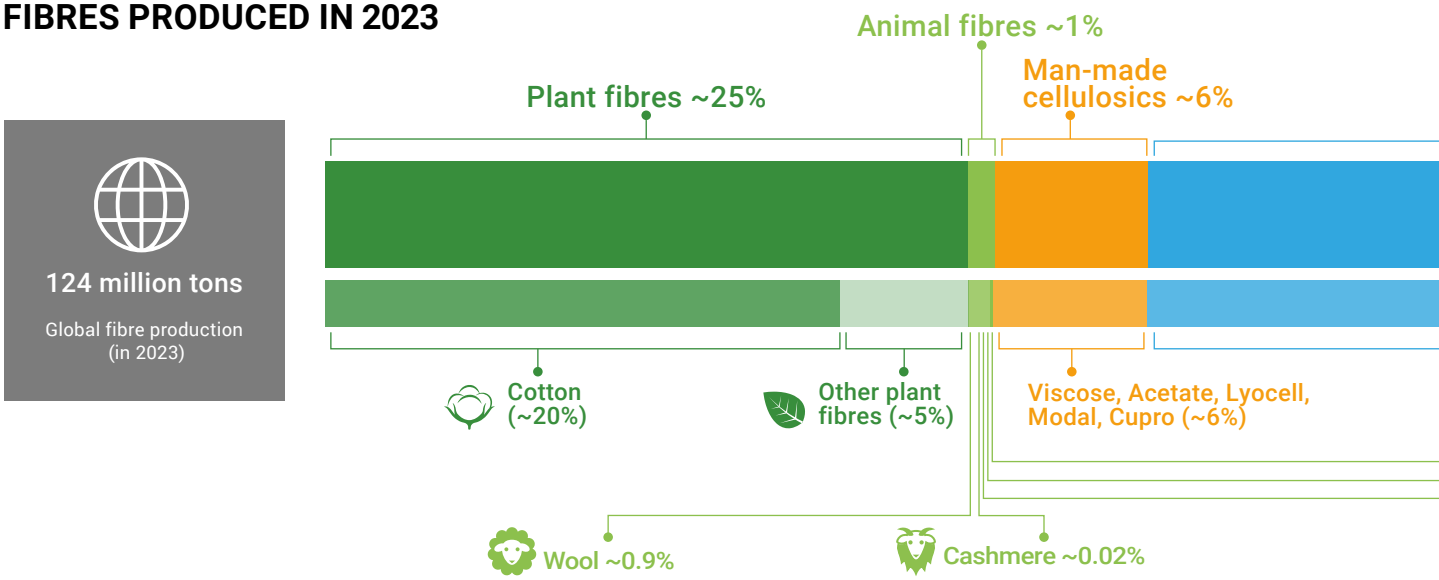
In the last two decades, global fibre production has more than doubled from 58 million tons in 2000 to a new record of 124 million tons in 2023.[4] If business continues as usual, the fibre market is expected to continue growing rapidly, reaching 160 million tons by 2030.[5] Around 60% of all the textiles produced are used in clothing.[6] Less than 1% of all material used to produce them is recycled into new clothing.[7]

While most of the fibre produced is of synthetic origin, a 2017 study estimated that, by 2030, the fashion industry will use 35% more land for cotton, forest for cellulosic fibres, and grassland for livestock, or a total of 115 million hectares, an area almost the size of South Africa.[8]

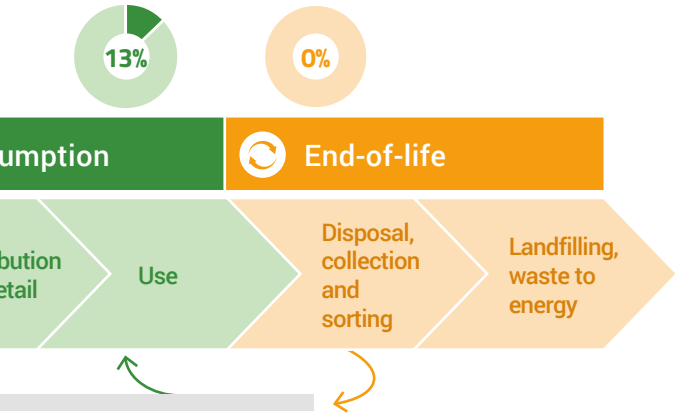
The production of raw materials for textiles carries the risk of significant negative impacts on land, such as degradation, soil erosion, overgrazing, desertification, deforestation, freshwater depletion, pollution, waste, biodiversity loss, carbon emissions and climate change.

According to the UNCCD, up to 40% of the world's land is degraded, and degradation is continuing at an alarming rate.[9] An area equivalent to four football fields of healthy land becomes degraded every second, adding up to at least 100 million hectares each year.[10] Generally, it is much more cost-effective to prevent it from happening where possible than to reverse the consequences. Restoring soil lost through erosion is a slow process.

FIBRES PRODUCED IN 2023



Source: Redrawn from Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

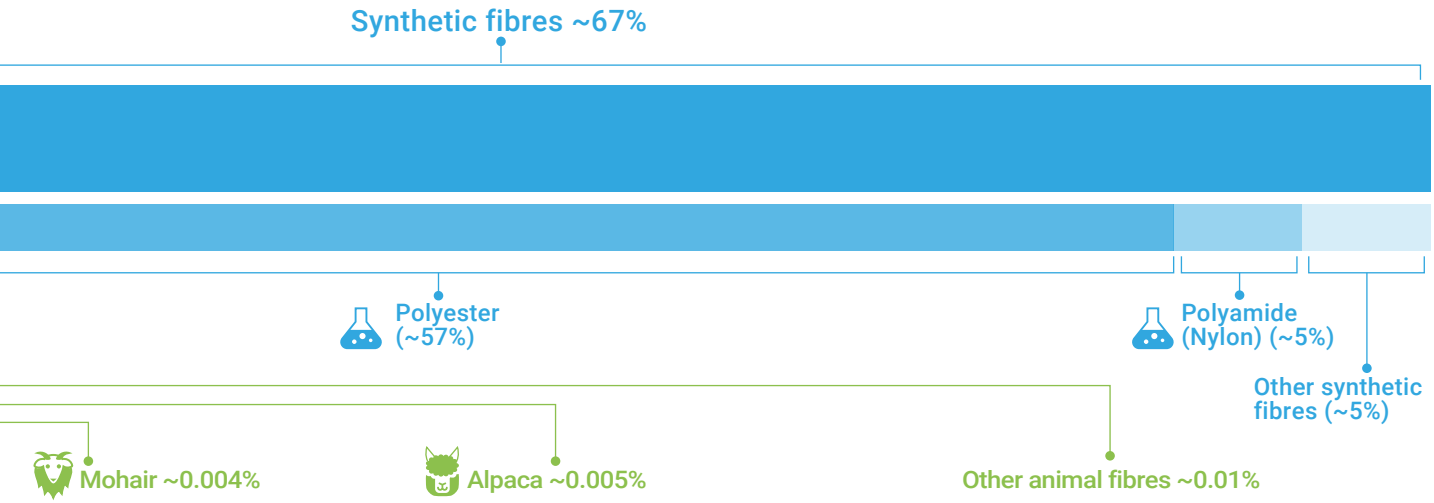


It can take 500 years for 2.5 centimetres of soil to form but only a few years to destroy it.[11]

