Solidaridad

COTTON AND CLIMATE

NOVEMBER 2023

Citation:
Solidaridad (November 2023) 'Cotton and Climate'

Author:
Tamar Hoek (Solidaridad Europe)

Additional text contributors:
Rajan Bhopal (PAN UK), Richard Doughty (Doughty Consultancy)

Additional sources:
WWF Water Risk Filters

Editor:
Richard Doughty (Doughty Consultancy)

Graphic design:
Catalyze Communications, Bingo! Graphic Design

This publication was made with support from the Reclaim Sustainability! programme, a collaboration between the Dutch Ministry of Foreign Affairs and Solidaridad

Ministry of Foreign Affairs

CONTENTS

EXECUTIVE SUMMARY

© SOLIDARIDAD

Cotton has more potential for sustainability than synthetic fibers, but if retailers and brands don't change their relationship with cotton farmers and their value chains, the damage to livelihoods, environments, and future production may become irreversible.

There are some things we know for certain:

NET-ZERO FOSSIL FIBERS ARE NOT POSSIBLE, BUT NET-ZERO COTTON MIGHT BE

Current cotton farming practices too often are ecologically damaging and contribute to climate change. But unlike with synthetic and plastic fibers, cotton has the advantage of coming from a natural plant. Addressing cotton's climate challenges has more potential than the plastic alternative.

WE HAVE AN URGENT NEED TO ADAPT AND MITIGATE

Within the foreseeable future almost every cotton producing region will be negatively affected by climate change. Smallholder farmers who already live in poverty because of low cotton prices are not resilient enough to be able to adapt to ensure reliable production. The alternative, cheap plastic fibers, will only deprive poorer communities of income and worsen our impact on our planet.

ABOVE PHOTO © HICHAKO / ADOBE STOCK

SYNTHETIC AGROCHEMICALS MUST BE PHASED OUT

The use of synthetic pesticides and fertilizers are the largest sources of greenhouse gas emissions in the production phase, and they come with a host of other damaging environmental impacts. Healthy soil captures carbon, and is a key tool in climate change mitigation that synthetic agrochemicals inhibit.

REGENERATIVE PRACTICES MUST BECOME THE NEW NORM

Harm reduction is no longer enough. We need to move beyond 'net-zero' to 'net-positive', where we seek to repair the earth's water, land, and atmospheric systems from the damage we have done. Cotton is no exception to this need.

WE NEED ACTION AND RESPONSIBILITY

While all value chain actors have a role individually and collectively, some have a greater influence - and therefore, responsibility - than others; especially retailers and brands.

THE SOLUTION

Farmers can be supported to adapt to climate change, and adopt regenerative agricultural practices, but only if retailers and brands change their relationship with cotton farmers, workers, and their value chains. Companies should invest money and resources in smallholder production, lead their value chains, and collaborate with all stakeholders to change this course.

" COMPANIES NEED TO INVEST IN COTTON FARMING TO ADDRESS CLIMATE CHANGE.

CLIMATE CHANGE LEADERSHIP

The 2020s are the decade of action on climate change.[1] Everyone in the cotton value chain is being affected by climate change, as well as contributing to it. The need to accelerate our efforts is becoming clearer as more extreme climate events occur, which themselves are affecting cotton production.

This paper highlights the responsibility of corporate actors in the cotton value chain, most especially consumer-focused retailers and brands, about the need to address cotton production in a changing climate.

Companies can enable cotton farmers to adapt and grow cotton in a changed climate, and in such a way that it not only doesn't contribute to climate change, but actually helps tackle it. These are entirely achievable possibilities.

An unsustainable cotton sector is a choice... we hope this paper will help the cotton community to choose instead to lead their value chains to protect this valuable resource and the communities who rely on it.

© CLIMAX FILM PRODUCTION / SOLIDARIDAD

Summary of recommendations

- **Retailers and brands:** Take responsibility for the value chain by investing in producers so they can adapt to, and help mitigate, climate change.
- **Farmers and Standards systems:** Agrochemicals are the biggest source of emissions in the production phase, which also harm soils and drive biodiversity loss. They must be phased out and training, support, and resources provided to adopt more sustainable and regenerative agroecological practices.
- **Civil Society Organizations, Multi-Stakeholder Initiatives, and Governments:** Support stakeholders to transition from a harm reduction 'sustainability' mindset to a 'regenerative' mindset.

See more on page 30

© CLIMAX FILM PRODUCTION / SOLIDARIDAD

Chapter 1

INTRODUCTION

Cotton production is not one of the main drivers of climate change[2], but current practices are contributing to emissions, and agriculture in general is an untapped opportunity to capture carbon and mitigate some of the effects of climate change.

Much of the climate-focus in the cotton sector has rightly been on sustainability within textile and clothing manufacturing. However, farmers and farm workers will suffer from the effects of climate change most acutely, and need support to adopt regenerative practices, adapt to a changing climate, and build resiliency.

As a crop that is naturally more tolerant to dry or arid conditions, it is a candidate for farmers in geographies where other crops may be less suited. However, climate change will prove highly disruptive to cotton production, which will only exacerbate the volatility we have seen in the market.[3] The picture is dynamic; in the foreseeable future almost all cotton producing regions will be negatively impacted by climate change, likely reducing their crop options further, and experienced cotton farmers will need support from the cotton industry if they are to play their full part in mitigating climate change.

This paper broadly covers two interconnected topics:

1. The expected impact of climate change on cotton production, and steps to adapt and mitigate those impacts
2. Causes of emissions from cotton production, and steps to reduce those emissions.

Following from this analysis, this paper will make recommendations for cotton value chain actors. As the Cotton 2040 Initiative has noted; "Whether adequately prepared or not, the cotton system will be forced to change in the face of the dramatic changes that our warming climate will catalyze."[4]

This paper focuses on cotton production. Other climate considerations are relevant elsewhere in the value chain (such as ginning, spinning, weaving, dyeing, trading, retail, recycling, and disposal). Full life-cycle assessments (LCAs) are recommended to understand the total impact that cotton and its uses have on our climate and environment, and they should be used to inform Science-Based emissions reduction targets.

A more climate-friendly fiber?

Cotton lint is the most widely used natural fiber in the world. Out of all the 113 million tonnes of textile fibers produced in 2021, cotton accounted for 22% - second only to synthetic polyester at 54%.[5]

Textile Exchange estimates that for 2021 approximately 503 million tonnes of CO_2 emissions came from textile production worldwide. Of this,

- 11.5% were from cellulosic fibers (like viscose, acetate, and lyocell),
- 14% from plant-based fibers (like cotton, rubber, and jute),
- 18% from animal fibers (like feathers, woll, silk, and leather), and
- 56% from synthetic fibers.

Of these categories, between 2020 and 2021, only plant-based fibers saw a drop in CO_2 emissions.[6]

Synthetic fiber types such as nylon and polyester have a high emission value compared to plant fibers such as cotton or linen, because they require a high level of energy use in their production. So, a polyester shirt has a greater carbon footprint than a cotton shirt (5.5 kg vs. 4.3 kg).

Current cotton farming practices are too often ecologically damaging and contribute to climate change. But unlike with synthetic and plastic fibers, cotton has the advantage of coming from a natural plant. Some assessments indicate that more carbon is removed from the atmosphere and stored in cotton fiber than is emitted in growing and ginning the crop.[7] The potential benefits of addressing cotton's climate challenges are therefore greater than for the plastic alternative.

The Sustainable Cotton Hub

This paper is published on the SustainableCottonHub.org which seeks to lay out the sustainability challenges in cotton production, looking at economic, social and environmental sustainability factors through a series of studies and papers.[8] Following in the footsteps of three editions of the Sustainable Cotton Ranking published in 2016, 2017, and 2020, the first paper on Corporate Responsibility in the cotton sector was published in April 2023.[9]

Further papers are planned, including a closer look at the impacts of hazardous agrochemicals, the realities of labor in cotton and textiles, and the persistent issue of poverty in the supply chain. Concrete recommendations for the various actors across the cotton value chain will accompany many papers, offering realistic ways forward to make meaningful change.

Please get in touch with your comments and questions, or join the conversation on social media and search or use #sustainablecottonhub. The Sustainable Cotton Hub is open for collaboration with other civil society organizations.

Request for information can be addressed to:

Solidaridad

Solidaridad Europe
Tamar Hoek
Senior Policy Advisor Sustainable Fashion
tamar.hoek@solidaridadnetwork.org

Annemiek Smits
Corporate Partnerships Manager
- Cotton, Leather & Textiles
annemiek.smits@solidaridadnetwork.org

Chapter 2

IMPACT OF CLIMATE CHALLENGE ON COTTON PRODUCTION

JKIMAGES / SOLIDARIDAD

All agriculture is vulnerable to climate change, and cotton production in particular, with almost every cotton growing region projected to be negatively impacted.

The effects of climate change are more pronounced in countries with poorer resources, making them more vulnerable.[10] Farmers in all cotton growing regions (including significant producers like China, India, USA, Brazil, Pakistan, Australia, West Africa, and Turkey) are exposed to increased climate risk, and smallholder farmers will be less equipped to adapt. Both the quality and quantity of cotton, as well as working conditions, will be increasingly affected, and these climate hazards are projected to become more frequent, lengthy, and intense.[11]

© CLIMAX FILM PRODUCTION / SOLIDARIDAD

Climate change and extreme weather are becoming significant challenges for the cotton sector. As Cotton 2040 identify; "Climate change can cause direct damage to cotton crop either through gradual, incremental, changes, such as atmospheric warming or changes in total rainfall, or through sudden changes and extreme weather events such as flooding, hailstorms or heatwaves."[12]

While cotton as a crop can grow in arid and semi-arid regions, effective watering is used to significantly increase yields, both capturing more carbon[13] and providing vital additional income for smallholders and poorer rural communities. Reduced water availability along with higher temperatures will reduce yields, and increased instances of extreme weather events (droughts, floods, etc) will increase the risk of short-term crop failures, and longer-term production declines.

Overview: Climate change risks

A warming atmosphere is increasing the likelihood and impact of 'climate hazards' such as extreme temperatures, drought, floods, wildfires, and rising sea levels. Knock-on effects such as larger and more widely spread pest populations, or damaged irrigation, energy, and transportation infrastructure will further exacerbate the impacts of climate change. It also makes weather more volatile and unpredictable which all make farm management, decision making, and adaptation more challenging.

Despite being more tolerant to warmer temperatures than some other crops, certain stages of the cotton plant's growing cycle are particularly sensitive to unusual temperatures, an excess or lack of water, or pests and disease. These will lead to lower quantity and quality of cotton, with negative consequences for farmer livelihoods and the cotton value chain. Farmers and workers' health may also be affected through risks from high temperatures and dehydration, landslides, or higher prevalence of diseases (e.g. malaria).

Climate change will prove highly disruptive to cotton production, which will only exacerbate the volatility we have seen in the market.[14] Across the value chain we have not seen the necessary speed and scale of effort needed to support existing producers to adapt and prepare. As Textile Exchange have observed; "Without rethinking untethered growth, the [textile] industry will not stay within the 1.5° pathway."[15] Sufficient investment and support for cotton producers is needed to maintain production in a sustainable way, without which cotton's future will be highly questionable, especially compared to more reliably produced, but environmentally poor, synthetic fibers.


© ANNEMARIEKE VAN DEN BROEK

Highlights of climate risk in cotton producing regions

2040[16]

- **Shortened growing season**: A shorter time-window to grow cotton affects plant health, reduces yields, and puts pressure on planting and harvesting workforces. While a small number of regions will experience a slightly longer growing season, the growing season is projected to shorten across northern sub-Saharan countries in Africa, particularly across cotton growing regions in south-west Mali, south-east Senegal, the majority of cotton growing regions in Burkina Faso, and all cotton growing regions in northern Ghana. Arizona USA, central Venezuela, and northern Colombia will also experience shortened growing seasons.

- **Extreme heat**: Every cotton producing region will see as many, or more, days with temperatures above 40°C, which pose a significant risk to cotton yields. The worst affected cotton producing regions include the northern sub-Saharan regions of southern Mali, Burkina Faso, southern Chad, southern Niger, northern Nigeria, southern Senegal, and across regions in the Middle East in Turkey, Syria, and Iraq, and across the majority of cotton growing areas in Pakistan and India. However extreme heat will be worse across southern Sudan and central Chad. Higher risk of wildfires are projected for southern Pakistan, southern Syria, central Iraq, Egypt, southern Arizona USA, central Chad, northwest India, southern Niger, central Sudan, and Yemen.

