Int. J. Agr. Ext. 12 (01) 2024. 143-152 DOI: 10.33687/ijae.012.001.5170

Available Online at EScience Press

International Journal of Agricultural Extension

ISSN: 2311-6110 (Online), 2311-8547 (Print)

https://esciencepress.net/journals/IJAE

A DESK STUDY TO REVIEW THE FUTURE OF GROWING SUSTAINABLE COTTON WITH THE BEST YIELD IN PAKISTAN

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ARTICLE INFO

Article History

Received: January 04, 2024

Revised: April 19, 2024

Accepted: April 25, 2024

Keywords

Sustainable cotton

Organic cotton

Textile industry

Yield decline

Cost of production

Quality

Export

ABSTRACT

In recent years, Pakistan has faced challenges related to declining cotton production, which has led to increased imports to meet the demands of its textile industry. Addressing these challenges and implementing sustainable farming practices are essential for the continued growth and competitiveness of Pakistan's cotton sector. This desk review study is mainly concerned to know the current practices and current level of yield of cotton being obtained by the farmers. In addition, what are the challenges in way of sustainable cotton production and how institution is playing role support of sustainable cotton production. Pakistan has historically been one of the top cotton-producing countries globally, typically ranking among the top five cotton producers. Cotton production contributes significantly to the country's agricultural output. The most commonly grown cotton varieties in Pakistan are Gossypium hirsutum (upland cotton) and Gossypium arboreum (tree cotton). The cotton-growing regions in Pakistan are primarily located in the provinces of Sindh and Punjab. These regions have suitable climate and soil conditions for cotton cultivation. Pakistan's cotton industry faces various challenges, including pest infestations (such as the cotton leafhopper and pink bollworm), water scarcity, outdated farming practices, and issues related to the quality of cotton produced. The country also experiences fluctuations in cotton production due to factors like weather conditions and disease outbreaks. Based on the critical analysis presented in this review paper, priority recommendations for advancing sustainable cotton farming in Pakistan include investing in research and development tailored to the specific needs of cotton farming, particularly focusing on breeding, agronomy, pest management, and soil conservation. Additionally, there is a growing need to promote organic cotton cultivation through collaboration between international donors, the textile sector, and the agriculture department, especially in areas like Cholistan and Baluchistan.

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INTRODUCTION

Current State of Cotton Farming in Pakistan

Cotton is one of the prominent kharif crops, widely grown in more than 60 countries around the world creating an employment opportunity and rendering livelihood support to the millions of people across the world. This crop is mainly responsible for providing the raw materials for the agro-based industry (Hossain et al., 2007). Around the world cotton production decline has become one of the central challenges to deal with. This drastic decline is likely to adversely distress the livelihoods of farmers, textile industry and the economy.

The production process of cotton is widely discussed in Pakistan, perhaps all the disciplines from genetics to sociology and agricultural extension have added their findings to the literature about the prospects of the cotton and its future outlook in the Pakistan and Punjab province in particular where 80% of total cotton of country is being produced. Government of Pakistan has reported a 29% production decline in 2015 and 17% decline in cotton area and production during 2019 (Government of Pakistan, 2017, 2019). Couple of research studies have projected the cotton production to increase in future (Ali et al., 2013; Ali et al., 2015). Conversely, the recent study Ashraf et al. (2018) have projected cotton to decline drastically in Punjab province by 2025 subject to agronomic, physical, human, crop production, crop protection and advisory services approach related factors. Almost 1.7 million farmers across Pakistan grow cotton and are aspirants to sustain their livelihoods through it. The textile sector of country comprising of 10 industrial sub-sectors, over 1000 ginneries, 8000 mill sector looms, over 250,000 non-mill sector looms, more than 13 million spindles, 700 knitwear units, 4000 garment units, 300 oil expellers and almost 2000 small scale oil expellers in Pakistan had deep insights on cotton production for their sustainable working. In case cotton fails to grow, the other way is to import cotton which not only increases the cost of production but also the national exchequer import bill suppresses the economy. Overall production of the cotton in the Pakistan is way behind the potential. Therefore, growing a sustainable cotton with best yield in Pakistan is much needed.