While the production of yarn, fabric and finished items of clothing as well as the distribution and use of apparel take their toll on land and the environment too, this publication focuses on the beginning of the lifespan of clothing, when the fibre is cultivated, and on the end. Of all the fibre used for clothing, 87% is landfilled or incinerated.[12]

This publication provides a snapshot of the impact of fashion on land and does not represent a comprehensive study of interactions between the textile industry and the environment. As not all fibres or fibre categories could be taken into account, only a selection is presented. Further, the focus of the publication lies firmly on clothes, leaving out other fashion items such as shoes, handbags and accessories.

Finally, land impact can never be seen in a vacuum but as part of a broader picture, linked to social, economic and environmental factors, especially since fibres are often closely linked to people and their livelihoods. As all fibres have their respective benefits and challenges, it cannot be argued that one fibre should replace another completely. Ultimately, producing and consuming less but better, and moving towards a more circular fashion industry can help ensure that fibre production does not literally cost the earth.



COTTON

The ubiquitous natural fibre and largest land user

Cotton is the most used natural fibre in the world and the second most produced fibre in the textile industry. The fabric is comfortable, breathable and hard-wearing. Yet its cultivation comes at a cost to the land: large-scale cotton cultivation depletes the water resources of drier regions, and the industry depends heavily on chemical fertilizers, herbicides and insecticides.

Between **2 and 2.5m²** of **land is needed** to **grow** the **cotton** for **one T-shirt** in the US.[13]

→ **20% of global fibre** production is cotton.[14]

→ **2.5% of arable land** worldwide is used for **cotton cultivation.**[15]

→ **4.7% of pesticides** and **10%** of **insecticides** sold worldwide go into **cotton farming.**[16]

1,931 litres of **irrigation water** and **6,003 litres** of **rainwater** is needed on average to produce **1 kg of lint**, or **raw cotton fibre**, roughly equivalent to **one T-shirt** and **one pair of jeans**[17]

Conventional Cotton

While cotton is a practical, renewable, biodegradable and recyclable source of fibre, growing and processing the crop has a hefty environmental impact. It needs a lot of water compared to flax (used to make linen) or hemp, for example. This can become problematic in water-scarce regions. Poor irrigation practices and water management add to the problem, with potentially long-lasting impacts on people and the environment.[18]

Further, as cotton is highly vulnerable to pests and weeds, crop protection is essential for cotton cultivation. This can take many forms, with huge amounts of synthetic pesticides and chemical fertilizers used, which seep into soil and wash into waterways, harming both biodiversity and ecosystems, and the health of rural communities.[19]

The cultivation of cotton as a monoculture heavily dependent on irrigation and pesticides can result in land degradation through salinization and erosion.[20] Furthermore, cotton farming is sometimes linked to deforestation to clear land for cultivation.

What are the alternatives to conventional cotton farming?

There are four main alternatives to conventional cotton:

1 **Organic cotton.**
This avoids harmful pesticides and synthetic fertilizers, is often grown on rain-fed farms, but usually needs more land than conventional cotton due to lower yields.[21]

2 **Cotton licensed or certified under Voluntary Standard Systems.**
An example for this is Better Cotton, which targets improvements across a range of issues associated with cotton farming.

3 **Recycled cotton.**
Recycled cotton covers only about 1% of demand, however, this sector is expected to grow quickly in the coming years.[22]

4 **Other fibres.**
Alternative natural fibres such as hemp or flax have lower environmental impacts but their own sets of challenges, while synthetic fibres are non-biodegradable, and man-made cellulosic fibres are still an emerging industry.[23]

WORKING WITH FARMERS TO IMPROVE COTTON SUSTAINABILITY IN INDIA

India is the second largest producer of cotton in the world, cultivating over 12 million hectares of cotton.[33] As well as challenges related to climate change, water scarcity and poor soil health, farmers face perpetual pressure from pests, which often leads to an overuse of pesticides, putting the health of both people and the environment at risk.[34]

Better Cotton is a global not-for-profit organization supporting the production of more equitable and sustainable cotton at the farm level. It has been working in India since 2011, supporting farmers to understand the best ways to use pesticides and fertilizers, rotate crops, protect the environment, and improve working conditions in their communities. Today, the organization collaborates with over 842,000 licensed farmers in India, covering 1.3 million hectares of land and producing approximately 917,000 metric tons of certified cotton crops.[35, 36] Since 2014, farms involved in the programme have reduced pesticide use by 53% and water usage for irrigation by 29%.[37] Globally, about 22% of the cotton produced is now certified by Better Cotton.[38]

© Tim Dirven / Panos Pictures, Aral Sea, 2015

COTTON AND THE ARAL SEA

Unsustainable cotton production can have serious environmental, economic and social consequences. An example is the Aral Sea in Central Asia shared by Uzbekistan and Kazakhstan. In the 1960s the fourth largest lake in the world, by the 2000s it had lost around 90% of its water volume due to unsustainable agricultural practices, mostly in cotton cultivation.[24]

During the Soviet Union, a lot of water from the Aral Sea's inflowing rivers, the Amu Darya and Syr Darya, was diverted for cotton production, which eventually led to significant water shortages and downstream pollution with pesticides and fertilizers.[25] The retreating sea affected the surrounding areas, where salt, sand and dust storms and polluted water damaged soils. This led to lower crop yields, salinization, desertification, loss of biodiversity and livelihoods, such as fishing, and augmented health problems.[26, 27]

While the Aral Sea may never recover completely, policy reforms and more sustainable agricultural practices and irrigation techniques are being employed to restore the land.[28] Cotton is also substituted with less water-demanding crops.[29] Further, countries plant drought and salinity-tolerant trees and other plants to curb sandstorms and stabilize the new ecosystem across the former Aral seabed.[30]

Central Asia still produces a lot of cotton – estimated 1.1 million tons/year in 2018/19 – and its water footprint is 70% of water consumption in irrigation in the Aral Sea basin.[31, 32] There is still room to improve irrigation efficiency and make cotton cultivation less thirsty and more environmentally sustainable.

WOOL

Luxury animal fibre with a deep connection to land

Obtained primarily from sheep, which dominate this category, but also from goats, yaks, camels and alpacas, wool enjoys the image of a natural and environmentally friendly material.[38, 40] The reality, however, is nuanced.