- **Water scarcity**: Severe short-term droughts (insufficient rain for 3 months) and long-term droughts (insufficient rain for 18 months affecting groundwater recharge) are projected for the vast majority of cotton growing regions. Severe long-term droughts will be more likely for Florida and Texas USA, northern Argentina, central Somalia, north-eastern Thailand, southern Vietnam, and in cotton growing regions in north-eastern China. Large proportions of cotton growing regions in Syria, Iraq, Iran, Afghanistan, Egypt, northern Sudan, Tajikistan, Kyrgyzstan, Uzbekistan, Turkmenistan, Pakistan and north-western China will experience less than the minimum required total rainfall during the growing season for rain-fed cotton to flourish. India faces significant physical water risk, with Gujarat being most exposed.

- **Extreme rain, flooding, and landslides:** Cotton does not favor waterlogged soils, and increased rainfall during the growing season is expected for Myanmar, India, Thailand, Vietnam, and China, as well as north-eastern Argentina, north-eastern Democratic Republic of Congo, and Uganda. However extreme rainfall events, which heighten the risk of flooding and field damage, are projected to increase in intensity across the majority of cotton growing regions. More high intensity extreme rainfall events are projected for Egypt and Sudan, as well as the majority of cotton growing regions in Pakistan, northwest and central India, eastern Iraq, and southern Arizona USA.

  Rivers and lakes are also more likely to burst their banks, especially along the tributaries of Lake Kyoga (Uganda), the Zambezi River (Mozambique), the Congo River (Democratic Republic of Congo), the Mississippi River (USA), tributaries of Lake Rio Yguazi (Paraguay), the São Francisco River (Brazil), the Orinoco River (Venezuela), the Padma and Brahmaputra rivers (Bangladesh), the Indus river (Pakistan), the Irrawaddy River (Myanmar), the Mahi and Tapi Rivers (Gujarat), and the Godavari river (Andhra Pradesh, India). Coastal flooding is also more likely for the south coast of West Bengal in India, and Shanghai, Jiangsu, and Zhejiang along the eastern coast of China.

  An increased risk of precipitation-induced landslides are projected for cotton growing regions in Ethiopia's Choke Mountains, the northern regions of Vietnam, and north-eastern regions in India. Increased landslide risks are also projected for the Taurus Mountains and Armenian highlands (Turkey), the Zagros mountain range (Iraq), Nepal, the Zhejiang province in eastern China, the Andes (Peru and Ecuador), and across the majority of cotton grown areas of Haiti.

- **Wind and storms**: Strong winds over 25mph (40.2kmh) and storms with winds of over 55mph (88.5kmh) are a direct threat to cotton. While the USA, Somalia, South Africa, and Gujarat (India) will experience stronger winds, the greatest wind speeds are projected for cotton growing regions around the eastern coast of Sudan, the eastern coast of Rio Grande do Norte (Brazil), and the northern tip of Madagascar. Some key hotspots will be more exposed to storms, particularly the western coast of Turkey, and the Zagros Mountains (Iran), as well as Texas, Oklahoma, and Kansas (USA), the south-eastern Amazonian region of Bolivia, southern Spain, eastern Sudan, and Zhejiang and Fujian along the eastern coast of China.

Water availability

The climate crisis is a water crisis. The most significant effect of global warming is its impact on the water cycle, with temperature rises increasing the demand for water, leading to greater water extraction. The same is true for cotton; with higher average temperatures, more water will be needed to produce the same yields.

Water supply is also expected to become more variable. Cotton thrives on providing the right amount of water at the right moments in the growing cycle, and therefore irrigation is used in many cotton producing regions. If water supply variability increases, it will affect plant growth and reduce yields.

In instances where a lot of water is fed to cotton plants, cotton production can contribute to water stress - and poor management practices can lead to overconsumption of water. As water becomes more scarce or less reliably accessible, and demand from other crops and non-agricultural use rises, the risk of conflict increases. While rainfed cotton is more susceptible to changes in rainfall patterns, irrigated cotton is also expected to suffer in the long run due to increased competition for freshwater.

Producers in general can be supported to implement more sustainable water usage, including modern irrigation methods (drip or automated), minimal tillage, cover cropping, pest management systems, and other technological solutions, such as remote sensing to measure soil moisture.[17] [18]

For an in depth analysis of projected physical water risk in cotton growing regions, please see Appendix 1.

Soil conditions

Healthy soil provides the nutrients cotton needs to grow, but as the effects of climate change are felt more and more soil health is expected to decline. Flooding and changing weather patterns, including sustained winds, can erode the nutrient-rich top layer of soil, which will likely increase the use of synthetic fertilizers; a downward spiral.

Moreover, long term soil health is worsened by synthetic pesticides and excessive nitrogen application. Among the soil nutrients depleted by high fertilizer, pesticide, and water usage include soil organic carbon, which over time can decrease productivity and increase GHG emissions.

Extreme weather

Climate change and extreme weather are becoming significant challenges for the cotton sector. As Cotton 2040 identify; "Climate change can cause direct damage to cotton crop either through gradual, incremental, changes, such as atmospheric warming or changes in total rainfall, or through sudden changes and extreme weather events such as flooding, hailstorms or heatwaves."[19]

This is already happening. As Textile Exchange noted; "This growing season [2022-23], we've seen the cotton industry suffer through floods, droughts, pest plagues, and fires across the globe, affecting farmers, ginners, traders, suppliers and many others involved in the textile industry."[20] In 2022 alone, flooding in Pakistan killed approximately 1,700 people, and decimated around one-third of the country's cotton crop[21], while drought in the USA (similar to 2010 and 2011[22]) led to record abandonment of cotton harvests resulting in approximately 14 million fewer cotton bales than the previous year.[23]

Instances of heavy rainfall or flooding can particularly impact cotton plant growth because of the root structure. Cotton's vertical tap root makes it susceptible to becoming waterlogged, wherein the root cannot absorb adequate nutrients or oxygen from the soil.

All global cotton growing regions will be exposed to increased risk from at least one climate hazard by 2040.[24] Extreme-weather events will worsen without dramatic intervention, and poorer cotton producers are expected to suffer disproportionately. Smallholder cotton production in particular is less mechanized, with associated risks from heavy lifting, long hours in hot environments, and exposure to harmful agrochemicals.[25] [26]

© SOLIDARIDAD

Pests and diseases

Pests already threaten cotton production, but warmer climates can increase pest populations and enable them to spread to new areas. Pest species and diseases can react more quickly to climatic variations than plants, and climate change has already driven pests to be more common at increased elevations and latitudes.[27] [28]

Higher CO_2 levels will increase the severity of diseases, induce fungal growth and spore formation, and will destroy more plant tissue.[29] Additionally, due to shifts in phenology (lifecycle events), some pest populations such as bollworms may further increase because there will be less of a need to go into diapause to avoid colder winter temperatures.[30] [31]

The International Trade Centre found that global warming can affect disease control in three main ways. Firstly, it may change how diseases behave. Secondly, it can create conditions that help diseases thrive. Thirdly, it might affect how infected hosts respond to diseases. Chemical control methods may in fact become less effective, because rising temperatures could lead to diseases showing up at different times, and that the chemicals may break down faster under higher temperatures.[32]

Chapter 3

SOURCES OF EMISSIONS IN COTTON PRODUCTION

© SOLIDARIDAD

Overview

Cotton lint is the most widely used natural fiber for textiles in the world. Out of all the 113 million tonnes of textile fibers produced in 2021, cotton accounted for 22% - second only to synthetic polyester at 54%.[33]

Several Life Cycle Assessments (LCAs) of cotton products concur that textile manufacturing and consumer-use are the main sources of cotton's overall environmental impact. Furthermore, in conventional cotton production, water-use and eutrophication are the largest detrimental environmental factors.[34] [35] [36] [37] [38] [39]

Some LCAs indicate that cotton is a carbon-negative crop; that on a global average, cotton cultivation absorbs more CO_2 than cultivation activities and required materials emit.[40] However, there is a high degree of variation in both GHG sequestration and emissions depending on production methods. Across the 70 countries around the world where cotton is grown, the vast majority of cotton farmers are smallholders. Larger, more mechanized, cotton farms exist predominantly in the highest producing and exporting countries like China, USA, Brazil, and Australia.

© GETTY IMAGES

The two systems are commonly referred to as 'low input' and 'high input'. Low input systems, as more often used among lower-income producers, use more manual labor and perhaps cattle for field operations instead of motorized vehicles, and fewer quantities of fertilizers and pesticides. Comparatively, 'high input' systems rely on intensive production processes to maximize yields that use carbon-based fuels for irrigation, field operations, and greater quantities of agrochemicals.[41]

Accurately measuring and attributing the GHG emissions profile (usually described as CO_2 equivalent, or CO_2e) of these different systems, and the respective practices and emissions sources within, is not straightforward.[42] Field measurements are costly and difficult to apply, and there are different methods for calculating emissions which can complicate comparisons. This can create different estimates, for example:

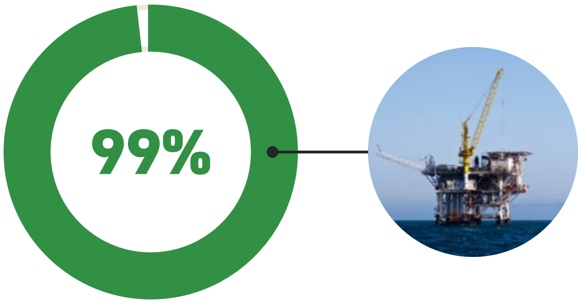
- The International Cotton Advisory Committee's Panel on Social, Environmental and Economic Performance estimated GHG emissions in cotton production to range from 0.15 to 4 tonnes of CO_2e per hectare.[43]
- Carbon Trust calculated that between 4 and 12 tonnes of CO_2e were emitted per tonne of cotton lint,[44]
- WWF calculated that a project intervention in India helped reduce CO_2e emissions from 1.5kg to 0.43kg per kilogram of seed cotton produced,[45]
- Cotton Incorporated calculated that aggregated cotton production in China, India, and USA averaged 1.8 tonnes of CO_2 emissions per tonne of cotton lint,[46] and that the impact of cotton cultivation and ginning on global warming potential was 1,428kg of CO_2e per tonne of cotton fiber (without accounting for the carbon stored by the fiber itself).[47]

Nonetheless, the various existing assessments find some consistent sources of emissions. They include:

1. **Field energy use.** This concerns the energy used for machines to prepare or irrigate the land. On larger farms this more often involves fossil-fuel powered machines, such as tractors or generator-powered irrigation machinery. Where these are powered by renewable energy sources, or by manual labor, the emissions profile is much reduced.
2. **Residue management.** After cotton has been harvested, the rest of the plant (mostly cotton stalks) is usually repurposed or disposed of. Depending on the manner of disposal this can involve carbon emissions, the worst option being burning.
3. **Land use changes.** This concerns the clearing of native vegetation to establish new agricultural grounds.

   Cotton is also linked to deforestation. The savannas in Australia's Northern Territory[48] and bushland in New South Wales[49] are under threat, and as a rotation crop to soy, cotton is likely linked to deforestation in the Brazilian Cerrado[50] [51], one of the world's most important biomes.[52]
4. **Synthetic Agrochemical use.** This concerns the use of artificial pesticides and fertilizers. They are the largest source of emissions in the production phase, and are explored in more detail in the following pages.

Agrochemical emissions



99% OF ALL SYNTHETIC CHEMICALS ARE DERIVED FROM FOSSIL FUELS.[53] AS THE CENTRE FOR INTERNATIONAL ENVIRONMENTAL LAW HAS NOTED, “AGROCHEMICALS ARE FOSSIL FUELS IN ANOTHER FORM”.[54]

Chemicals used for cotton agriculture fall into two categories; fertilizers and pesticides, both of which are a key source of carbon emissions during cotton's production. Some LCAs have estimated that nearly half of cotton production's global warming potential comes from the production and use of agrochemicals - predominantly from fertilizers.[55]

Cotton production has been troubled by indiscriminate and over-use of synthetic agrochemicals as farmers seek to control insects, pests, weeds and plant growth.[56] This is in part because not enough farmers are trained to understand soil health, ecosystem dynamics, pest management, plant management, or the consequences of over-using synthetic chemicals. However economic pressures are also a driver, particularly for smallholder producers with few alternatives but to maximize profits to earn a living.