Importance of Sustainable Cotton Farming

Transitioning to sustainable cotton farming practices holds immense significance from environmental, social, and economic standpoints. Environmentally, sustainable practices such as organic farming, agroforestry, and water-efficient irrigation systems can mitigate soil degradation, reduce water pollution from chemical inputs, and preserve biodiversity. Socially, sustainable cotton farming can improve the livelihoods of farmers by promoting fair labor practices, ensuring safe working conditions, and empowering local communities. Moreover, it can enhance food security, alleviate poverty, and promote gender equality by providing opportunities for women and marginalized groups in the agricultural sector. Economically, sustainable cotton farming practices can lead to long-term profitability and resilience for farmers, as they reduce input costs, increase yields, and improve market access through certification schemes like organic and fair trade. Additionally, sustainable cotton production can strengthen supply chain transparency, build consumer trust, and foster partnerships with textile companies committed to ethical sourcing. Overall, transitioning to sustainable cotton farming practices is essential for promoting environmental stewardship, social equity, and economic prosperity in the cotton industry. Cotton's economic significance is profound, contributing up to 40% of merchandise exports and over 5% of GDP in some countries, while also being a major source of fiber for the textile industry with an economic impact of at least $600 billion annually (Khan et al., 2020).

The sustainability of cotton production is challenged by environmental impacts such as soil degradation, pesticide use, and water consumption, necessitating reforms and the adoption of new technologies, including genetically modified seeds and sustainable farming systems (Amouzaou et al., 2018; Soumare et al., 2021; Grose, 2009). Climate change is expected to affect cotton yields, water use efficiency, and nitrogen productivity, with potential decreases in water use efficiency by up to 20% without soil amendments, highlighting the need for adequate soil fertility management practices (Amouzou et al., 2018). Whereas, sustainable cotton production can offer a multitude of potential benefits that extend far beyond the field. Firstly, it significantly reduces the environmental footprint of cotton cultivation by minimizing the use of synthetic pesticides and fertilizers, thus decreasing water and soil pollution. Through practices like organic farming and integrated pest management, sustainable cotton production promotes biodiversity conservation and protects ecosystem services. Moreover, it fosters improved soil health by promoting soil organic matter accumulation, enhancing soil structure, and reducing erosion, ultimately leading to increased fertility and crop productivity. Additionally, sustainable cotton production enhances resilience to climate change by promoting water conservation techniques, such as drip irrigation and rainwater harvesting, which mitigate the impacts of drought and water scarcity. By embracing sustainable practices, cotton farmers can adapt to changing climatic conditions and contribute to building a more sustainable and resilient agricultural system. Voluntary Sustainability

Standards (VSS) and Corporate Social Responsibility (CSR) initiatives are being implemented to address environmental and social issues in cotton production, aiming to reduce the use of water, chemical pesticides, and fertilizers, and to uplift livelihoods of farmers (Radhakrishnan, 2017; Ward and Mishra, 2019; Takacs, 2012).

Challenges in Cotton Farming

Cotton farming in Pakistan is a critical sector for the country's economy, but it faces several challenges that affect productivity and sustainability. These challenges range from environmental stresses to economic and management issues.

- Climate change, traditional agricultural practices, and resource depletion are major challenges leading to low productivity in cotton farming in Pakistan (Jamil et al., 2021)
- Environmental impacts such as pesticide and fertilizer use, field emissions, and irrigation inefficiencies are significant concerns, with eco-efficiency varying across different farm sizes (Ullah et al., 2016).
- High temperatures and water scarcity exacerbated by climate change pose risks to cotton production, especially in areas already experiencing extreme heat (Malik and Ahsan, 2016; Khalid et al., 2023; Imran et al., 2022).
- The introduction of genetically modified (Bt) cotton has helped control pests, but there are still issues with pest management and the need for improved strategies (Khalid et al., 2023; Ali and Ahmed, 2021).
- Economic factors such as the high cost of diesel, agricultural inputs, and pesticides, as well as marketing challenges like middleman monopolies, affect cotton growers' profitability (Khan et al., 2016).
- There is a gap in climate knowledge among farmers, and a lack of weather agro-advisory systems to help manage climate extremes (Imran et al., 2022)
- The cotton germplasm in Pakistan requires improvement to address biotic and abiotic stresses, with modern breeding techniques and genetic modification being potential solutions (Razzaq et al., 2021; Rahman et al., 2014).