Wool is a warm, breathable and highly durable material, which are big benefits when being worn.[41] It is also biodegradable and easily recyclable due to its relatively long fibres.[42]

While often being seen as a by-product of meat production, wool is a key focus of many production systems, where animals are bred for fibre yield and quality.[43] Animal rights activists have raised concerns over livestock welfare and fibre harvesting practices, and wool production can have negative impacts on the environment if livestock are not managed sustainably.[44] Wool clothing can also be expensive.[45]

Negative land impacts of large-scale, unsustainable wool production can include:

- **Overgrazing**, leading to land degradation.[46]
- **Deforestation** and **habitat loss** to create more pasture for grazing animals.[47]
- **Water** and **soil pollution** from pesticides to keep livestock parasite-free and chemicals used to wash wool.
- **Loss of biodiversity** and **exclusion** of wild grazing species that compete with livestock for forage and space.[48]
- **High emissions of methane**, a potent greenhouse gas, from ruminants such as sheep and goats.[49]

Through sustainable practices, **well-managed rangelands**, and the **adaptation of voluntary standards**, which bring transparency and assurance on **animal welfare** and **environmental concerns**, risks to land can be minimized, avoided or even mitigated.[50]

A recent study finds, however, that livestock can support biodiversity, and sequester carbon, helping with climate change, if grazing is managed properly and the number of livestock is moderate.[51]

Rearing livestock takes a lot of space, but many rangelands around the globe where extensive livestock production takes place would not be suitable to other forms of land use.[52] They are marginal areas where crops cannot be cultivated. Livestock rearing, in this cases, provides a way for people to utilise this space, often by moving between pastures with their livestock.[53]

Wool and synthetic fibres

Alternatives to wool are often synthetics, such as polyester, acrylic, and nylon which have their own environmental and land impact. Wool blended with synthetic fibres makes it harder to recycle and are more likely to end up as landfill.[54]

CASHMERE WOOL AND ITS IMPACT ON LAND IN MONGOLIA

→ **24.6 million goats live in Mongolia**, outnumbering the human population by more than 8 to 1.[56]

→ **70% of pastureland in Mongolia** is estimated to have been degraded to some extent through a combination of climate change and overgrazing.[57]

4-8 cashmere goats are on average needed for enough fibre to make **one cashmere sweater**.[55]

Demand for cashmere is on the rise with market analysts estimating that the industry will grow by more than 6% a year until 2030, by which time it will be worth $4.23 billion.[58] In Mongolia, the second largest producer of cashmere in the world after China, this has led to a big increase of goats grazing on the country's rangelands. Cashmere is often the primary source of income for nomadic herder communities, making up almost 5% of the country's GDP.[59] It also has a great societal importance in preserving the cultural heritage and traditional knowledge of nomadic and pastoral communities.[60]

However, rearing cashmere goats can have a negative impact as well. Goats may present a threat to biodiversity as they compete for space and forage with wild grazing species.[61] In certain parts of Mongolia, they have led to the degradation of ecosystems and damage of pastureland where the grassland cannot support the necessary fodder for the hungry goats.[62] Overgrazing together with extreme weather and climate change has further also led to desertification.[63]

© Horizon Images / Alamy Stock Photo, Mongolia, 2013

Improving the sustainability of Mongolia's cashmere

"Addressing sustainability challenges in the global cashmere industry requires collaborative efforts from various stakeholders – governments, fashion brands, consumers, and non-governmental organizations", according to the Sustainable Fibre Alliance (SFA).[64] The organization has identified the need for things like better grazing management, more efficient processing of livestock products, reduced water, energy and carbon consumption, better animal welfare standard, support for communities that depend on the cashmere industry, higher consumer awareness about the environmental and ethical issues associated with cashmere production and more certification and transparency in the global cashmere value chain. Further, an integrated, unifying approach to balance the health of people, animals and ecosystems, often known as One Health, is needed as the three are closely interlinked and dependent of each other.

THE GLOBAL RANGELAND STANDARD

To make wool more sustainable it is important to consider it together with the rangelands and other ecosystems in which it is produced. The Global Rangeland Standard (GRS) developed by the non-profit Rangeland Stewardship Council and partners* in 2024 aims to promote best practices worldwide for responsible rangeland management. The standard, which is being developed in collaboration with herders, will focus on traditional and culturally attentive practices, human health and well-being, animal welfare, traceability, gender equality and effective land management.[65]

*The **GRS** is developed in partnership with the UNCCD, the SFA, and with the support of rangeland stakeholders. It is supported by the Global Environment Facility-funded STELARR (Sustainable Investments for Large-Scale Rangeland Restoration) Project, which is implemented by IUCN and executed by ILRI (International Livestock Research Institute) and partners.

CAMEL WOOL AND THE LUXURY MARKET

Camel hair has not yet received much attention from the global fashion industry. The warm and waterproof fibre has only recently emerged on the luxury market. However, according to a recent report of the Saudi Arabian Fashion Commission, further growth is projected for luxury camel fashion products, given the rapid growth of the luxury fashion market in the Middle East and especially Saudi Arabia.[66]

While, as with all livestock, there are limits to how many animals land can sustain without negative impacts, camels present an interesting alternative to other animals as they are perfectly adapted to arid environments.[67] They are natural foragers that can subsist on a wider variety of plants, little water and on land that is not used for conventional agriculture.[68]

LINEN & HEMP

Plant-based fibres, a long-lived tradition of sustainability

Plant-based fibres, including bast fibres such as jute, flax, hemp and others, have a global market share of about 5% excluding cotton and wood-based fibres.[69] If farmed carefully, plant-based fibres can be more environmentally sustainable than cotton, wool or synthetics.

Clothes made with these fibres are quick to dry, durable and biodegradable.[70] They might, however, also be a bit coarse or prone to wrinkling. They are also generally more expensive to produce and more energy-intensive in the spinning process.[71]

LINEN : THE RESILIENT ONE

Linen is made of fibres won from the stem of the flax plant.[72] Based on estimates around 0.4 million tons of flax are produced each year, equivalent to almost 0.3% of global fibre production.[73]

Around **64%** of the **flax used for fibres** in 2023 was cultivated in **Europe**, the plant being grown along the coast from northern France to Belgium and the Netherlands.[74]

Flax fibres are difficult to weave, and parts of the production process must be done by hand.[75] Compared to cotton, linen is therefore more labour intensive and time consuming, and more costly.

It is, however, relatively sustainable. Flax is a carbon sink crop (meaning it absorbs more CO_2 from the atmosphere than it releases) and is naturally pest-resistant, drought-tolerant, and regenerative.[76] Thus, production does not need much chemical intervention.[77] Flax also has a short growth cycle, so is often cultivated between the growing seasons of other crops. As part of a regenerative system this crop rotation can increase soil health and support biodiversity.[78] In Europe, flax grows primarily in areas with enough rainfall to make irrigation largely unnecessary.[79]

HEMP : THE CONTROVERSIAL ONE

Sharing many of the characteristics of flax, including its resistance to disease and ability to capture carbon, hemp can also be counted as a more environmentally friendly crop.[80] The plant can support soil health and biodiversity, suppress weeds and be part of a crop rotation system that boosts yields.[81]

While tending to be a little scratchy on the skin, hemp fabric is breathable, antibacterial, thermoregulating and highly resistant.[82] It also softens over time.