ABOVE PHOTO © GETTY IMAGES

This puts ecologies and people at risk through:

- Direct contact with harmful chemicals,
- Soil contamination, runoff and water eutrophication,
- The potential introduction of unwanted chemicals into the food chain, [57] and
- Failiures to enable farmers to maximize their net income through sustainable methods.[58]

Fertilizers are 'a chemical or natural substance or material that is used to provide nutrients to plants'.[59] Over-use of synthetic fertilizers can harden and deplete organic carbon in soil, affect soil organisms, and make soil more acidic, ultimately reducing soil fertility.[60] Nitrogen fertilizers used to improve cotton output are often deployed inappropriately, which impacts yields and cotton's quality.[61] In some cases, excess fertilizer application has been found to not increase yields, while contributing significantly to GHG emissions.[62]

Pesticides are 'any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth'.[63] The properties that make them efficient killers of pests often make them hazardous for other organisms, the environment, and humans too.[64 65]


© SOLIDARIDAD

In Brazil, the world's fourth-largest cotton producing country, farmers use more agrochemicals than cotton farmers in any other country.[66] Pesticide poisonings and groundwater contamination has been rising - with more than 90% of some water samples testing positive for pesticides.[67] 4 out of the top 10 most commonly used pesticides in Brazil are banned in the EU for their danger to human health and the environment.[68]

Agrochemicals contribute to climate change throughout their lifecycle via manufacturing, packaging, transportation, application, and even through environmental degradation and disposal.

- Pesticides, on average, take more energy to manufacture than fertilizers. It has been estimated that manufacturing 1kg of pesticide active ingredient requires, on average, about 10 times more energy than 1kg of nitrogen fertilizer.[69] [70] However, the quantity of pesticides used is commonly less than for fertilizers.
- Nonetheless both the production and use of Nitrogen-based fertilizers are a key source of GHG emissions. Nitrous Oxide is a stronger greenhouse gas than CO_2, due to its longer lifetime of approximately 110 years and greater infrared absorption potential - the Global Warming Potential (GWP) of Nitrous Oxide is 265–298 times that of CO_2 for a 100-year timescale.[71]
- Pesticides, just as fertilizers, emit Nitrous Oxide - and some pesticides are themselves greenhouse gasses. The fumigant sulfuryl fluoride (used to fumigate commodities during transport and storage), is a powerful greenhouse gas. Emitting just one ton (0.91 tonnes) of sulfuryl fluoride is the equivalent of emitting 4,780 tons (4,336 tonnes) of CO_2.[72]
- The release of pesticides into the environment, and the subsequent interactions with organisms in the soil, result in further emissions. It is estimated that less than 0.1% of applied pesticides reach their target, with the other 99.9% ending up on plant leaves, in the soil, in water, or in the air. This creates a significant GHG footprint and environmental impact far beyond their intended use.[73]
- Long term pesticide use has serious impacts on soil health, including its ability to sequester carbon and support healthy plant growth. They can have a detrimental impact on fungal communities and soil microbes - which are responsible for making soil nutrients available for plants, and for producing the most stable forms of soil organic carbon that can remain in the soil for longer periods of time.[74] Farmers can get into a negative cycle of using increasing quantities of agrochemicals to deal with soil nutrient deficiencies and escalating pest and disease problems. The longer this practice continues, the less prepared for a warmer climate the soil is, and the more likely it is that soil will capture less carbon and erode further.
- Cumulatively, this means that soil will be less healthy and store less moisture, making it more susceptible to erosion in the hotter and windier weather conditions expected as a result of climate change. This is a destructive cycle that must be stopped.

"There is no doubt that agrichemical use can be significantly reduced, or even eliminated, from cotton while improving farmers' profits and protecting their natural resources. But this can't be done without investing in farmers to make changes. They need: high quality, practical training; participatory research that meets their needs; and independent sources of information. With this support, we have seen that farmers are eager to transition to more sustainable agroecological practices and do so successfully"

Pesticide Action Network UK

© SOLIDARIDAD

Chapter 4

CLIMATE-SMART COTTON PRODUCTION

© CLIMAX FILM PRODUCTION / SOLIDARIDAD

“AGROECOLOGY ALSO PUTS AGRICULTURE ON THE PATH OF SUSTAINABILITY BY DELINKING FOOD PRODUCTION FROM THE RELIANCE ON FOSSIL ENERGY (OIL AND GAS). IT CONTRIBUTES TO MITIGATING CLIMATE CHANGE, BOTH BY INCREASING CARBON SINKS IN SOIL ORGANIC MATTER AND ABOVE-GROUND BIOMASS, AND BY AVOIDING CARBON DIOXIDE OR OTHER GREENHOUSE GAS EMISSIONS FROM FARMS BY REDUCING DIRECT AND INDIRECT ENERGY USE.”

Olivier De Schutter, ***UN Special Rapporteur on the right to food***[75]

Several different agricultural approaches incorporate practices that are relevant to either climate change, emissions, adaptation, or mitigation.

While there are some differences regarding how multi-disciplinary the practice is, or if it also seeks to address social as well as environmental concerns, they nonetheless involve complementary approaches that would have positive impacts on emissions, and particularly on soil health.[76]

© SOLIDARIDAD

ORGANIC

"Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system."[77] Organic farming allows for the use of purchased inputs if they meet organic standards.

AGROECOLOGY

"Agroecology is a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems. It seeks to optimize the interactions between plants, animals, humans and the environment while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced."[78]

REGENERATIVE AGRICULTURE

"Regenerative agriculture focuses on improving the health of soil, which has been degraded by the use of heavy machinery, fertilizers and pesticides in intensive farming." Regenerative farming methods include minimizing the plowing/tilling of land, rotating crops to vary the types of crop planted, using animal manure and compost to return nutrients to the soil, and use of cover-cropping and shade trees. These methods enhance the soil's ability to absorb and retain water, mitigating the impacts of droughts and floods.[79] [80] [81]

The Sustainable Agriculture Initiative, a collection of mostly larger companies and traders in agricultural value chains, have launched a global framework for regenerative agriculture, defining it as "an outcome-based farming approach that protects and improves soil health, biodiversity, climate, and water resources while supporting farming business development."[82]

CLIMATE-SMART AGRICULTURE

"Climate-Smart Agriculture (CSA) is an approach to help the people who manage agricultural systems respond effectively to climate change. The CSA approach pursues the triple objectives of sustainably increasing productivity and incomes, adapting to climate change and reducing greenhouse gas emissions where possible. This does not imply that every practice applied in every location should produce "triple wins". Rather the CSA approach seeks to reduce trade-offs and promote synergies by taking these objectives into consideration to inform decisions from the local to the global scales and over short and long time horizons, to derive locally-acceptable solutions."[83]

NATURE-BASED SOLUTIONS

"Nature-based solutions are actions that protect, sustainably manage, and restore natural and modified ecosystems to address societal challenges. They can provide long-term positive benefits that flow from healthy ecosystems and target significant challenges by providing climate change mitigation, disaster risk reduction, food and water security, and improved health outcomes."[84]

NATURAL FARMING

Natural farming is adopting farming methods that do not use any input that is purchased from the market. It includes practices like intercropping, cover cropping, using trap crops, mulching, agroforestry, and natural biomass (including from on-farm livestock), but no 'added' inputs.[85]

Characteristics of these respective practices that have relevance for cotton and climate mitigation or adaptation are described in the following pages.

Climate change mitigation

Reducing emissions

As described earlier, conventional cotton production does have a climate impact and emissions vary depending on production methods. Nonetheless the four most common sources of emissions from raw cotton farming are from field energy use, residue management, land-use changes, and synthetic agrochemicals. Reducing emissions is possible in all cases, and will have varied impacts depending on the existing production methods.

Field energy use
Wherever possible, farmers should be supported to move away from fossil-fuel powered machines, such as tractors or generator-powered irrigation machinery. This disproportionately applies to larger cotton farms, which are mostly located in countries that grow cotton for export, as smallholder cotton farming tends to be less mechanized. Wealthier farmers in higher-income countries will more likely be able to access renewable energy options with greater ease than poorer or rural farmers, and should actively take steps to realize this.

Residue management
All steps should be taken to end residue burning practices. Farmers should be supported to adopt more climate-friendly alternatives such as using cotton stalks and other residue material as mulch to cover the soil - further increasing soil fertility, moisture retention, and reducing the need for synthetic fertilizers.

Land use changes
The drivers of native vegetation conversion and deforestation are predominantly economic. As cotton production becomes more volatile, and average yields decline, the pressure to expand agricultural land even further will be significant. Addressing the underlying inequalities within cotton's value chain, including ensuring a living wage for producers, is critical and systemic intervention that can help protect existing natural resources.[86]

Legislative and regulatory measures also have a role to play, the most notable recent development being the EU Deforestation-free Regulation.[87] While cotton is not yet one of the commodities captured by the regulation, it serves as a common rotation crop for soy which is.[88] [89] As more commodities are captured under the EUDR and similar legislation, we hope that cotton will be considered for inclusion to ensure a level playing field.

Synthetic agrochemical use
Farmers should be supported to move away from using synthetic agrochemicals (pesticides, fertilizers, etc), and replace them with alternatives that produce fewer emissions, or better yet sequester carbon.

As Pesticide Action Network have noted; "utilising ecological pest and crop management practices reduces the need for petroleum-derived pesticides and fertilisers, and therefore reduces associated emissions of greenhouse gases."[90]

Fertilizer alternatives include:

- **Crop management.** Including practicing crop rotation, and using legumes (such as pulses) for intercropping or as a source of green manure.
- **Using on-farm, or locally sourced, biomass.** This can include composting crop residue (such as cotton stalks), livestock manure, wood chips, legumes, leaves, weeds, and other suitable material.
- **Organic manures and natural mineral fertilizers.** These can include de-oiled castor cakes (DOC), rock phosphate, gypsum, muriate of potash, etc.
- **Organic liquid fertilizers.** Liquid manures, such as diluted cow urine, biogas slurry, or fermented manures provide nutrients that are needed in later growth stages.[91]

Pesticide alternatives include:

- Many of the same pest management practices serve as both adaptation and mitigation strategies. The need for indiscriminate pesticide usage, and its associated emissions, is reduced by applying **integrated pest management** strategies such as **crop rotation, biological controls, traps and physical controls,** and **field hygiene**. These methods are explored in greater detail in the following 'Climate change adaptation' section.

CASE STUDY - BIOFERTILIZERS (FROM BETTER COTTON)

Lata Gaikwad lives in the village of Junewani in Nagpur, India. She realized that excess use of chemical fertilizers made her soil hard and inhospitable for earthworms, and she intended to gradually move towards organic farming.

Beginning early 2020, Lata made various bio-inputs on a small scale to support her own farms. Upon joining the Better Cotton programme, she was supported by the Ambuja Cement Foundation

(ACF) team with training, knowledge, and the techniques of making biofertilizers such as vermicompost, biopesticides such as neem ark, dashparni ark and of gradually moving towards organic agriculture. She noticed that while her yield may not have improved, her input cost had reduced substantially. Supported by her husband and her son, she is now making bio-inputs in bulk and wants to sell it as a product to her fellow farmers.

> **WE SHOULD NOT HARM ANY LIVING BEING TO MAKE OUR LIVELIHOOD. USING CHEMICALS TO KILL LIVING ORGANISMS IS ALSO A FORM OF VIOLENCE.**
>
> ***Lata Gaikwad, Entrepreneur***[92]

CASE STUDY - OBEPAB (FROM PAN UK)

Building resilience through practical training in agroecology

The Organisation for the Promotion of Organic Agriculture in Benin (OBEPAB)'s cotton programme has demonstrated the viability of organic production through agroecology. After almost 30 years, the impacts of high quality farmer training in organic cotton in Benin are clear: while organic yields remain similar to conventional farmers, organic smallholder farmers earn significantly higher net income and are more resilient to climate change through a focus on soil fertility, reduced reliance on costly inputs, and crop diversification.

Organic cotton farmers in Benin have replaced chemical fertilizers with biological practices, such as applying oil palm cake, compost, and rotating with legumes in place of chemical fertilizers. As a result recent studies have shown that soil organic carbon content is on average 50% higher on these organic plots. These agroecological practices have also boosted nitrogen levels and improved pH and, as well as sequestering considerable carbon in the soil, soils with higher organic matter have better moisture retention, nutrient uptake, and microbial activity.

In recent years, extremes of weather are becoming increasingly common in Benin. In 2021, long dry spells were followed by heavy rain causing cotton yields for organic and conventional farmers to drop by 25% compared to 2018. However, agroecological growers were at a distinct advantage. The many practices they undertake to build healthy soil with high organic matter content result in good structure, fertility and – most importantly in the face of climate stress – moisture retention capacity. The addition of compost, green manure, cover crops, retention of crop stubble and use of mulch all help to keep moisture in the soil and available to the plants when needed. High organic matter also keeps plant nutrients in solution and available to be taken up by plants, with the assistance of soil microbes that thrive in humus-rich soil. So even under drought conditions the cotton plant can access the moisture and nutrients it needs. In contrast, soils with low organic matter content do not retain moisture and, even with high application of fertilizers delivering a range of chemical elements, microbes are not there to assist their uptake.