In recent years, the cotton industry in Pakistan has faced numerous challenges that have affected its production and economic viability. The country, being the world's fifth-largest cotton producer, relies heavily on this crop for its fiber and oil, which significantly contributes to the local oil industry (Khalid et al., 2023; Malik and Ahsan, 2016). Despite the introduction of Bt cotton in 2010, which accounts for over 90% of all cotton grown in Pakistan, the production is under immense pressure and is continuously declining (Khalid et al., 2023; Chaudhry et al., 2021).

The decline in cotton production has been attributed to a variety of factors. Environmental and climate change issues, water scarcity, agronomic problems, and socio-economic constraints have been identified as major contributors to the reduction in cotton cultivation areas, production, and average yield (Chaudhry et al., 2021). Specifically, the high temperatures and water scarcity associated with climate change pose a significant threat, as current cultivation occurs in regions already experiencing extreme heat (Khalid et al., 2023; Chaudhry et al., 2021).

Moreover, the cost of production and protection of the crop has become a concern for cotton growers. High prices of diesel, agricultural inputs, and pesticides have been highlighted as prominent problems. Marketing issues, particularly the monopoly of middlemen, have also been affecting growers directly, leading to a call for government intervention to provide incentives, regulate input costs, and establish fixed rates for cotton to benefit the growers (Khan et al., 2016).

The decline in cotton production is not only a concern for the farmers but also for the entire cotton-associated industry, including over 1000 ginning factories and 400 textile mills, which represent a significant investment and provide livelihoods for millions (Khan et al., 2016). The study conducted in the Sub-District Jampur of District Rajanpur revealed that the livelihood of many is dependent on this single crop, and any threats to its production, protection, and marketing could lead to substantial economic losses (Khan et al., 2016)

The challenges facing cotton production in Pakistan are multifaceted, requiring a comprehensive approach to address environmental, agronomic, and socio-economic constraints. The need for reforms and further research to explore the reasons behind the decline in cotton cultivation is urgent to revive the crop and safeguard the national economy2. Additionally, modern breeding

techniques and genome editing may offer solutions to improve resistance against biotic and abiotic stresses, which could be crucial for the future prospects of cotton production in Pakistan.

Sustainable Cotton Farming Practices

Explore various sustainable farming practices that can be adopted to address the challenges mentioned above. This could include techniques like crop rotation, integrated pest management, organic farming, conservation tillage, and water-efficient irrigation methods.

The introduction of Climate Smart Agriculture (CSA) practices has been a key development in enhancing the efficiency of natural resources, resilience, and productivity of the agricultural production system while reducing greenhouse gas emissions1. CSA practices, such as water-smart technologies, energy-smart approaches like minimum tillage, and knowledge-smart strategies including crop rotation and improved varieties, have been adopted by farmers in Punjab, Pakistan. These practices have led to uniform germination, higher yield, and financial returns, as well as increased resource use efficiency (Imran et al., 2018). Eco-efficiency of cotton-cropping systems has been assessed through an integrated approach combining life cycle assessment and Data Envelopment Analysis. This study found that pesticides, fertilizer use, field emissions, field operations, and irrigation are the main sources of environmental impacts in Southern Punjab. Despite the challenges, small farms have managed to balance higher profits with higher levels of eutrophication, maintaining overall eco-efficiency comparable to larger farms (Ullah et al., 2016). The impact of tillage and nitrogen on cotton yield and quality within a wheat-cotton system was explored, indicating that reduced tillage with appropriate nitrogen levels could be a sustainable strategy to enhance cotton yield and quality without adversely affecting soil organic matter and total soil nitrogen (Usman et al., 2014). Participation in training programs, information access, risk perception, and credit access positively influence the adoption of sustainable "better cotton" practices in Pakistan's cotton belt (Zulfiqar et al., 2021).

sustainable cotton production practices in Pakistan involve reducing pesticide and fertilizer use, adopting reduced tillage and appropriate nitrogen application, utilizing biotechnology such as Bt cotton, implementing whitefly control strategies, updating educational curricula, fostering international cooperation, and employing modern breeding techniques, while also considering the expansion of organic cotton in suitable areas (Bao-Jin, 2011; Bhutto et al., 2022).