An estimated 0.2 million tons of hemp were produced in 2023, representing 0.2% of the global fibre market.[83] Cultivating hemp (Cannabis sativa) is illegal in some countries due to its narcotic properties, even though the concentrations of psychoactive constituents in hemp cultivated for fibre on an industrial scale for are very low.[84, 85] Production is, however, expanding as more authorities have legalized cultivation recently.[86]

WOOD-BASED FIBRES

A deforestation risk or a sustainable solution to land degradation?

Man-made cellulosic fibres (MMCFs), such as viscose, lyocell, modal, acetate, and cupro are most commonly made from wood pulp. Cellulose, a chief part of the cell walls of plants, is extracted from the pulp of trees, such as beech, birch, eucalyptus, fir and poplar, or from bamboo.[87, 88] Fabric made from these fibres is often soft, breathable and absorbent.

Over the past decade, MMCFs have received increasing attention as more environmentally friendly alternatives to other fibres, such as cotton or synthetics.[89] At 7.9 million tons in 2023, accounting for about 6% of global fibre market, production has more than doubled since 1990 and is expected to continue to grow in the coming years.[90]

The pros and cons of wood-based fibres

Because they are wood-based and renewable, MMCFs can have less of a negative environmental impact when compared to any other fibres.[91] This is especially the case if the wood is sourced sustainably, and proper management of chemicals and water is in place during the manufacturing process as this is where MMCF can be most harmful for the environment.[92] The technology used in milling and the associated energy use should also be considered.[93]

If fibres come from forest sources that are not managed sustainably, where for example illegal logging is taking place, there is a risk of forest degradation and deforestation.[94] Deforestation damages ecosystems and heightens the risk of soil erosion, loss of fertility and increased flooding due to the removal of trees that anchor the soil.[95] It also results in biodiversity loss, as forest species lose their habitat, and contributes to climate change through the release of carbon stored in trees and forest soils.

However, if managed sustainably, the forests can maintain or even enhance their biodiversity, make the forest ecosystems resilient and preserve soil and water quality. It takes less land, and generally no irrigation or fertilizer, to produce a ton of wood-based fibre which are key advantages over, for example, cotton.[96]

In 2023 an **estimated 60-65%** of all **MMCFs were certified** by at least one of the two leading international organizations that provide certification for forests and forest product, the Programme for the Endorsement of Forest Certification Schemes (**PEFC**) or Forest Stewardship Council (**FSC**).[97]

The future?

There is a **growing** trend towards more **wood-based fibres** and **more certified traceability** of raw material sourcing, which increases transparency of the **MMCF sourcing**.

According to a recently published survey, 71% of European consumers would like to see a label certifying that the forest fibres in fashion collections come from sustainably managed forests.[98]

Further, MMCFs can also be made from non-wood/bamboo materials such as waste textiles, agricultural food waste or other plant-based materials.[99] While the technology is still much under development, some latest innovations can, for example, turn old fabrics and waste (e.g. old newspapers) into new fibres in sustainable patented processes.[100]

VISCOSE AND LYOCELL, THE MOST USED MMCFS FOR TEXTILES

- **Viscose (rayon)** is the most used manmade cellulosic fibre, having a market share of roughly 80% of all MMCF.[101]

- **Lyocell** is made from eucalyptus, beech, oak or spruce trees. Tencel is the name of the same fibre branded by the Austrian company Lenzing, while Newcell and Excel is lyocell manufactured by other companies.[102]

BAMBOO FIBRE

The use of bamboo fibres for clothing is, while still modest, on the rise.[103] It is strong, flexible, has antibacterial properties and provides UV protection. While bamboo belongs to the grass family, its woody, tall structure and rapid growth is similar to trees. Growing very quickly and in many areas of the world, bamboo is often seen as a good renewable resource.[104] It does not need much water, pesticides or fertilizer and captures carbon.

However, if not managed well and sustainably, the aggressive growth of bamboo can also become the challenge. The resilient bamboo has invasive tendencies and can inhibit growth of other plants, which can lead to disruption of native vegetation and biodiversity.[105] Furthermore, like for all viscose a chemically intensive process is needed to create bamboo rayon, which can pose risk for human health.[106] While this is not the only way to make fabrics, it is the one most often applied. It is important to know where the bamboo was grown and under which circumstances to determine if it is sustainable.[107] Certifications and standards exist for bamboo clothing, which ensure environmental sustainability, ethical sourcing and quality for certified items.[108]

ORANGES AND CO.

Agricultural waste fibres turn trash into resource

Scientists and industry looking for a solution to the puzzle of sustainable fashion are also looking to a new source of recyclable materials: agricultural waste. Byproducts of the global agri-food sector such as fruit peel, seed oil, plant leaves and biogas can be used to make man-made cellulosic fibres (MMCFs) from material that would otherwise have been burned or gone to waste.[109] While research on some options is still at an early stage, others are being pushed by startups and gaining traction.

The green credentials of agricultural waste fibres depend on several factors. As byproducts, the production of these materials does not add to the pressure on land and other resources. Still, the environmental footprint of the original crop, including inputs such as irrigation or farm chemicals, needs to be taken into account. In addition, not all of the resulting fibres may be biodegradable.

Some newcomers to the fashion world

Oranges
Orange Fibre extracts cellulose from the peel of oranges grown for their juice, which produces 700,000 tons of orange waste a year in Italy.[110, 111] The company, which began as a university project, transforms the peel into a silk-like fabric.[112] The citrus cellulose has also already been incorporated into a lyocell fabric.[113]

Hemp seed oil, flaxseed oil, pineapple leaves, banana trees, rice straw and sugarcane bark
Circular Systems has been producing fibres from hemp seed and flaxseed oil, pineapple leaves, banana trees, rice straw and sugarcane bark since 2019.[114] The company claims waste from these six crops could yield more than 250 million tons of fibre each year, which is more than current global fibre demand.[115]

Coffee Ground Fibre
To feed the world's demand for caffeine, farmers produce more than 10 million tons of coffee beans every year.[116] But once the roasting, grinding and brewing are done, we are left with millions of tons of waste.[117] Under the name S.Café®, the company SingTex has been combining leftover coffee grounds with polyester from recycled plastic bottles since 2009.[118, 119]

SYNTHETICS

Non-biodegradable fibres leave their footprint on land

The rise of synthetic fibre and fabric starting in the mid-1990s has enabled the emergence of fast fashion, with cheap clothing produced for the mass-market and styled according to the latest trends.[124] Today, more than two thirds of all clothes produced are made from synthetic fibres, such as polyester or polyamide (nylon), which are plastics derived from oil and gas.