With a reliance on agroecology and locally-produced products, organic farmers trained by OBEPAB spent just 18% of their cotton revenue on production costs, whereas conventional farmers had spent 72% of their earnings in production. As a result, OBEPAB farmers earned higher profit despite similar yields. With disrupted weather patterns increasingly the norm in Benin due to climate change, agroecological practices offer an approach to both mitigate climate change and adapt to its impacts.[93]

Sequestration

Cotton, unlike synthetic fibers, captures carbon from the atmosphere during the plant stage. While the scientific understanding of exactly how soil sequesters carbon is developing[94], there is a widespread consensus that farming activities that improve soil health (cover-cropping, minimum tillage, reduced synthetic chemical use) can increase the soil's capacity for both carbon and water storage.[95] [96] [97]

Furthermore, carbon is stored in the cotton fiber itself. Some estimates indicate that on a global average the amount of carbon stored is greater than the emissions associated with cultivation activities and required materials. However, there is a high degree of variation in both GHG sequestration and emissions depending on production methods - so much so that the amount of variation can be enough to entirely wipe out the net-positive amount of CO_2e captured.[98]

This indicates that cotton has potential not only as a net-zero fiber, but even a net-positive fiber - provided that steps are taken to reduce its emissions profile.

Further steps can be taken to increase carbon sequestration at farm level, including mulching, crop rotation, and agroforestry - the cumulative effects of which all improve soil health.[99] [100]

As Textile Exchange have noted; "Supporting producers to build carbon in the soil through regenerative agriculture approaches can directly and indirectly support brands' climate goals within and outside of their supply chains, both by generating fewer emissions from their supply chain through reduced use of agricultural fossil fuel inputs and by preventing the release of carbon from the soil through tillage and other disturbance."[101]

© ANNEMARIEKE VAN DEN BROEK

Climate change adaptation

While interventions to improve the longer-term economic circumstances faced by cotton smallholders are essential, there remains a time-sensitive need to adapt to growing cotton in a changed climate.

As described earlier, climate change and extreme weather are becoming significant challenges for the cotton sector. As Cotton 2040 identify; "Climate change can cause direct damage to cotton crop either through gradual, incremental, changes, such as atmospheric warming or changes in total rainfall, or through sudden changes and extreme weather events such as flooding, hailstorms or heatwaves."[102]

Climate change will prove highly disruptive to cotton production, which will only exacerbate the volatility we have seen in the market.[103] Supporting climate change adaptation is, in effect, a business-continuity investment; shoring up production in the face of increased volatility.

Climate tolerant cultivars

Many widely used cotton varieties are expected to be vulnerable to the impacts of climate change, including heat stress, drought, weeds, and pests and diseases. One option being explored is selectively breeding cotton varieties, known as cultivars, that can be more tolerant of these impacts.[104] [105]

© SOLIDARIDAD

Of these impacts, drought and heat factors have been more thoroughly explored on different cultivars/ genotypes. They have been found to have negative consequences for plant height, number and weight of bolls, as well as fiber fineness and strength. Some genotypes performed better than others under stress conditions, and have been recommended for further development.[106]

It is important that such breeding activities support native varieties where possible, as is consistent with other regenerative practices. Native varieties can prove to be more resilient to specific local factors, such as predominant pests or disease.

Flood management

In areas with a predicted increase in floods and heavy rainfall, effective flood management is an important adaptation strategy. Waterlogged roots cannot take up adequate amounts of nutrients from the soil; limiting plant growth and yields.

Two days of standing water can be enough to deplete clay soils of oxygen, especially where high nitrogen levels are present. As roots become deprived of oxygen, plants are unable to maintain the normal respiration necessary for growing shoots and roots. In waterlogged soils, roots will tend to proliferate nearer the soil surface where more oxygen is present. Sediment carried away by water run-off, reduced growth, and shallow roots can mean that cotton plants are more susceptible to drought stress later in the season.[107] Ironically, this can mean that flooding leads to more water usage, not less.

Cotton can handle saturated soil for a short period of time, but there are subsequent risks from pests and weeds like thrips or pigweed. On farms where heavy machinery is used to assist clear-up efforts, this can lead to significant soil-compacting even up to half a meter down.[108] After water-logging soil can often crust, increasing water run-off and therefore reducing the amount of water that enters the soil to support plant growth. Commonly the response is to harrow, till or cultivate the soil, however given that cotton roots will now be closer to the surface this should be done carefully to avoid damaging existing root structures and further inhibiting plant growth.

All flood management mechanisms are affected by the capacity of local infrastructure. Nonetheless a variety of landscape and farm management tools can be used to reduce the impact of heavy rains and flooding, including;

- **Protective Berms:** A berm is a flat or raised strip of land created to separate or protect an area of land. Berms are helpful in diverting slower-moving flood waters away from crops.
- **Run-off areas:** Creating dedicated spaces to channel and collect excess water, such as swales, run-off ponds or reservoirs, or enhancing existing keyline waterflow features - which is often used in conjunction with other land improvement strategies like organic and regenerative agriculture. While its impact is more limited, widespread rainwater harvesting for domestic or agricultural use is also recommended. (See 'Water Management').
- **Soil cover:** Using cover crops and maintaining perennial plant cover helps soil retain sediment, moisture, and the organic processes that go with them. This helps them absorb more water by avoiding run-off, and particularly increases soil carbon which can hold more water.
- **Agricultural drainage:** Surface ditches and subsurface permeable pipes can drain standing or excess water. While both can take significant time to put in place, the latter involves more significant investment and planning, as well as maintenance.[109]

High wind/storm adaptation

The main method of managing high wind events is through establishing windbreakers, usually in the form of rows of trees. In more arid regions, especially as climate change worsens, farmers and local authorities may need to source native vegetation solutions that can grow and survive in a changed climate and still serve the same purpose.

Hedgerows and intercropping are recommended to help reduce the impact of day to day increased wind which can exacerbate soil erosion, and help trap more moisture in the soil. Rock or stone walls can serve a similar purpose, and can have the added benefit of serving as firebreaks in the event of wildfires, but are less helpful in supporting soil health.[110]

Pest and disease management

A variety of pest and disease management processes are in use today to great effect. However the industry still overly relies on pesticides, herbicides, insecticides, and other agrochemicals. These must be phased out as quickly as possible, and farmers must be supported to adopt more sophisticated, targeted, and environmentally friendly management techniques. Overall there is strong scientific support for replacing the current dominant chemical-input approach with a biological approach as a means of both climate change mitigation and building resilience.[111] [112] [113] [114]

Integrated Pest Management (IPM) is an approach to managing pests, diseases or weeds in which chemical pesticides are used only as a last resort, if at all. It uses a combination of different control methods, based on good crop husbandry, plant breeding, and physical or biological control methods, underpinned by effective monitoring strategies.[115] [116] [117] [118]

Some of these techniques include:

- **Crop selection and rotation:** Many pests and diseases prefer one or more crop types over others. A regular rotation of healthy crops can not only support healthy soils, but also inhibit pest build-up, or recurring disease varieties. This can also include planting cotton varieties that are less susceptible to pests or disease (e.g. Bt cotton).
- **Field hygiene**: Maintaining good field hygiene to prevent contaminants, pests, and diseases from surviving to infest the following crop.
- **Biological controls:** Many insects that are considered pests have natural predators or parasites, and managed populations of these natural enemies can sustain themselves on the pest population in the area. Other pests are susceptible to certain fungi or bacteria (beneficial entomopathogens) which can inhibit their presence, or can be disrupted by pheromone attractants and further reduce the need for synthetic chemical treatments. Additionally farmers are recommended to use, or intercrop, plant varieties that deter pests, and remove weeds that are favored by those pests.
- **Traps and physical controls:** Light and attractant traps can be used to monitor pest levels or, in higher-densities, to reduce pest numbers. Some insect capture methods involve self-contained feed sources, or pheromone sources that mimic potential mates. The disposal of captured insects can pose ethical considerations[119], and while some are exploring the use of insects or insect by-products for fertilizer use[120], this should be considered carefully before being applied especially if food or feed crops are among the rotated crop mix.[121] Nets can also be used to limit insect infiltration.
- **Infestation control:** Can include quarantining or cultivating practices, including isolating, removing, or pruning diseased elements, and infestation management through removing or trapping pests to inhibit breeding.

The 'Food spray' - Biological pest control

Pesticide Action Network UK (PAN UK) began working with Integrated Pest Management expert Robert Mensah in 2006 to develop an alternative pest control tool for smallholder cotton farmers.

They developed a 'food spray' - applied as a foliar spray and made using cheap and locally available ingredients (partly fermented maize or waste-brewers yeast and a little soap and sugar). Instead of killing insects, the yeast odors attract the natural enemies of pests into the cotton field. The sugar provides sustenance while waiting for cotton's pests to arrive. As the cotton pests emerge, their predators are already present in great enough numbers to keep pest populations in check.

A vital element of success is farmer training. They need to manage their crop habitat to provide a welcoming home for natural enemies – for example planting alfalfa strips – and avoid the use of broad-spectrum insecticides. They must also recognise the difference between pests and natural enemies and monitor the balance of the two. If pest populations begin to accelerate too fast, then timely action can be taken to keep them in check.

Today, the food spray technique is used by more than 14,000 smallholder farmers in Ethiopia and Benin on cotton and vegetables and is being piloted by 11 organizations in India, Uganda, Jamaica.[122]

Water Management

Optimizing the water use efficiency
Using water efficiently and optimizing water-use in the production of cotton is an important adaptation strategy. Water shortage is a large problem and limiting factor for cotton production, as well as the main predicted climate risk and impact.

There is an important distinction between rain-fed and irrigated cotton. Irrigation systems can be costly to install and maintain, meaning they are used less by poorer farmers. Cotton that relies largely on rainwater will become more susceptible to prolonged periods of drought.

There will be an increasing demand for fresh water supplies, especially in areas where demographic pressure is high and water resources are limited. Irrigated cotton production will likely compete with other crops for water use (which can lead to conflicts).[123]

Therefore, optimizing water-use efficiency in the production of cotton is an important adaptation strategy. The treatment of run-off and polluted water to make it available for other purposes are examples of good practices that save water. Other water saving practices include Temporary Check Dams (often used towards the end of the monsoon season by placing cement bags across a stream to pool water[124]) or installing water-tanks to catch rainwater and retain it into dry periods.

Water retention/drip irrigation
Water is often a limiting factor for cotton growth, and increasing the amount of water available for cotton crops can support cotton productivity, which can be crucial for smallholders who rely on cotton as a means of income.

There are different ways this can achieved, such as conserving or retaining run-off water, establishing farm ponds, using irrigation to better control the amount of water being used and the time of it's application, and increasing water holding capacity (water retention) of the soil through more effective soil management practices, such as minimum tillage, mulching, and cover-cropping.

It is important to repeat here that as water becomes more scarce or less reliably accessible, and demand from other crops and non-agricultural use rises, the risk of conflict increases.[125] While rainfed cotton is more susceptible to changes in rainfall patterns, irrigated cotton is also expected to suffer in the long run due to increased competition for freshwater. This emphasizes further the need for water retention strategies to mediate the impact of greater volatility in water availability.

CASE STUDY - FARM PONDS (FROM BETTER COTTON)

Farm ponds as an alternative for groundwater

Many smallholder farmers depend on groundwater sources for irrigating their crops because of inconsistent rainfall. This can deplete groundwater stocks more quickly, and increase concentrations of contaminants. In 2018-19, 300 water samples collected from different groundwater sources in India's Malwa region found that groundwater quality of some villages were "Category - 4" (the lowest quality in the scale) due to high EC, salinity, and presence of ions of carbonate, bicarbonate, calcium and magnesium. This made the water unsuitable for irrigation.

Poor groundwater quality can consistently affect soil pH, which in turn adversely affects yields.

While some farmers were able to enhance the suitability of available groundwater for irrigation by mixing groundwater and canal water in equal proportions, others were supported to install farm ponds as a longer-term solution. A farm pond is a dug-out structure at the lowest portion of the farm area with inlet and outlet structures for collecting and storing water. A pond 12 meters square and 3 meters deep can store enough rainwater/run-off to irrigate 3 acres of land 4 times using a drip irrigation system, easing the burden on groundwater supplies.[126]

Soil Management

The importance of maintaining healthy soil is widely recognized, and has connections with many of the other topics explored in this paper. Healthy soil not only sequesters carbon, but stores moisture more effectively, erodes less easily, improves biodiversity, and can increase yields.