Review of Global Efforts on Sustainable cotton farming

One innovative approach is the development of a chemical technology to recover cotton from textile waste, which not only provides an alternative source of cotton but also addresses the issue of waste management. This technology involves a sequence of processes including dye leaching, dissolution of organic materials, and bleaching for purification, showing promising results in terms of recycling rate, profitability, and greenhouse gas emissions reduction (Yousef et al., 2019). Soil conservation measures have been identified as crucial in Australian cotton farming systems. The adoption of improved cotton cultivars with genetic modification, along with better soil, water, and crop management practices, has positioned Australia as a leader in high-yielding, environmentally sustainable cotton production. However, there is still room for improvement in the sustainability of these practices (Nachimuthu and Webb, 2016)

In China, a light and simplified system of sustainable cotton production has been established, which is adapted to the local economic level and management mode. This system includes technologies such as single-seed precision sowing and simplified plant pruning, aiming to reduce labor intensity and input costs while maintaining high yields (Dai et al., 2017)

A systematic review highlights the need to address agronomic, socioeconomic, and policy domains for sustainable cotton production on small landholdings. It suggests exploring agronomic practices, socioeconomic settings, and institutional policies to enhance sustainability, with a focus on reducing the use of nitrogenous fertilizers and pesticides and improving technology adoption among farmers (Tlatlaa et al., 2023)

Intensive cotton farming technologies in China have led to significant increases in yield and output. However, these technologies are labor-intensive and involve a high input of chemicals, posing challenges such as soil pollution and labor shortages. A new farming technology reform is suggested to support sustainable production, including rational use of plastic film and chemicals, and simplifying field managements (Dai and Dong, 2014)

Research coordinated by the Australian Cotton Cooperative Research Centre indicates that limitations associated with cotton production in tropical northern Australia can be overcome by tailoring and validating production practices to local conditions. This includes understanding biotic and environmental constraints and avoiding the transplantation of southern farming practices without local adaptation (Yeates et al., 2013).

The role of biotechnology in producing durable hybrids and reducing chemical inputs is emphasized, along with the importance of global standards and voluntary sustainability initiatives in assessing sustainability issues in cotton production. The cotton industry's outreach from small farmers to fashion stores is also noted, with a call for a mass-market transformation towards sustainable cotton (Grose, 2009; Radhakrishnan, 2017)

Modern concepts and techniques for better cotton production are discussed, including the use of GPS, GIS, remote sensing, IPM, IWM, and INM. These technologies and concepts are crucial for site-specific management of agricultural inputs and for addressing challenges such as soil health, water quality, and climatic variability (Ghaffar et al., 2020).

The use of total factor productivity (TFP) and total social factor productivity (TSFP) indices to measure sustainable cotton production is explored. The study of Alabama's long-term Old Rotation experiment demonstrates that productivity and sustainability can be improved over time, even when accounting for externalities such as soil erosion and pesticide use (Mitchell et al., 1996)

In conclusion, sustainable cotton production is a multifaceted challenge that requires a combination of innovative recovery technologies, improved agronomic practices, socioeconomic considerations, policy support, and modern technological advancements to ensure the long-term viability of cotton farming while minimizing its environmental impact.

Technology and Innovation

Innovative technologies and innovation had positive influence on the cotton production over the time. For instance, non-Bt and traditional varieties were not high yielding and gradual development in research and improvement in genetic material made the Bt varieties available to farmers, which are not only high yielding but also resistant to insect pests' infestations. Bt-cotton technology has increased economic growth, reduced pesticide use, and increased yield in cotton production, benefiting farmers and the textile industry (Tokel et al., 2021). Bt cotton in Burkina Faso increased cotton yields by 21.3% and income by $106.14 per ha, while reducing energy use by 6.6%, potentially enhancing sustainability and competitiveness in world cotton markets (Vitale et al., 2011). Bt gene cotton adoption in Pakistan leads to a 33-37.5% higher net yield per acre compared to conventional cotton (Mansoor et al., 2020). Bt cotton in Pakistan provides health advantages like reduced acute pesticide poisoning and higher biodiversity, while also reducing soil and groundwater contamination, leading to an aggregate benefit of $283 per acre (Kouser and Qaim, 2013). Moreover, increasing organic manure application, selecting suitable varieties, rational plant densities, and using chemical control can significantly increase cotton yield by 9.5%-37.5% in large scale land (Yue-jin, 2012).