67% of clothes are made from polyester and other synthetic fibres derived from fossil fuels.[120]

→ **87% of the fibre** used for clothing is landfilled or incinerated.[121]

→ **EU consumers** discard about **5.8 million tons** textiles annually around **11 kg per person** – of which about two thirds consist of synthetic fibres.[122]

→ **9%** of the **annual microplastic losses to oceans** is due to the textile sector (synthetic fibres).[123]

What is the link between land and synthetics?

The land footprint of synthetics in the fibre production stage is indirect and small, related to oil extraction, land degradation from drilling and refinery infrastructure. Synthetic fibres instead leave a much bigger imprint at the end of their life. Effectively non-biodegradable (they take hundreds of years to break down), **huge quantities of synthetic fibres end up in landfills.**[125] They also often contain chemicals, which help the longevity of the clothes but after being discarded leach into soil and groundwater if improperly disposed of.[126] In addition, synthetics have an immense energy and carbon footprint incurred during both production (being made from crude oil) and disposal, while microplastics seep into the ocean and soil.[127] All of these issues have long-term and largely unknown consequences on people and biodiversity.[128]

Circularity and other solution approaches

In order to solve the issue of pollution through synthetics and plastic in general, two main challenges need to be overcome.[129] Firstly, the current system needs to be changed away from cheap, quickly disposable clothing items, overproduction and consumption. Secondly, the caused pollution needs to be tackled.

Circular economy is often presented as a solution for both challenges.[130] New business models and product designs that lengthen the lifespan of clothing, recycle, reuse or recover them need to be established and scaled up.[131] Further, change requires new policies, and the industry to play an important part in reducing the land impact of clothes. Alternative fibres and material innovation need to be incentivized and recycling technologies advanced.[132] Also, consumers awareness should be increased.

There is, however, no single answer that can solve the transnational problem caused by the volumes of discarded clothing.

In terms of clothing waste, "a multi-level approach, well-coordinated between exporting and importing countries and involving national and sub-national authorities alongside affected communities, is needed", according to United Nations Economic Commission for Europe (UNECE).[133] "Implementing this mix of measures requires the engagement of multiple authorities and stakeholders concerned with local environmental and social issues".

THE LANDFILL IN THE ATACAMA DESERT, CHILE AND CIRCULAR ECONOMY

The landfill in the Alto Hospicio Municipality in the Chilean Atacama Desert has seen enormous growth in the illegal dumping of textile waste. Several tens of thousands of tons of textile waste have been discarded on around 300 hectares, some of which are burned on-site.[134] To tackle such problems, Chile, the 10th largest importer of used textiles, is trying to put its economy on a more sustainable footing.[135] In 2021, it launched a Roadmap for a Circular Chile by 2040[136] and followed it up three years later with the ***Draft Circular Economy Strategy for Textiles***.[137] The latter publication identifies two major issues: the high per capita consumption of textiles and high imports of second-hand clothing.

In 2022 alone, 131,574 tons of second-hand textiles were brought into Chile, much of which cannot be recycled and has little economic value. About 70% of these textiles end up in landfills or illegal dumps.[138] The textile strategy proposes 20 initiatives to reduce overconsumption, add value to waste streams, support enterprises with circular business models and create green jobs, and clean up illegal dumping sites.[139]

RECYCLING AND UPCYCLING IN KENYA

Africa Collects Textiles (ACT) is a social impact enterprise that collects used textiles and footwear for reuse and recycling in Kenya (Gikomba market) and Nigeria.[140] ACT collects, sorts, redistributes and donates clothes, prepares sorted material of non-blended fabrics (e.g. acrylic, wool, cotton) for further use, and works with local communities to make some of that material into new products. The aim is to promote circular economy and to monetize used textiles and textile waste in order to expand operations and for charitable purposes. Material that cannot be used – mostly blended material and synthetics – is shredded.[141] ACT says some of it can find a use, for instance to stuff furniture, while the rest is disposed of responsibly.

The organization has developed a model for kick-starting circularity in fashion in Africa, making sure more and more textiles are diverted from the rivers and landfills, while generating green and sustainable employment, mainly for youth and women.[142]

ACT is applying eco-innovation and the product environmental footprint methodology through UNEP's InTex Project, which promotes innovative business practices and economic models in the textile value chain in Africa and elsewhere and is funded by the European Union.[143]

197.981 kg
Textiles collected

1,200 tn
CO_2 Saved

200 jobs
Created[144]

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ENDNOTES

1 UNCCD Secretariat (2020). Ibrahim Thiaw Desertification Day Message: Your Choice Matters. UNCCD. https://biodiversity.gov.bb/ibrahim-thiaw-desertification-day-message-your-choice-matters/

2 Cherny-Scanlon, X. and Agnes, K. (2016). Time for a Responsible Fashion Council? https://link.springer.com/chapter/10.1007/978-981-10-0245-8_4

3 UNEP (2020). Sustainability and Circularity in the Textile Value Chain: Global Stocktaking. https://wedocs.unep.org/handle/20.500.11822/34184

4 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

5 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

6 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

7 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

8 Global Fashion Agenda & Boston Consulting Group (2017). Pulse of the Fashion Industry. In: UNEP (2021). Sustainable Fashion Communication Strategy 2021 – 2024. https://wedocs.unep.org/bitstream/handle/20.500.11822/41076/Sustainable_Fashion_Strategy.pdf?sequence=3&isAllowed=y

9 UNCCD (2024). Our Land. Our Future. COP16 Riyadh 2024. https://www.unccd.int/sites/default/files/2024-04/UNCCD_COP16_narrative_EN.pdf

10 UN (2024). United for Land. Our Legacy. Our Future. https://www.un.org/en/observances/desertification-day

11 UNCCD (2011). Desertification: A Visual Synthesis. https://library.unccd.int/Details/books/10

12 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

13 Cotton Today (2024). Protecting Global Agricultural Land. https://cottontoday.cottoninc.com/our-sustainability-story/land/

14 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

15 UNEP (2021). Sustainable Fashion Communication Strategy 2021 – 2024. https://wedocs.unep.org/bitstream/handle/20.500.11822/41076/Sustainable_Fashion_Strategy.pdf?sequence=3&isAllowed=y

16 Better Cotton (n.d.). Pesticides and Crop Protection. https://bettercotton.org/field-level-results-impact/key-sustainability-issues/pesticides-and-crop-protection-in-cotton-farming/

17 Benavidez Clayton, E. (2023). How Much Water Does Cotton Use? Better Cotton. https://bettercotton.org/world-water-day-2023-how-much-water-does-cotton-use/

18 Benavidez Clayton, E. (2023). How Much Water Does Cotton Use? Better Cotton. https://bettercotton.org/world-water-day-2023-how-much-water-does-cotton-use/