Some of the primary mechanisms for effective soil management include:

- **Phase out synthetic agrochemicals:** Healthy soils need less fertilizer and pesticides, reducing costs for farmers and reducing cotton's emissions profile. A healthy build-up of nutrients in the soil can be reached by using less synthetic Nitrogen-fertilizer, and optimizing its application. Overdosing on nitrogen can destroy granular soil structure and compacts the soil. In organically managed soils, the crops mainly depend on the nutrients supplied by minerals (such as nitrogen, phosphorus, and potassium) and by the organic matter in the soil.[127] These take up, store and release nutrients (through exchange, weathering, and decomposition). Soil organisms play a vital role in this process and should be supported through careful soil cultivation and regular application of organic matter. Pests and diseases are managed through integrated pest management practices.
- **Crop rotation:** Rotating between different crop varieties supports soil fertility as different crops have different nutrient requirements. Moreover crop diversification can be seen as a risk management strategy in a changing climate.[128]
- **Intercropping:** Intercropping is a method of planting at least two crops in alternating rows in the same season, with below ground microbial interactions helping to support soil health. Cotton is often cultivated using wider row spacing, and often has a longer growth period making it especially suitable for intercropping with legume crops, including gram, bean, and cowpea, which grow rapidly and complete life cycles in a shorter time.[129]
- **Cover cropping:** Maintaining soil cover keeps nutrients and water in the soil. It is advised to use organic cover, as covering with plastics can cause soil pollution. Leguminous cover cropping is often used as they can help to fix atmospheric nitrogen (N) for use by subsequent crops, reduce or prevent erosion, attract beneficial insects, and produce biomass and add organic matter to the soil.[130]
- **Mulching:** Mulching is the practice of covering the soil surrounding crops to enhance conservation of soil moisture, control soil erosion, and capture more water.[131] [132]
- **Minimum/No tilling:** The minimization of soil tillage/plowing helps keep both nutrients and water in the soil, and reduces the amount of carbon emitted into the atmosphere.
- **Composting:** Compost can serve as a fertilizing agent, and can consist of a range of materials including green plants, animal manure, cotton stems, and other biological material like food waste. The manure is used to cover and fertilize the soil to promote beneficial bacteria and fungi. These decompose organic matter and produce nutrient-rich soil which can increase yields.[133]

Farmer story - Organic cultivation

(from Organic Cotton Accelerator)

Since 2005, Likha who lives in the Binjwarya Choraha village in Jodhpur, Rajasthan, allocated half a hectare of land to growing cotton. Over the years he noticed changes in the quality of his soil. The deterioration was so bad that it became impossible to till and irrigate effectively and the hardness and saltiness of the soil prevented water from percolating beneath the surface.

In 2018, with support, training, and inputs from a local partner, he shifted to organic cultivation practices. Over time his yield has increased from 200-300kg per bigha (0.6 acre) to 400 kg per bigha, with a noticeable improvement in the quality of the soil.

When he was using conventional farming methods, Likha says that his soil was "dead" after rainfall. Once he introduced organic, rather than chemical, inputs though it became rich in organic activity.[134]

Chapter 5

RECOMMENDATIONS FOR COTTON VALUE CHAIN ACTORS

© GETTY IMAGES

Retailers & Brands

Consumers are concerned about sustainability and expect brands to change behavior.[135 136] As the community with the greatest share of money and influence in the value chain, cotton retailers and brands must be a driving force for good.

Take responsibility for your value chain by investing in producers:

- Go beyond just purchasing 100% of cotton from certified sources and establish agricultural budgets to invest in regenerative and agroecological practices that support producers to adapt to, and mitigate, climate change.
- Adopt SBTi-approved scope 3 emissions reduction targets that go beyond the 1.5 threshold, and commit to emissions targets for cultivation as well.
- Help consumers understand the social and environmental sustainability challenges in your supply chain, the need to act, and provide them with a perspective for action.[137]

Support Standards to add more value:

- Standard systems are playing a crucial role to address some of the worst harms in cotton production, but retailers and brands should encourage them to raise their ambition, move from sustainable to regenerative practices, prove their impact, and involve farmers even more.
- Request the standards organizations you work with to facilitate partnerships with smallholder cotton farmers, so you can significantly increase your financial investment in regenerative and agroecological practices, and climate change adaptation and mitigation, at producer level.
- Insist on using standards that have strong commitments on reducing agrochemical use and farmer training in agroecological approaches. This should include an overall reduction in agrochemical use and phasing out Highly Hazardous Pesticides by 2030.
- Consumers find standards complex. Help them understand the sustainability challenges in cotton's supply chain, and how by working with standards you are helping to address them.[138]

Proactively engage with Multi-Stakeholder Initiatives (MSIs):

- MSIs can play a critical role in providing forums and interventions to address issues in the cotton value chain. Engage with MSIs that bring smallholder farmers and workers to the table in a meaningful way, and enhance partnerships with producer organizations to support and enable genuine participation.

Standards Systems

> "Companies should approach regenerative agriculture as an investment in a fundamentally different system that has multiple co-benefits, not a variation on the current extractive model. Centuries of Indigenous knowledge and the weight of scientific evidence show that regenerative practices can make critical contributions to improving soil health, biodiversity, water availability and quality, and to a fundamentally different business approach that prioritizes community and ecosystem health."
>
> ***Textile Exchange*[139]**

Standard systems are playing a crucial role that no one else is, and can support climate adaptation and mitigation at a wide scale by involving farmers even more, and credibly proving their impact:

- Urgently facilitate retailers and brands partnering with smallholder cotton farmers so they significantly increase their financial investment in climate change adaptation and mitigation.
- Adopt ambitious strategies, including price premiums and mechanisms, to guarantee living incomes for smallholder cotton farmers, so they can build resilience and adapt to growing cotton in a changed climate.
- Invest further in farmer training, and show in real terms how training leads to good farmer livelihoods, as well as regenerative and agroecological practices.
- Consumers find standards complex. Help them understand the sustainability challenges in cotton's supply chain, and your role in addressing them.[140]

© CLIMAX FILM PRODUCTION / SOLIDARIDAD


© CLIMAX FILM PRODUCTION / SOLIDARIDAD

Farmers & Farmer Organizations

Farmers, especially smallholders who are producing the majority of the world's cotton, are critical to the sector. Farmers deserve a healthy environment, a greater share of the cotton sector's value, and support to adapt to climate change.

For individual farmers, please consider:

- Climate change is going to affect how you farm. Preparing now will mean you are more likely to keep growing cotton in the future.
- Switching from conventional cotton farming to more environmentally friendly farming practices can improve your health, your soil, and reduce production costs.
- Diversifying your crops to make your income, and environment, more resilient.

For farmer organizations, please consider:

- Training farmers and workers on more environmentally friendly and socially responsible farming practices. Including; climate risk planning, reducing water use, improving soil moisture retention, improving groundwater infiltration in the landscape, choice of cotton species, rainwater harvesting, safe working conditions for labor, etc.
- Making it easier for farmers to buy and use safer alternatives to agrochemicals, such as biopesticides and organic amendments.

Traders

Traders are the gatekeepers of the cotton sector. If they choose, they could open up the value chain, connect retailers with farmers, and use their position to strongly promote adaptation and mitigation.

- Use your purchasing practices to guarantee support for a living income and sustainable farming practices as a prerequisite for commercial arrangements, and proactively support producers who are transitioning to regenerative production.
- For agricultural trading companies that have expanded to either own or lease land for production[141], aim to empower farmers to adapt to and mitigate climate, not control them.

Governments

Public policy is a key mechanism for achieving change. Standards, CSOs, and responsible companies are stepping in to compensate for government failure to regulate irresponsible businesses and enable responsible production, but this is not sufficient. We need meaningful government action.

Governments in predominantly consuming countries:

- Establish multilateral partnerships with producing countries, involving farmers, farmer organizations, and CSOs, to support smallholder farmers to adopt sustainable farming practices.
- Introduce or enhance measures, including changes in subsidies, to support a managed transition away from synthetic agrochemicals towards safe use of agroecological alternatives such as biopesticides and organic practices.[142]
- Model good purchasing practices by sourcing your own cotton products from certified sources.

Governments in predominantly producing countries:

- Consider price support mechanisms to support a living income for smallholder cotton farmers, and reward cotton that is grown more sustainably.
- Repurpose agricultural subsidies to promote climate change adaptation, crop diversification, and other more sustainable and regenerative farming practices.
- Regulate agrochemicals to eliminate Highly Hazardous Pesticides and fertilizers, and promote use of safer alternatives such as biopesticides and agroecological practices.

© SOLIDARIDAD

Multi-Stakeholder Initiatives

To further their critical role in providing forums and interventions to address issues in the cotton value chain, Multi-Stakeholder Initiatives (MSIs) need legitimacy through involving farmers, to drive more ambitious long-term solutions, and to communicate openly their impacts and challenges.

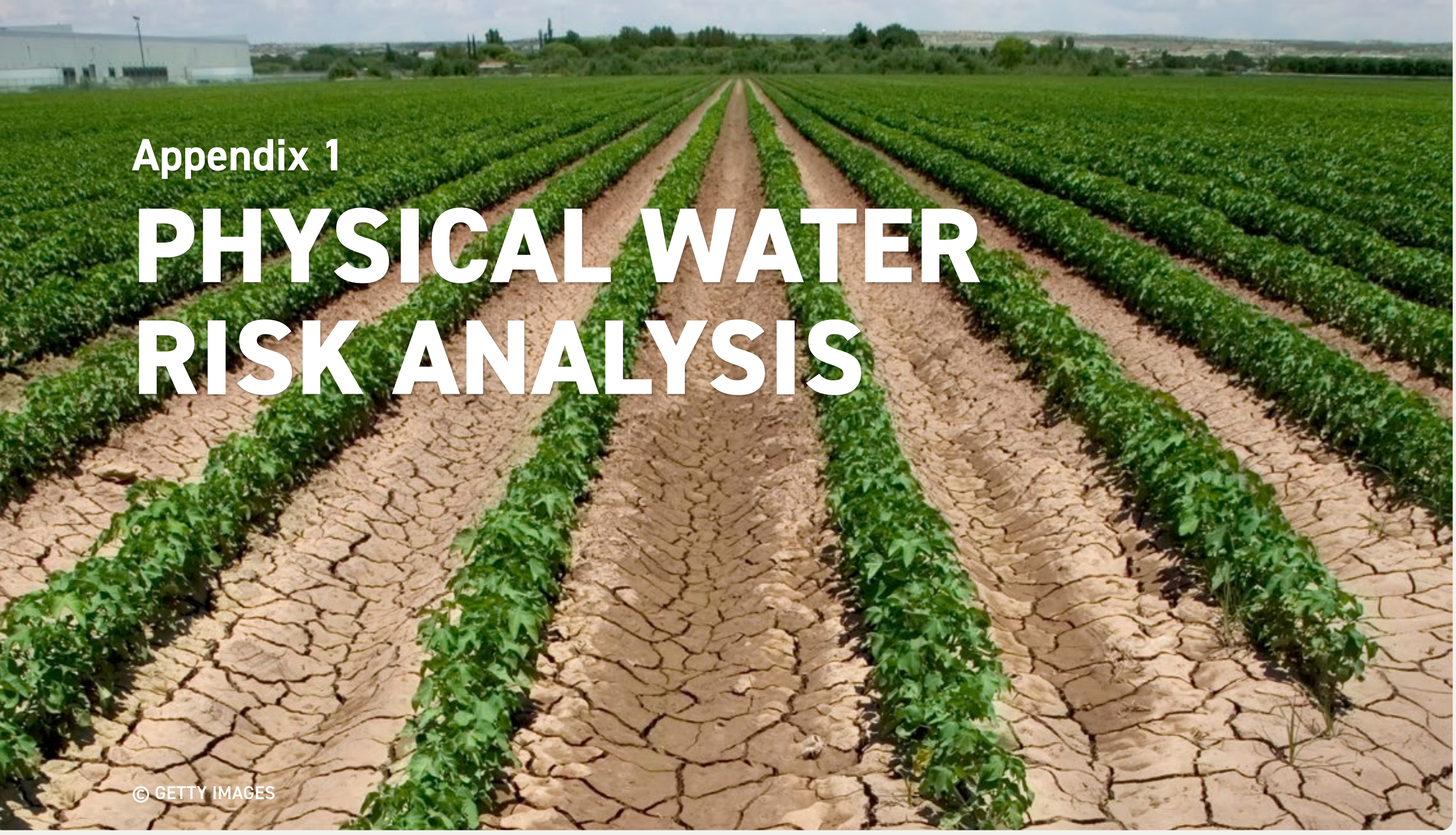
- Drive companies to go further in ensuring cotton provides farmers with good livelihoods and is environmentally sustainable. Companies buying 100% of their cotton from certified sources is the bare minimum.
- Sustainable production and consumption is essential for our environment, climate, and for the livelihoods of farmers and their communities. MSIs have a role to play specifically in promoting crop diversification which can support climate change adaptation, mitigation, and farmer resiliency.[143]
- Require your members to adopt responsible purchasing practices and to be transparent.