Modern technologies like GPS, GIS, and remote sensing can increase cotton production and sustainability by managing agricultural inputs and reducing greenhouse gas emissions (Ghaffar et al., 2020). In a study, Bradburn and Kauter (2013) cited the success story from Cotton in Australia. They explored that Australia's cotton industry has achieved significant gains in yields and environmental performance through scientific research, with future opportunities in genetically modified cotton, biotechnology stewardship, precision agriculture, water management, resistance, greenhouse gas emissions, and carbon farming. In this context, Radhakrishnan (2017) was of the view that sustainable cotton production, incorporating biotechnology and voluntary sustainability initiatives, can improve the livelihood of 250 million families and the environment. The developed strategy using sustainable and commercial chemicals effectively recovers cotton from waste textiles, offering a sustainable and profitable alternative to agriculture-based cotton production (Yousef et al., 2019). Similarly, enhancing seed development could be a more effective and achievable strategy to increase cotton fiber yield and quality than manipulating candidate genes (Ruan, 2013). Farmers in Punjab, Pakistan adopt Bt cotton to reduce bollworm damage, reduce pesticide requirements, and increase yield and profit, but are uncertain about its effectiveness against insect pests and its vulnerability to viral infection (Arshad et al., 2009).

Policy and Regulatory Framework

The cotton industry in Pakistan has been impacted by issues such as high input costs, limited access to credit, and lack of government support. These factors can make it difficult for farmers to invest in modern equipment, better seeds, and other inputs needed to increase yields and improve the quality of cotton. The Pakistani government has introduced various policies and initiatives to support cotton farmers and improve cotton production. These measures include subsidies, research and development programs, and efforts to promote the use of modern farming techniques. However, cotto growers in Pakistan usually remain unaware of the cotton policies and regulations. In a study, Spielman et al. (2017) stated that farmers in Pakistan mistakenly believe they are cultivating non-Bt cotton when in fact they are cultivating Bt cotton, highlighting the need for policy and regulation in the transgenic cotton seed market. There are serious issues found in the cotton seed market, especially when large number of unapproved cotton seed varieties are marketed. Similarly, the cotton seed is marketed with the fake variety name, and the dealers are not held accountable for marketing poor quality seed.

Moreover, in Pakistan, public and private sector extension agents are serving farmers and providing them with advisory services. Number of generic companies had non-technical (non-agrarian) field staff which are disseminating information and different technologies among farmers. There are growing observations that due to non-technical staff advice the number of use of inputs especially the pesticides are increasing. In Pakistan. The trend of bio-pesticides is almost negligible. From couple of years, Agriculture Department, Government of Punjab, through extension field staff advised farmers to use a solution made from “Kortumma, Oak, Neem” and other local plants and farmers can themselves prepare these bio-pesticides. However, there is now follow up studies and empirical evidences on the use of these bio-pesticide solution.

Following bio-pesticides crop management can be very effective, however, improving pest management and updating university curriculums can potentially revive cotton production in Pakistan, despite declining yields due to factors like climate variability and early sowing (Ali and Ahmed, 2021). Plant breeding can resolve conflicts in sequential cropping patterns like cotton and wheat in Pakistan's Punjab, but changes in pest management and price relationships require ongoing review of breeding priorities (Byerlee et al., 1987). Adaptation strategies, including access to credit, extension, education, farming experience, and information, can effectively increase cotton yield in Pakistan's heat stress regions (Anwar et al. 2021).

Market Access and Value Chain Integration

Market access and value chain integration play a crucial role in the success and sustainability of cotton farmers. Firstly, market access ensures that cotton farmers have a reliable outlet to sell their produce, providing them with income and livelihood security. By gaining access to local, regional, and global markets, farmers can diversify their customer base, negotiate fair prices, and reduce dependency on middlemen. Moreover, market access enables cotton farmers to capitalize on opportunities for value addition, such as processing and manufacturing, thereby increasing the value of their products and enhancing profitability. Additionally, value chain integration facilitates collaboration and coordination among stakeholders involved in the cotton supply chain, including farmers, input suppliers, processors, traders, and retailers. By integrating vertically and horizontally along the value chain, farmers can access resources, information, and technology to improve productivity, quality, and market competitiveness. Furthermore, value chain integration fosters transparency, traceability, and accountability, ensuring that benefits are equitably distributed among all actors. Market access and value chain integration empower cotton farmers to maximize their economic potential, enhance their resilience to market fluctuations, and contribute to sustainable development in the cotton sector. Indian cotton markets are integrated, with prices tending to respond to changes in demand and supply together (Mamatha et al., 2022).