19 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

20 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

21 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

22 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

23 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

24 Jet Propulsion Laboratory (2014). NASA Data Find Some Hope for Water in Aral Sea Basin. https://www.jpl.nasa.gov/news/nasa-data-find-some-hope-for-water-in-aral-sea-basin/

25 Galloway, K. (2024). The environmental impact of cotton production. International Science Council. https://council.science/blog/the-environmental-impact-of-cotton-production/

26 Kruzman, D. (2024). What a shrinking sea might teach us on life after environmental disaster. National Geographic. https://www.nationalgeographic.com/environment/article/aral-sea-climate-change-desert-laboratory

27 Galloway, K. (2024). The environmental impact of cotton production. International Science Council. https://council.science/blog/the-environmental-impact-of-cotton-production/

28 Kruzman, D. (2024). What a shrinking sea might teach us on life after environmental disaster. National Geographic. https://www.nationalgeographic.com/environment/article/aral-sea-climate-change-desert-laboratory

29 Kruzman, D. (2024). What a shrinking sea might teach us on life after environmental disaster. National Geographic. https://www.nationalgeographic.com/environment/article/aral-sea-climate-change-desert-laboratory

30 Hyolmo, S. L. (2024). Uzbekistan plants a forest where a sea once lay. Mongabay. https://news.mongabay.com/2024/05/uzbekistan-plants-a-forest-where-a-sea-once-lay

31 FAO (2021). Recent trends and prospects in the world cotton market and policy developments. https://openknowledge.fao.org/handle/20.500.14283/cb3269en

32 Water Footprint Implementation (2020). Water Footprint Analysis of Central Asia. https://bluepeace-centralasia.ch/knowledge/publications/BluePeace-Water_Footprint_Analysis_en.pdf

33 Better Cotton (n.d.). Better Cotton in India. https://bettercotton.org/where-is-better-cotton-grown/better-cotton-in-india/

34 Better Cotton (2024). India Impact Report 2014-2023. https://bettercotton.org/wp-content/uploads/2023/11/Better-Cotton-India-Impact-Report_-5.pdf

35 Better Cotton (2024). India Impact Report 2014-2023. https://bettercotton.org/wp-content/uploads/2023/11/Better-Cotton-India-Impact-Report_-5.pdf

36 Better Cotton (2024). 2023-24 Annual Report. https://bettercotton.org/wp-content/uploads/2023/11/Better-Cotton-India-Impact-Report_-5.pdf

37 Better Cotton (2024). 2023-24 Annual Report. https://bettercotton.org/wp-content/uploads/2023/11/Better-Cotton-India-Impact-Report_-5.pdf

38 Better Cotton (2024). India Impact Report 2014-2023. https://bettercotton.org/wp-content/uploads/2023/11/Better-Cotton-India-Impact-Report_-5.pdf

39 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

40 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

41 Mathews, B. (2022). An Industry Briefing: Wool, Fashion and Sustainbility. Apparel Insider. https://apparelinsider.com/wp-content/uploads/2022/04/Wool-Paper.DIGITAL.pdf

42 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

43 Bolotnikova, M. (2023). The greenwashing of wool, explained. Vox. https://www.vox.com/future-perfect/24008053/wool-marketing-environment-sustainable-claims-sheep-animal-cruelty-fast-fashion

44 Bolotnikova, M. (2023). The greenwashing of wool, explained. Vox. https://www.vox.com/future-perfect/24008053/wool-marketing-environment-sustainable-claims-sheep-animal-cruelty-fast-fashion

45 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

46 Sustainable Fibre Alliance (n.d.). Environment. https://sustainablefibre.org/environment/

47 Bolotnikova, M. (2023). The greenwashing of wool, explained. Vox. https://www.vox.com/future-perfect/24008053/wool-marketing-environment-sustainable-claims-sheep-animal-cruelty-fast-fashion

48 Bolotnikova, M. (2023). The greenwashing of wool, explained. Vox. https://www.vox.com/future-perfect/24008053/wool-marketing-environment-sustainable-claims-sheep-animal-cruelty-fast-fashion

49 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

50 Mathews, B. (2022). An Industry Briefing: Wool, Fashion and Sustainbility. Apparel Insider. https://apparelinsider.com/wp-content/uploads/2022/04/Wool-Paper.DIGITAL.pdf

51 Chandler, D. L. (2024). Study finds lands used for grazing can worsen or help climate change. MIT News. https://news.mit.edu/2024/study-finds-lands-grazing-can-worsen-help-climate-change-0315

52 Houzer, E. and Scoones, I. (2021) Are Livestock Always Bad for the Planet? Rethinking the Protein Transition and Climate Change Debate. Brighton: PASTRES.

53 Houzer, E. and Scoones, I. (2021) Are Livestock Always Bad for the Planet? Rethinking the Protein Transition and Climate Change Debate. Brighton: PASTRES.

54 Shedlock, K. and Feldstein, S. (2023) At What Cost? Unravelling the Harms of the Fast Fashion Industry. Center for Biological Diversity. https://www.biologicaldiversity.org/programs/population_and_sustainability/pdfs/Unravelling-Harms-of-Fast-Fashion-Full-Report-2023-02.pdf

55 The Cashmere Choice (2020). How many goats does it take to make a sweater?. https://www.cashmerechoice.co.uk/blogs/guide/how-many-goats-does-it-take-to-make-a-sweater#:~:text=A%20single%20cashmere%20goat%20does,to%20make%204%20wool%20jumpers.

56 B. Ooluun (2024). Mongolia counts 64.7 million head of livestock. Mongolian National News Agency. https://montsame.mn/en/read/335867#:~:text=Ulaanbaatar%2C%20January%2019%2C%202024%20%2F,cattle%2C%20and%20473.9%20thousand%20camels.

57 Simões, M. (2021). How sustainable cashmere is reversing land degradation in Mongolia. https://www.undp.org/blog/how-sustainable-cashmere-reversing-land-degradation-mongolia

58 Chan, M. (2023). Cashmere demand is threatening Mongolia's steppe. Can the industry go sustainable? https://edition.cnn.com/style/mongolia-cashmere-sustainable/index.html

59 SWITCH Asia (2020). AVSF Sustainable Cashmere Programme Mongolia. https://www.switch-asia.eu/site/assets/files/2630/2020_avsf_scp-1.pdf

60 Apparel Insider (2023). Cashmere – A Fashion Industry Briefing. https://apparelinsider.com/wp-content/uploads/2023/09/Apparel-Insider_Cashmere_Digital.pdf

61 Cherny-Scanlon, X. (2016). The Wild Side of Fashion: Sourcing Wool & Leather with Wildlife Conservation in Mind.

62 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

63 Trankman, B. (2018). Nomads no more. UNDP. https://www.undp.org/blog/nomads-no-more

64 Apparel Insider (2023). Cashmere – A Fashion Industry Briefing. https://apparelinsider.com/wp-content/uploads/2023/09/Apparel-Insider_Cashmere_Digital.pdf