Civil Society Organizations

CSOs can bring insight and expertise to the table, but only if they engage:

- Support the transition from a harm reduction 'sustainability' mindset to a 'regenerative' mindset.
- Engage more in supporting smallholder cotton farmers in their transformation towards growing cotton using regenerative and agroecological practices.
- Build farmer and worker organizations' capacity so they can make their voices heard globally and locally, including advocacy campaigns with farmer and worker organizations towards retailers and brands, governments, and MSIs.
- Collaborate with other CSOs to unite behind common calls for action.

© JKIMAGES / SOLIDARIDAD



Appendix 1

PHYSICAL WATER RISK ANALYSIS

© GETTY IMAGES

Cotton is often thought of as a thirsty crop, but this is not always the case. It's actually moderately resistant to drought, making it attractive to farmers in regions like Africa and India, and over half of the world's cotton area is watered purely from rainfall.[144]

However this tolerance means that cotton is generally grown in arid and semi-arid regions, which are areas facing water scarcity - and practically all smallholder farmers surveyed in India and China indicate a lack of water availability impacting crop productivity.[145]

Cotton's water usage can depend on where cotton is grown, whether it is irrigated or rainfed, the type of irrigation system, the types and quantities of fertilizers and pesticides applied, the soil type, and how water gets reintroduced back into ecosystems. Cotton production can contribute to water stress if water is displaced or contaminated, and poor management practices can lead to overconsumption of water. For example, surface irrigation methods, such as flooding, can lead to high amounts of evaporation, deep percolation, and surface runoff. The use of groundwater and surface water for irrigation can deplete freshwater resources if not managed responsibly.

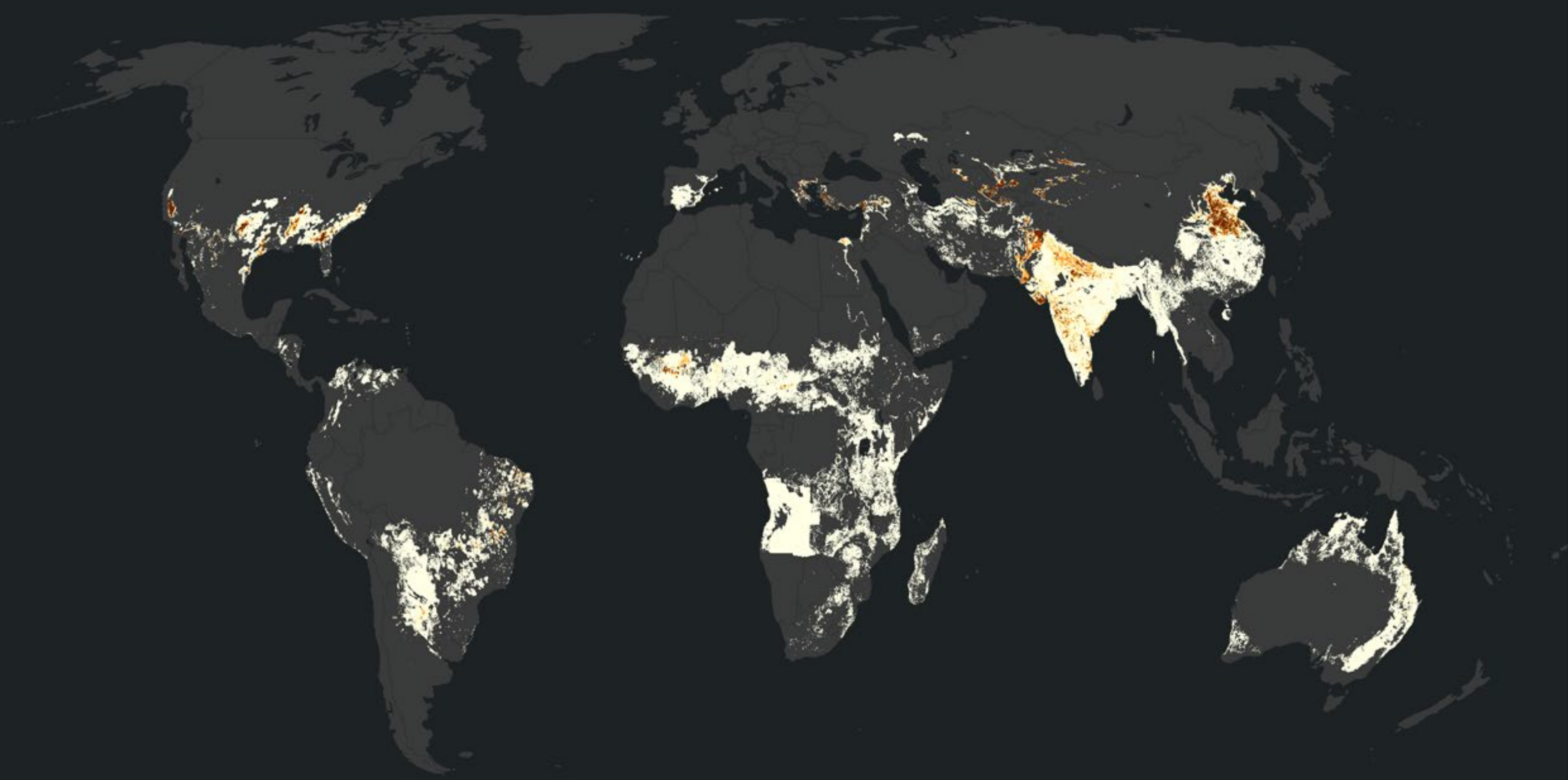
In addition to water quantity, water quality can also be severely impacted by the runoff of agrochemicals such as fertilizers and pesticides. This can lead to acidification, eutrophication, and atmospheric pollution.

The risk of these effects are higher in areas with weak, fragmented - or worse - corrupt water governance. While improving water governance is critically important for some high-risk areas, producers in general can be supported to implement more sustainable cotton production, including modern irrigation methods (drip or automated), minimal tillage, cover cropping, integrated pest management strategies, and other technological solutions, such as remote sensing to measure soil moisture.[146] These practices can significantly lower cotton's impact on freshwater resources and biodiversity, and can reduce greenhouse gas emissions. But to implement these solutions, smallholder farmers urgently need financial support and capacity development.

Cotton production and physical water risk
The climate crisis is a water crisis. The most significant effect of global warming is its impact on the water cycle, with temperature rises increasing the demand for water, leading to greater water extraction.

While water risks can include *regulatory* (legal, water management, etc), and *reputational* risks (importance to local communities, conflict potential, etc), the below visualizations project *physical* water in cotton growing regions.[148] Physical water risk includes water scarcity, flooding, water quality, and ecosystem services (when surrounding ecosystems are degraded, which in turn negatively impacts the water ecosystem).[149] Looking at physical water risk and cotton growing regions together like this shows us both where cotton production may potentially be impacted worst, but also where cotton production may be contributing to high physical water risk.

FIGURE 1
COTTON PRODUCING REGIONS ACROSS THE GLOBE.[147]

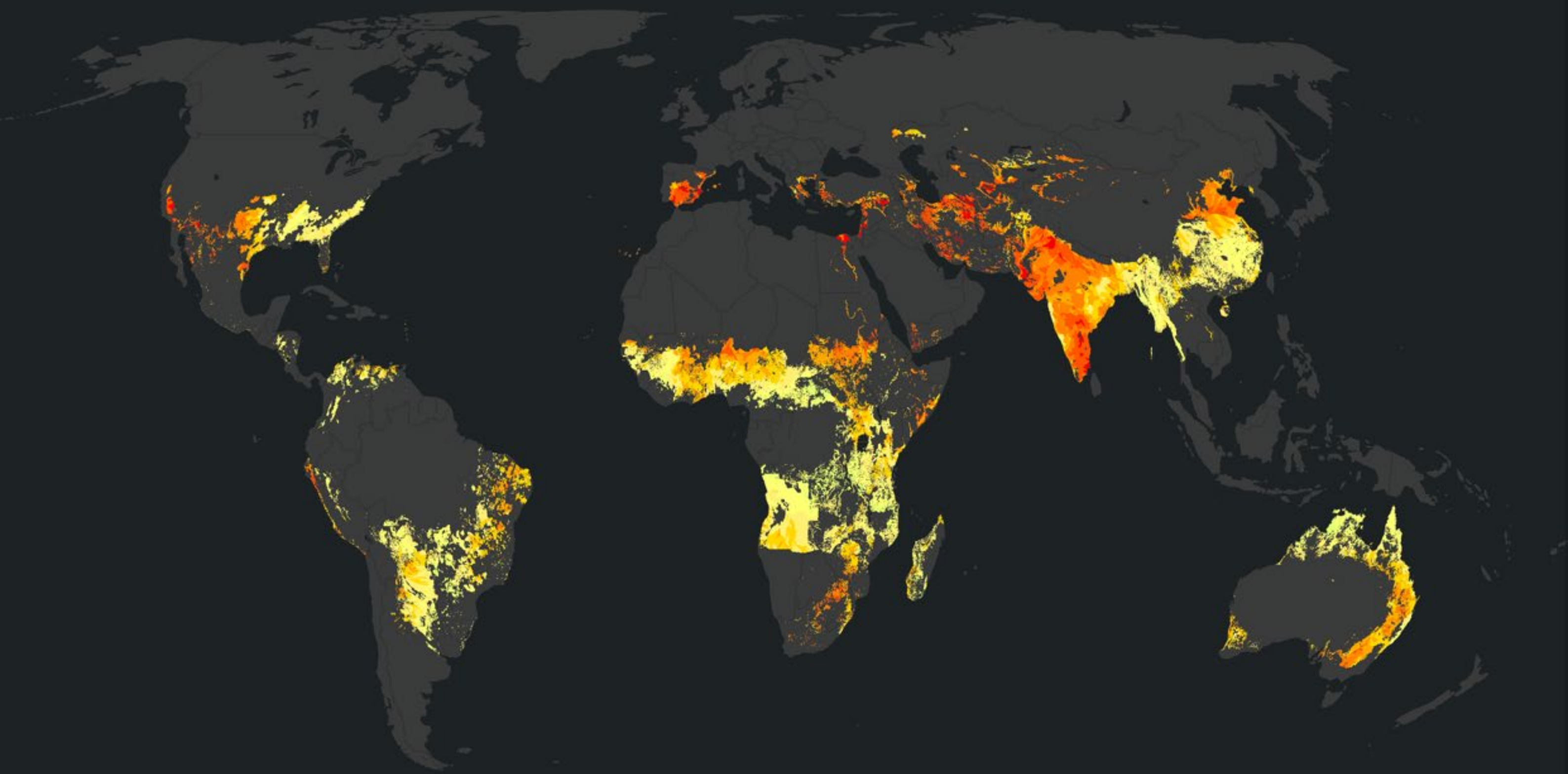


COTTON 2015 PRODUCING REGIONS BASED ON FROLKING ET AL. 2020

Cotton Production

Low High

FIGURE 2
GLOBAL COTTON PRODUCTION AND PHYSICAL WATER RISK IN 2020



COTTON 2015 PRODUCING REGIONS BASED ON FROLKING ET AL. 2020

Physical Water Risk in 2020 (Baseline)