Exploring opportunities for value addition, fair trade practices, and partnerships with textile industry stakeholders can significantly benefit cotton farmers and enhance the sustainability of the cotton supply chain. Firstly, value-addition initiatives, such as processing cotton into higher-value products like yarn, fabric, and garments, can increase the profitability of cotton farming and create additional income streams for farmers. By participating in value-added activities, farmers can capture a larger share of the value chain and mitigate the risks associated with volatile commodity markets. Moreover, adopting fair trade practices ensures that

cotton farmers receive fair prices for their produce, enabling them to invest in their farms, improve living standards, and strengthen local economies. Fairtrade certification also promotes social justice, environmental sustainability, and ethical labour practices throughout the cotton supply chain. Additionally, forging partnerships with textile industry stakeholders, including manufacturers, retailers, and brands, can create synergies and unlock opportunities for collaboration, innovation, and market access. By working together, cotton farmers and textile industry stakeholders can co-create sustainable value chains, promote transparency and traceability, and meet the growing demand for ethically sourced and environmentally friendly cotton products. Leveraging value addition, fair trade practices, and partnerships with textile industry stakeholders can drive positive social, environmental, and economic outcomes for cotton farmers and contribute to a more sustainable cotton sector (Sundaramoorthy et al., 2014).

CONCLUSION AND RECOMMENDATIONS

The current state of cotton farming in Pakistan reflects a complex landscape with both challenges and opportunities. The decline in cotton production poses a significant threat to the livelihoods of millions of farmers, the textile industry, and the national economy. However, transitioning to sustainable cotton farming practices holds immense promise for addressing these challenges while promoting environmental stewardship, social equity, and economic prosperity.

To ensure the future of growing sustainable cotton with the best yield in Pakistan, it is imperative to address the multifaceted challenges facing the cotton sector. This requires a comprehensive approach encompassing technological innovation, policy reform, and stakeholder collaboration. Based on the critical analysis presented in this review paper, the following recommendations are proposed:

- Invest in research and development initiatives to develop and disseminate innovative technologies and practices tailored to the specific needs and constraints of cotton farming in Pakistan. This includes advancements in breeding, agronomy, pest management, and soil conservation.
- There is growing need of research and investment on organic cotton in Pakistan. The collaboration between the international donors, textile sector, Agriculture department can promote cultivation of organic farming of cotton for the textile sector in particular. Similarly, new pockets for organic cotton can be located in the areas such as Cholistan and Baluchistan.
- Encourage the adoption of sustainable farming practices such as organic farming, integrated pest management, conservation tillage, and water-efficient irrigation methods through awareness campaigns, training programs, and financial incentives.
- Advocate for supportive policies and regulatory frameworks that incentivize sustainable cotton production, protect farmers' rights, and promote market access and value chain integration. This includes measures to address input costs, credit accessibility, and market distortions.
- Strengthen extension services to provide farmers with timely and accurate information, training, and technical support on sustainable farming practices, climate-smart agriculture, and market opportunities. This includes enhancing collaboration between public and private sector extension agents.
- Foster collaboration and partnerships between government agencies, research institutions, NGOs, and private sector stakeholders to leverage expertise, resources, and networks for the advancement of sustainable cotton farming.
- Invest in farmer education and capacity-building initiatives to enhance their knowledge and skills in sustainable cotton production, climate resilience, and business management. This includes tailored training programs, demonstration plots, and farmer field schools.
- Facilitate market access and value chain integration for cotton farmers through initiatives that promote fair trade practices, value addition, and partnerships with textile industry stakeholders. This includes certification schemes, market linkages, and investment in processing infrastructure.
- Develop and implement climate resilience strategies and adaptation measures to help cotton farmers mitigate the impacts of climate

change, including heat stress, water scarcity, and pest outbreaks. This includes promoting drought-tolerant varieties, water-saving technologies, and early warning systems.

- Promote sustainable consumption patterns and consumer awareness campaigns to create demand for ethically sourced and environmentally friendly cotton products. This includes certification labels, eco-labeling schemes, and public outreach initiatives.
- Establish robust monitoring and evaluation mechanisms to track progress, assess impact, and identify areas for improvement in sustainable cotton farming initiatives. This includes performance indicators, baseline assessments, and regular reviews of policy implementation.

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