65 Rangeland Stewardship Council (n.d.). Projects. https://rangelandstewardship.org/projects-and-collaborations/

66 Saudi Arabian Fashion Commission (2024). Camel Couture: Exploring Camel Products in Contemporary Fashion. https://saudi-fashion-co.objects.frb.io/Camel-Couture-Exploring-Camel-Products-in-Contemporary-Fashion-English.pdf

67 Saudi Arabian Fashion Commission (2024). Camel Couture: Exploring Camel Products in Contemporary Fashion. https://saudi-fashion-co.objects.frb.io/Camel-Couture-Exploring-Camel-Products-in-Contemporary-Fashion-English.pdf

68 Ramet, J. P. (2001). The technology of making cheese from camel milk (Camelus dromedarius). FAO Animal Production and Health Paper. https://www.fao.org/4/t0755e/t0755e01.htm

69 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

70 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

71 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

72 Muthu, S. S., Gardetti, M. A. (2016). Sustainable Fibres for Fashion Industry, Volume 1. Springer Science+Business Media Singapore.

73 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

74 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

75 MasterClass (2021). What Is Linen? Everything You Need to Know About Using and Caring for Linen. https://www.masterclass.com/articles/what-is-linen-everything-you-need-to-know-about-using-and-caring-for-linen

76 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

77 Vujić, K. (2023). Is Linen the Most Sustainable Fabric? The Cut. https://www.thecut.com/article/everything-you-ever-wanted-to-know-about-linen.html

78 Vujić, K. (2023). Is Linen the Most Sustainable Fabric? The Cut. https://www.thecut.com/article/everything-you-ever-wanted-to-know-about-linen.html

79 Alliance for European Flax-Linen & Hemp (n.d.). Everything you need to know about European flax. https://allianceflaxlinen-hemp.eu/en/all-about-european-linen

80 91530 Le Marais (2023). Studio Sativa 91530. https://ww-w.91530lemarais.com/studio-sativa-eng

81 Textile Exchange (2023). Growing Hemp for the Future: A Glob-al Fiber Guide. https://textileexchange.org/knowledge-center/reports/grow-ing-hemp-for-the-future-a-global-fiber-guide/

82 91530 Le Marais (2023). Studio Sativa 91530. https://ww-w.91530lemarais.com/studio-sativa-eng

83 Textile Exchange (2024). Materials Market Report. https:// textileexchange.org/knowledge-center/reports/materials-mar-ket-report-2024/

84 Textile Exchange (2024). Materials Market Report. https:// textileexchange.org/knowledge-center/reports/materials-mar-ket-report-2024/

85 Ellen MacArthur Foundation (2017). A New Textiles Econ-omy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fash-ion%E2%80%99s%20future.pdf

86 Textile Exchange (2023). Growing Hemp for the Future: A Glob-al Fiber Guide. https://textileexchange.org/knowledge-center/reports/grow-ing-hemp-for-the-future-a-global-fiber-guide/

87 Fashion for Climate (2023). Identifying Low Carbon Sources of Man-Made Cellulosic fibres (MMCF) https://unfccc.int/sites/default/files/resource/Final_230630%20BLS23044%20UCC%20report%20MMCF%20fiber%20v04.pdf

88 PEFC International (2023). Enhancing Sustainability through Forest-Positive MMCF Sourcing: A Guide for Fashion Brands and Retailers. https://treee.es/WP02

89 EEA European Topic Centre on Circular economy and resource use (2023). The role of bio-based textile fibres in a circular and sustainable textiles system. https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2023-5-the-role-of-bio-based-textile-fibres-in-a-circular-and-sustainable-textiles-system

90 Textile Exchange (2024). Materials Market Report. https:// textileexchange.org/knowledge-center/reports/materials-mar-ket-report-2024/

91 PEFC International (2023). Enhancing Sustainability through Forest-Positive MMCF Sourcing: A Guide for Fashion Brands and Retailers. https://treee.es/WP02

92 Textile Exchange (n.d.). Manmade cellulosic fibers are com-monly made from wood pulp. https://textileexchange.org/manmade-cellulosics/

93 EEA European Topic Centre on Circular economy and resource use (2023). The role of bio-based textile fibres in a circular and sustainable textiles system. https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2023-5-the-role-of-bio-based-textile-fibres-in-a-circular-and-sustainable-textiles-system

94 PEFC International (2023). Enhancing Sustainability through Forest-Positive MMCF Sourcing: A Guide for Fashion Brands and Retailers. https://treee.es/WP02

95 PEFC International (2023). Enhancing Sustainability through Forest-Positive MMCF Sourcing: A Guide for Fashion Brands and Retailers. https://treee.es/WP02

96 EEA European Topic Centre on Circular economy and resource use (2023). The role of bio-based textile fibres in a circular and sustainable textiles system. https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2023-5-the-role-of-bio-based-textile-fibres-in-a-circular-and-sustainable-textiles-system

97 Textile Exchange (2024). Materials Market Report. https:// textileexchange.org/knowledge-center/reports/materials-mar-ket-report-2024/

98 PEFC International (2024). Consumer Survey 'Fash-ion from Sustainable Forests. https://cdn.pefc.org/pefc.org/media/2024-06/7fa86db2-6899-4fd6-bd5c-ec4a11b848e6/92961a3c-e5dd-50d9-aa30-2889730c76cb.pdf

99 Fashion for Climate (2023). Identifying Low Carbon Sources of Man-Made Cellulosic Fibres (MMCF). https://unfccc.int/sites/default/files/resource/Final_230630%20BLS23044%20UCC%20report%20MMCF%20fiber%20v04.pdf

100 Ioncell (n.d.). Enter the new era of textile production!. https:// ioncell.fi/

101 Textile Exchange (n.d.) Viscose is the most used manmade cellulosic fiber. https://textileexchange.org/viscose/

102 https://blog.bernina.com/en/2024/09/whats-the-differ-ence-tencel-lyocell-lenzing-modal-cupro-and-bemberg/

103 Amjad, A. I. (2024). Bamboo fibre: A sustainable solution for textile manufacturing. Advances in Bamboo Science (7). https://www.sciencedirect.com/science/article/pii/S2773139124000338?ref=pdf_download&fr=RR-2&r-r=8e2670cf98c266e0

104 Amjad, A. I. (2024). Bamboo fibre: A sustainable solution for textile manufacturing. Advances in Bamboo Science (7). https://www.sciencedirect.com/science/article/pii/S2773139124000338?ref=pdf_download&fr=RR-2&r-r=8e2670cf98c266e0

105 Amjad, A. I. (2024). Bamboo fibre: A sustainable solution for textile manufacturing. Advances in Bamboo Science (7). https://www.sciencedirect.com/science/article/pii/S2773139124000338?ref=pdf_download&fr=RR-2&r-r=8e2670cf98c266e0