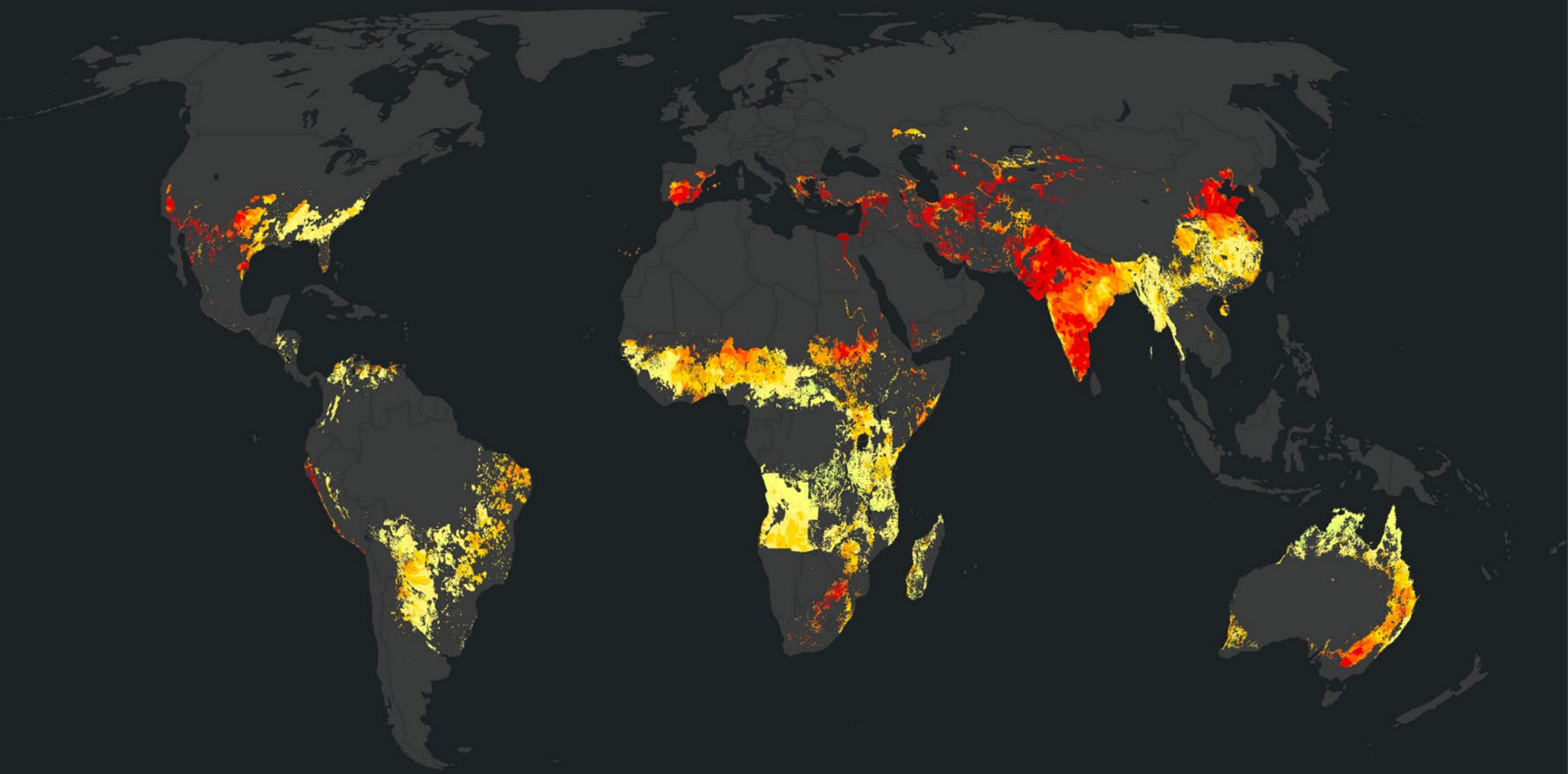
1.0 1.8 2.6 3.4 4.2 5.0

Very low Medium Very high

2020

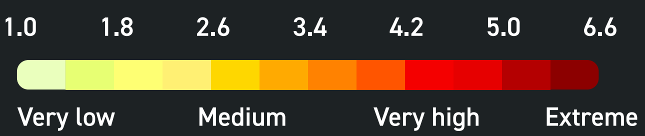
ALREADY AT RISK
In 2020, most of India, the US (especially California, New Mexico, Arizona, and Colorado), Uzbekistan, China (especially Shandong, Shanxi, Beijing, and Xinjiang), Pakistan, and Turkey already had very high or high physical water risk.

FIGURE 3
GLOBAL COTTON PRODUCTION AND CHANGE IN PHYSICAL WATER RISK BETWEEN 2020 AND 2050[150]



COTTON 2015 PRODUCING REGIONS BASED ON FROLKING ET AL. 2020

Physical Water Risk in 2050
(Pessimistic pathway)



2050

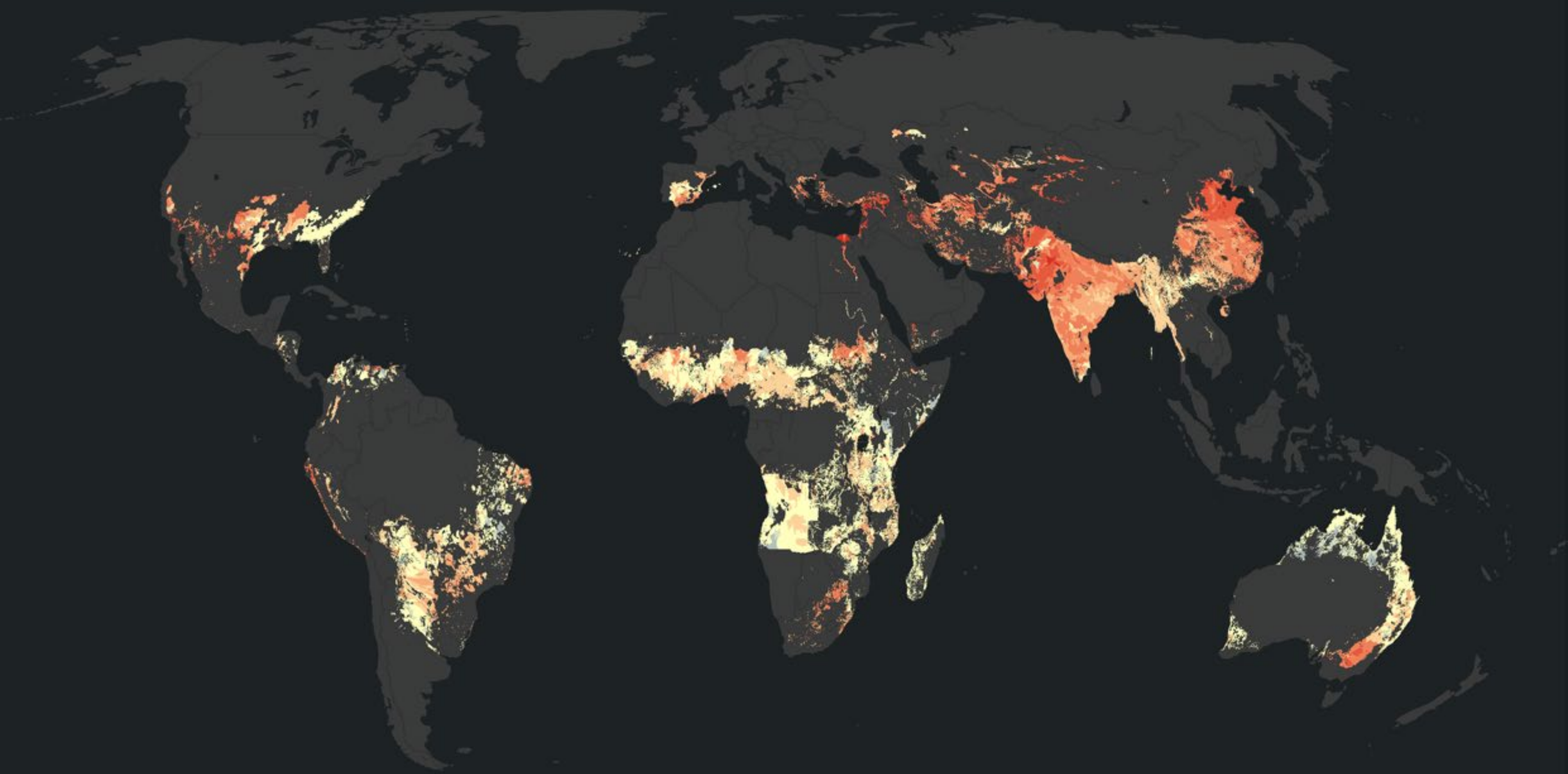
HIGHEST INCREASED RISK
The eastern coast and central China (e.g., Beijing, Shanghai, Shandong, Hebei, Tianjin, Shanxi, Xinjiang, Jiangsu, Liaoning, Henan, and Gansu), western and northern India (e.g., Haryana, Delhi, Rajasthan, Jammu and Kashmir, Gujarat, and Punjab), Turkey, the US (e.g, Colorado, New Mexico, Kentucky, Kansas, and California), Pakistan, and Uzbekistan will face the highest increase in physical water risks.

WORSE WATER SCARCITY
Water scarcity risk will be worst in western and northern India (e.g., Haryana, Punjab, Rajasthan, Gujarat, Delhi, Tamil Nadu, Uttar Pradesh, Telangana, and Andhra Pradesh), Uzbekistan, the eastern coast and central China (e.g., Shandong, Beijing, Xinjiang, Hebei, Tianjin, Shanxi, Shanghai, and Liaoning), the US (e.g., New Mexico, California, Colorado, and Arizona), and Pakistan.

WORSE FLOODING RISK
Western and southern India (e.g., Meghalaya, Tripura, Arunachal Pradesh, Sikkim, Assam, Nagaland, Goa, Tamil Nadu, Gujarat, Telangana, West Bengal, Andhra Pradesh, Maharashtra, Mizoram, Karnataka, Kerala, Orissa, Jammu and Kashmir, Bihar, Chhattisgarh, Uttar Pradesh, Manipur, Jharkhand, Delhi, Haryana, and Punjab), across China cotton-producing regions (e.g., Guangdong, Fujian, Hunan, Jiangxi, Guangxi, Chongqing, Zhejiang, Guizhou, Sichuan, Hubei, Hainan, Anhui), the US (e.g., Kentucky and Virginia), and Brazil (especially Rio Grande do Sul).

WORSE WATER QUALITY
Water quality will be worst across India, the eastern coast and central China, Pakistan, Turkey, and Uzbekistan, primarily due to agriculture extension and/or intensification.

FIGURE 4
HIGHLIGHTS OF WATER RISK IN COTTON PRODUCING REGIONS



COTTON 2015 PRODUCING REGIONS BASED ON FROLKING ET AL. 2020

Change in Physical Water Risk between 2020 and 2050 (Pessimistic pathway)

Decreasing risk | No change | Increasing risk

THE MOST SIGNIFICANT EFFECT OF GLOBAL WARMING IS ITS IMPACT ON THE WATER CYCLE.

© SOLIDARIDAD

REFERENCES


© SOLIDARIDAD

1 United Nations (accessed December 2022) 'Sustainable Development Goals - Decade of Action'

2 Global carbon Project (2022) 'Global Carbon Budget 2022'

3 ICAC (September 2022) 'Flooding and Drought Are Having a Crushing Impact on the Global Cotton Industry'

4 Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production'

5 Textile Exchange (October 2022) 'Preferred fiber and materials market report 2021'

6 Textile Exchange (March 2022) 'Climate+ Dashboard'

7 Cotton Incorporated (Apr 2017) 'The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric'

8 The Sustainable Cotton Hub

9 Solidaridad & PAN-UK (Apr 2023) 'Cotton and Corporate Responsibility'

10 Elahi, E. et al (Aug 2019) 'Extreme weather events risk to crop-production and the adaptation of innovative management strategies to mitigate the risk: A retrospective survey of rural Punjab, Pakistan'

11 Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production'

12 Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production'

13 Cotton Incorporated (Mar 2017) 'LCA Update of cotton fiber and fabric life cycle inventory'

14 ICAC (September 2022) 'Flooding and Drought Are Having a Crushing Impact on the Global Cotton Industry'

15 Textile exchange (October 2022) 'Preferred Fiber & Materials Market Report'

16 Summaries of assessments made by the Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production' and 'Physical Climate Risk and Vulnerability Assessment; India Analysis'

17 For example, the ICAC Soil and Plant health mobile application, and the WWF Cotton Doctor App as described here.

18 Leib, B. et al (Dec 2015) 'Placement and Interpretation of Soil Moisture Sensors for Irrigated Cotton Production in Humid Regions'

19 Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production'

20 Textile Exchange (March 2023) 'Material pathways: Accelerating action towards Climate+ goals'

21 Reuters (September 2022) 'Pakistan floods leave cotton workers' dreams in tatters'

22 Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production'

23 CNBC (November 2022) 'How drought cost America's cotton industry billions'

24 Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production'

25 UN Environment programme (January 2021) 'Environmental and health impacts of pesticides and fertilizers and ways of minimizing them'

26 Shah, P. et al. (July 2018). 'Life Cycle Assessment of Organic, BCI and Conventional Cotton: A Comparative Study of Cotton Cultivation Practices in India.'