106 Sanders, L. (2020). Bamboo: Eco-friendly fabric or environmen-tal disaster?. https://www.euronews.com/green/2020/11/30/bamboo-eco-friendly-fabric-or-environmental-disaster

107 Sanders, L. (2020). Bamboo: Eco-friendly fabric or environmen-tal disaster?. https://www.euronews.com/green/2020/11/30/bamboo-eco-friendly-fabric-or-environmental-disaster

108 Amjad, A. I. (2024). Bamboo fibre: A sustainable solution for textile manufacturing. Advances in Bamboo Science (7). https://www.sciencedirect.com/science/article/pii/S2773139124000338?ref=pdf_download&fr=RR-2&r-r=8e2670cf98c266e0

109 Common Objective (2021). The Magic Formula Behind Food Waste-Based Textiles. https://www.commonobjective.co/article/the-magic-forumula-behind-food-waste-based-textiles

110 Boztas, S. (2018). Nice threads: the waste-based fibres cleaning up fashion. https://www.theguardian.com/business-to-business/2018/feb/12/nice-threads-the-waste-based-fibres-cleaning-up-fashion

111 Orange Fiber (n.d.). https://orangefiber.it/

112 Common Objective (2021). The Magic Formula Behind Food Waste-Based Textiles. https://www.commonobjective.co/article/the-magic-forumula-behind-food-waste-based-textiles

113 Lenzing (2021). Lenzing collaborates with Orange Fiber as part of new TENCEL™: Limited Edition initiative. https://www.lenzing.com/newsroom/press-releases/press-release/lenzing-collaborates-with-orange-fiber-as-part-of-new-tenceltm-limited-edition-initiative

114 Circular Systems S.P.C. (2023) The NEW Natural Fiber: Transforming left-overs from crops into scalable high-value natural fiber fashion products. https://circularsystems.com/agraloop

115 Circular Systems S.P.C. (2023) The NEW Natural Fiber: Transforming left-overs from crops into scalable high-value natural fiber fashion products. https://circularsystems.com/agraloop

116 FAO (2024). Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL

117 Ballesteros, L., et al. (2014). Chemical, Functional, and Structural Properties of Spent Coffee Grounds and Coffee Silverskin. Food and Bioprocess Technology 7(12). https://www.researchgate.net/publication/262840577_Chemical_Functional_and_Structural_Properties_of_Spent_Coffee_Grounds_and_Coffee_Silverskin#pfa

118 SingTex (2021). S.Café Sustainable Performance. https://www.singtex.com/fabric/s-cafe/

119 International Comunicaffe (2016). Singtex: the Taiwanese Company that makes clothes out of coffee grounds. https://www.comunicaffe.com/singtex-the-taiwanese-company-that-makes-clothes-out-of-coffee-grounds/

120 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

121 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

122 EEA (2021). Plastic in textiles: towards a circular economy for synthetic textiles in Europe. Briefing no. 25/2020. https://www.eea.europa.eu/publications/plastic-in-textiles-towards-a/file

123 UNEP (2021). Catalysing Science-based Policy action on Sustainable Consumption and Production – The value-chain approach & its application to food, construction and textiles. One Planet, Nairobi. https://www.oneplanetnetwork.org/sites/default/files/report_unea5_catalysing_science-based_policy_action_on_scp_-_task_group_irp-one_planet_0.pdf

124 Textile Exchange (2024). Materials Market Report. https://textileexchange.org/knowledge-center/reports/materials-market-report-2024/

125 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

126 EEA (2021). Plastic in textiles: towards a circular economy for synthetic textiles in Europe. Briefing no. 25/2020. https://www.eea.europa.eu/publications/plastic-in-textiles-towards-a/file

127 EEA (2021). Plastic in textiles: towards a circular economy for synthetic textiles in Europe. Briefing no. 25/2020. https://www.eea.europa.eu/publications/plastic-in-textiles-towards-a/file

128 EEA (2021). Plastic in textiles: towards a circular economy for synthetic textiles in Europe. Briefing no. 25/2020. https://www.eea.europa.eu/publications/plastic-in-textiles-towards-a/file

129 UNEP forthcoming publication (2026).

130 UNEP (2021). Sustainable Fashion Communication Strategy 2021 – 2024. https://wedocs.unep.org/bitstream/handle/20.500.11822/41076/Sustainable_Fashion_Strategy.pdf?sequence=3&isAllowed=y

131 Ellen MacArthur Foundation (2017). A New Textiles Economy: Redesigning Fashion's Future. https://emf.thirdlight.com/file/24/uiwtaHvud8YIG_uiSTauTlJH74/A%20New%20Textiles%20Economy%3A%20Redesigning%20fashion%E2%80%99s%20future.pdf

132 UNEP forthcoming publication (2026).

133 UNECE (2024). Reversing direction in the used clothing crisis: Global, European and Chilean perspectives. https://unece.org/sites/default/files/2024-06/ECE_TRADE_484E_0.pdf

134 UNECE (2024). Reversing direction in the used clothing crisis: Global, European and Chilean perspectives. https://unece.org/sites/default/files/2024-06/ECE_TRADE_484E_0.pdf

135 Ellen MacArthur Foundation (n.d.). EPR for textiles in Chile. https://www.ellenmacarthurfoundation.org/epr-for-textiles-in-chile

136 Ministerio del Medio Ambiente, Gobierno de Chile (2022). Roadmap for a Circular Chile by 2040. https://economiacircular.mma.gob.cl/wp-content/uploads/2022/01/HOJA-DE-RUTA-PARA-UN-CHILE-CIRCULAR-AL-2040-EN.pdf

137 Ministerio del Medio Ambiente, Gobierno de Chile (2024). Propuesta Estrategia de Economía Circular para Textiles al 2040. https://consultasciudadanas.mma.gob.cl/storage/consultation/XEqK0q9ibeDmBAykvsINbiTxumnGh71ddgS5hejg.pdf

138 Janknecht, H. (2024). Chile's Draft Strategy for a Circular Textiles Sector by 2040. Compliance & Risks. https://www.complianceandrisks.com/blog/chiles-draft-strategy-for-a-circular-textiles-sector-by-2040/

139 Ministerio del Medio Ambiente, Gobierno de Chile (2024). Propuesta Estrategia de Economía Circular para Textiles al 2040. https://consultasciudadanas.mma.gob.cl/storage/consultation/XEqK0q9ibeDmBAykvsINbiTxumnGh71ddgS5hejg.pdf

140 Africa Collect Textiles (2024). What is Africa Collect Textiles? https://africacollecttextiles.com/

141 Africa Collect Textiles (2024). What is Africa Collect Textiles? https://africacollecttextiles.com/

142 Africa Collect Textiles (2024). What is Africa Collect Textiles? https://africacollecttextiles.com/

143 UNEP. InTex. https://www.unep.org/intex

144 Africa Collect Textiles (2024). What is Africa Collect Textiles? https://africacollecttextiles.com/

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