27 Descombes, P. et al (Dec 2020) 'Novel trophic interactions under climate change promote alpine plant coexistence'

28 Bebber, D. et al (Sep 2013) 'Crop pests and pathogens move polewards in a warming world'

29 International Trade Centre (Mar 2011) 'Cotton and climate change - Impacts and options to mitigate and adapt'

30 Huang, J. et al (Jan 2020) 'Effects of climate change and crop planting structure on the abundance of cotton bollworm, Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae)'

31 Bale, J.S. et al (Mar 2010) 'Insect overwintering in a changing climate'

32 International Trade Centre (Mar 2011) 'Cotton and climate change - Impacts and options to mitigate and adapt'

33 Textile Exchange (October 2022) 'Preferred fiber and materials market report 2021'

34 International Trade Centre (Mar 2011) 'Cotton and climate change - Impacts and options to mitigate and adapt'

35 Cotton Incorporated (Apr 2017) 'The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric'

36 Soil Association (Sep 2015) 'Cool cotton - Organic cotton and climate change'

37 Cotton Incorporated (Mar 2017) 'LCA Update of cotton fiber and fabric life cycle inventory'

38 Levi Strauss & Co (2018) 'Climate action strategy 2025'

39 Kirchain et al (Sep 2015) 'Sustainable Apparel Materials'

40 Cotton Incorporated (Mar 2017) 'LCA Update of cotton fiber and fabric life cycle inventory'

41 International Trade Centre (Mar 2011) 'Cotton and climate change - Impacts and options to mitigate and adapt'

42 FAO-ICAC, (2015) 'Measuring Sustainability in Cotton Farming Systems'

43 International Trade Centre (Mar 2011) 'Cotton and climate change - Impacts and options to mitigate and adapt'

44 Carbon Trust (2011) 'International Carbon Flows - Cotton'

45 WWF (2013) 'Cutting cotton carbon emissions - Findings from Warangal, India'

46 Cotton Incorporated (Apr 2017) 'The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric'

47 Cotton Incorporated (Mar 2017) 'LCA Update of cotton fiber and fabric life cycle inventory'

48 Arid Lands Environmental Centre (July 2022) 'This is a crisis': The Territory's peak environment groups respond to State of the Environment Report'

49 Davies, A et al. (October 2019) 'Stripped bare: Australia's hidden climate crisis'

50 Rainforest Foundation Norway (October 2018) 'Salmon on soy beans — Deforestation and land conflict in Brazil'

51 Rajão, R et al. (July 2020) 'The rotten apples of Brazil's agribusiness'

52 WWF (Accessed January 2023) 'Cerrado'

53 American Chemistry Council (Sep 2023) 'Guide to the Business of Chemistry'

54 Centre for International Environmental Law (Oct 2022). 'Fossils, Fertilizers, and False Solutions: How Laundering Fossil Fuels in Agrochemicals Puts the Climate and the Planet at Risk.'

55 Cotton Incorporated (Apr 2017) 'The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric'

56 Shah, P. et al. (July 2018). 'Life Cycle Assessment of Organic, BCI and Conventional Cotton: A Comparative Study of Cotton Cultivation Practices in India.'

57 United Nations Environment Programme (2022) 'Environmental and health impacts of pesticides and fertilizers and ways of minimizing them'

58 PAN Asia Pacific (2015). 'Replacing Chemicals with Biology'

59 FAO, 2019. The International Code of Conduct for the Sustainable Use and Management of Fertilizers

60 Pahalvi, H.N. et al. (April 2021). 'Chemical Fertilizers and Their Impact on Soil Health'

61 Shah, A.N. et al. (August 2022) 'Nitrogen use efficiency in cotton: Challenges and opportunities against environmental constraints'

62 WWF (2013) 'Cutting cotton carbon emissions - Findings from Warangal, India'

63 FAO/WHO (2014) 'The International Code of Conduct on Pesticide Management'

64 FAO/UN/ICAC (2015) 'Measuring sustainability in cotton farming systems: Towards a guidance framework.'

65 PAN-UK (June 2018) 'Is cotton conquering its chemical addiction?'

66 ICAC (November 2022) 'Cotton Data Book 2022'

67 Aranha A, Luana Rocha L (April 2019) '"Coquetel" com 27 agrotóxicos foi achado na água de 1 em cada 4 municípios'

68 Heinrich-Böll-Stiftung et al. (October 2022) 'Pesticide Atlas 2022'

69 Audsley, E. et al (Aug 2009) 'Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use'

70 Cotton Incorporated (Apr 2017) 'The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric'

71 United States Environmental Protection Agency (Apr 2023) 'Understanding Global Warming Potentials'

72 Mühle, J. et al (Mar 2009) 'Sulfuryl fluoride in the global atmosphere'

73 Pimentel Pimentel, D. Amounts of pesticides reaching target pests: Environmental impacts and ethics. J Agric Environ Ethics 8, 17–29 (1995). https://doi.org/10.1007/BF02286399

74 Khan, S.A. et al (2007) 'The Myth of Nitrogen Fertilization for Soil Carbon Sequestration'

75 UN Human Rights Council (Dec 2010) 'Sixteenth session, Agenda item 3; Report submitted by the Special Rapporteur on the right to food, Olivier De Schutter'

76 IPES-Food & Institute of Development Studies (Oct 2022) 'Agroecology, Regenerative Agriculture, and Nature-Based Solutions'

77 FAO/WHO Codex Alimentarius Commission (1999) 'What is Organic Agriculture?'

78 FAO 'Agroecology knowledge hub'

79 World Economic Forum (Oct 2022) 'What is Regenerative Agriculture'

80 IPES-Food & Institute of Development Studies (Oct 2022) 'Agroecology, Regenerative Agriculture, and Nature-Based Solutions'

81 Giller, K. et al (Mar 2021) 'Regenerative Agriculture: An agronomic perspective'

82 Sustainable Agriculture Initiative Platform (Sep 2023) 'Regenerating Together - A global framework for regenerative agriculture'

83 FAO 'Climate-Smart Agriculture'

84 Nature4Climate (Sep 2023) 'Nature as a critical climate solution'

85 Better Cotton (Sep 2021) 'Cotton Tales - Issue 4'

86 Solidaridad & PAN UK (Jun 2023) 'Cotton and Corporate Responsibility'

87 European Commission 'Deforestation free products'

88 Rainforest Foundation Norway (October 2018) 'Salmon on soy beans — Deforestation and land conflict in Brazil'

89 Rajão, R et al. (July 2020) 'The rotten apples of Brazil's agribusiness'

90 Pesticide Action Network UK (July 2023) 'Pesticides and the Climate Crisis: A Vicious Cycle'

91 FiBL 'Organic cotton crop guide'

92 Better Cotton (Apr 2023) 'Cotton Tales - Issue 12'

93 Pesticide Action Network UK (Jun 2022) 'Cotton in Benin, West Africa'

94 Textile Exchange (Sep 2022) 'Regenerative Agriculture Landscape Analysis'

95 Paustian, K., et al. (Jun 2020) 'Climate Mitigation Potential of Regenerative Agriculture Is Significant!'

96 Bradford, M. er al. (Nov 2019) 'Soil carbon science for policy and practice'

97 Giller, K. et al (Mar 2021) 'Regenerative Agriculture: An agronomic perspective'

98 Cotton Incorporated (Mar 2017) 'LCA Update of cotton fiber and fabric life cycle inventory'

99 FAO (2021) 'Climate resilient practices'

100 Better Cotton (Mar 2021) 'Cotton Tales - Issue 03'

101 Textile Exchange (Sep 2022) 'Regenerative Agriculture Landscape Analysis'

102 Cotton 2040 Initiative (June 2021) 'Physical Climate Risk for Global Cotton Production'

103 ICAC (September 2022) 'Flooding and Drought Are Having a Crushing Impact on the Global Cotton Industry'

104 Majeed, S. (Aug 2021) 'Heat Stress in Cotton: A Review on Predicted and Unpredicted Growth-Yield Anomalies and Mitigating Breeding Strategies'

105 Organic Cotton Accelerator 'Seed Programme'

106 Farooq, MA. et al (Mar 2023) 'Transgenerational impact of climatic changes on cotton production'

107 Morgan, G. (Jun 2015) 'How Waterlogged Soils Impact Cotton Growth and Management Decision'

108 Oldham, L. (Jun 2021) 'Soil management immediately after the flood'

109 Climate Change Adaptation Program (2022) 'Landscape Level Approaches to Mitigate Flood Impacts for Farms & Ranches'

110 FAO (2021) 'Climate resilient practices'

111 IAASTD (2009) 'Agriculture at a Crossroads - Global Report'

112 IATP (Sep 2014) 'Scientists' Support Letter for the International Symposium on Agroecology, 18–19 September, 2014'

113 IISD (Oct 2023). 'Historic Global Framework on Chemicals Adopted Following Years of Talks'

114 UNEP. (Dec 2022). 'Kunming-Montreal Global biodiversity framework: Draft decision submitted by the President'

115 PAN Asia Pacific (2015). 'Replacing Chemicals with Biology'

116 FAO (2021) 'Climate resilient practices'

117 FiBL 'Organic cotton crop guide'

118 Ministry of Agriculture, India (2014) 'Integrated Pest Management Package for Cotton'

119 Gjerris, M. et al. (Mar 2016) 'Ethical aspects of insect production for food and feed'

120 Poveda, J. et al (May 2019) 'Mealworm frass as a potential biofertilizer and abiotic stress tolerance-inductor in plants'

121 GMP+ International (Jul 2023) 'Insect innovation - building a safe culture from the start'

122 Pesticide Action Network UK 'Developing our foodspray technique'

123 WWF Water Risk Filter, using spatial distribution of cotton production data from Frolking et al (2020) 'GAEZ+_2015 Crop Production'

124 Better Cotton (Dec 2021) 'Cotton Tales - Issue 05'

125 WWF Water Risk Filter, using spatial distribution of cotton production data from Frolking et al (2020) 'GAEZ+_2015 Crop Production'

126 Better Cotton (Mar 2022) 'Cotton Tales - Issue 6'

127 Malik, M.N.A. (Sep 1998) 'Fertilizer Role in Sustainable Cotton Production'

128 Kandlinkar, M. Risbey, J. (Jun 2000) 'Agricultural Impacts of Climate Change: If Adaptation is the Answer, What is the Question?'

129 Lv, Q. et al ((Dec 2022) 'Cotton-Based Rotation, Intercropping, and Alternate Intercropping Increase Yields by Improving Root–Shoot Relations'

130 SARE (2007) 'Legume cover crops'

131 Blaise, D. (Jul 2021) 'Intercropping and mulching in rain-dependent cotton can improve soil structure and reduce erosion'

132 Mubiru, D. et al (Oct 2016) 'Climate trends, risks and coping strategies in smallholder farming systems in Uganda'

133 Khalilian, A. et al. (Jul 2013) 'Effects of Surface Application of MSW Compost On Cotton Production – Soil Properties, Plant Responses, And Nematode Management'

134 Organic Cotton Accelerator 'Farmer Stories; Likha'

135 International Trade Centre (June 2022) 'The State of Sustainable Markets 2021'

136 Cotton Incorporated (2017) 'Sustainability; concerned consumers'

137 Innovation Forum (December 2020) 'Building resilient smallholder supply chains'

138 Innovation Forum (December 2020) 'Building resilient smallholder supply chains'

139 Textile Exchange (Sep 2022) 'Regenerative Agriculture Landscape Analysis'

140 Innovation Forum (December 2020) 'Building resilient smallholder supply chains'

141 Public Eye (June 2019) 'Agricultural Commodity Traders in Switzerland – Benefitting from Misery?'

142 Institute for Agriculture and Trade Policy (November 2022) 'The Fertilizer Trap'

143 Payne, A (June 2022) 'Tackling Overproduction? The Limits of Multistakeholder Initiatives in Fashion'

144 Transformers Foundation (Accessed Nov 2022) 'Cotton myths debunked'

145 Solidaridad (March 2023) 'Smallholder Farmer Atlas'

146 For example, the ICAC Soil and Plant health mobile application, and the WWF Cotton Doctor App as described here.

147 WWF Water Risk Filter, using spatial distribution of cotton production data from Frolking et al (2020) 'GAEZ+_2015 Crop Production'

148 ibid.

149 WWF (2021) Water risk filter - methodology discussion

150 Visualizations based on the WWF Water Risk Filter Scenarios data and on the spatial distribution of cotton production data from Frolking et al. 2020.

© SOLIDARIDAD

Solidaridad

Solidaridad Europe
't Goylaan 15
3525 AA Utrecht
The Netherlands
+31 (0)30 272 0313