Brazilian Organic Cotton Network: Sustainable Driver for the Textile and Clothing Sector

Larissa Oliveira Duarte, Marenilson Batista da Silva, Maria Amalia da Silva Marques, Barbara Contin, Homero Fonseca Filho, and Julia Baruque-Ramos

Abstract The influence of stakeholders' pressures on adopting better environmental practices is well reported in the supply chain management literature. In this context, product development policies focused on sustainability require integration between economic, social and environmental issues that cover the entire production chain. Clothing and fashion are highly visible elements of society; therefore, the textile industry serves a manner to promote a sustainable and eco-friendly mindset. The incorporation of eco-friendly and fair-trade fibers can be a starting point for changing the existing industrial paradigm within the textile industry. At the same time, cotton fiber is the most commonly utilized natural fiber in the textile industry. Cotton is a soft, staple fiber that grows around the seeds of the cotton plant, native to tropical and subtropical regions around the world, such as the Americas, South Asia and Africa. It is mainly used in spinning to produce ring or open-end yarn for weaving and knitting applications. The annual global production of cotton fiber is about 26 million tons. However, cotton production worldwide uses more than 20% of all insecticides employed in agriculture. In many areas, irrigated cotton cultivation has led to the depletion of ground and surface water sources. Many conventional cotton farmers in developing countries are in a crisis due to decreasing soil fertility, increasing production costs, resistant pests, or low cotton prices. In this scenario, an increasing number of cultivators turn to organic cultivation in order to restore soil fertility, reduce production costs, or to get a better price for their certified organic harvest. Organic cotton appears as an environmentally preferable product,

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of added benefit to the environment, farmers and consumers. Organic farming is slowly gaining ground in the global cotton market. It is often promoted to address the economic, environmental and health risks of conventional cotton production. Moving from the language of commodity chains to commodity networks, helps portray the complex network of material and nonmaterial relationships connecting the social, environmental, political, and economic actors. Understanding how individuals, firms, government authorities, and nongovernmental organizations (NGOs) are involved in economic and social transactions and how these different actors both shape and are shaped by network relations. In Brazil, organic and fair-trade cotton are widely seen as opportunities for smallholder farmers to improve their livelihoods. The cotton crop, due to its agronomic characteristics on climate adaptation, historical, cultural and economic value, established and gained prominence in family agriculture in the semi-arid region of Brazil. In this production network, trust was a critical factor in recruiting farmers and ensuring their continued participation in the organic and agroecological cotton production system and securing European customers' organic profile. Farmers' organizations as well as national and international environmental NGOs are instrumental in mediating and (re)building social networks among organic farmers and with the other actors in the supply chain. Linking small producers to markets, as integrating them into value chains is widely recognized as a valuable way to increase community development and benefit sustainable fashion brands.

Keywords Organic cotton · Sustainability · Sustainable networks · Agroecological · Textile and apparel · Biodegradable · Cellulosic fiber · Design · Fashion

1 Introduction

Cotton (*Gossypium* spp.) is cultivated for over 7,000 years, mainly for the production of its fiber [1]. Cotton and flax are the oldest natural plant fibers grown by man [2, 3]. In Europe, cotton played an important role in industrial development, especially in England [3, 4]. In America, this fiber was one of the most important sources of pre-Columbian civilizations, such as the Mayans in Guatemala, and the people of Chimu, Nazca and Paracas in Peru. In Brazil, cotton was already cultivated by natives [2, 3, 5].

Global cotton industry includes more than 100 million farm families across 75 countries [6]. It is one of the most widespread crops in the world in terms of land area [7]. Its production systems vary globally, ranging from labor-intensive systems in Africa and Asia, to highly mechanized systems in Australia, Brazil and the United States [7]. Cotton supply network actors range from small and large farmers, intermediates, traders and ginners, to sophisticated mills, textile processors, brands, exporters, global manufactures and retailers, transnational NGOs and consumers [8–11].

The market is expected to witness significant growth in demand for environment-friendly, versatile, biodegradable, and cost-effective fibers globally [12].

The sustainable raw materials contemplate the development and adoption of different types of environmentally friendly raw fibers, such as organic cotton, hemp, bamboo, lyocell, reused textiles and recycled fibers [13]. As a driver of innovation and sustainability in business models, the use of sustainable raw material means reliable access to a source of materials, technological development and communication of brand commitment to sustainable practices. Impacts on cost structure are not uncommon, as these technologies often have to be internally developed or externally acquired [14].

In this way, both agricultural and textile industries have experienced social-environmental issues linked to unhealthy workers conditions, water and soil pollution and biodiversity loss, characterized by the intense use of chemical products and natural resources [15]. Furthermore, the textile supply chain is long, complex, fragmented and opaque. Successfully translating demand for more sustainable cotton into actual sourcing depends on the entire supply chain taking part. However, many brands and retailers still have a limited overview of their own supply chain. They are therefore denied the opportunity to engage with key suppliers. Without clear indications of market demand, more sustainable cotton producers may return to conventional cotton farming [16].

Organic cotton appears as an environmentally preferable product, of added benefit to the environment, farmers and consumers [17, 18]. It is produced without the use of synthetically compounded chemicals [11, 19]. It emphasizes a system of production that seeks to maintain and replenish soil fertility and the ecological environment of the crop [17, 20].

In addition to these issues, this study is composed of this introduction (**1.0** subitem) and four following main topics. The **2.0** outlines data on cotton production in the world, Latin America and Brazil, and also aspects on fiber quality, colored cotton, certifications, characterizing production systems and producers. The **3.0** is devoted to organic cotton aspects, such as sustainable agriculture, a panorama of organic cotton (worldwide, in Latin America and Brazil), motivations and constraints, market potential and communicating organic cotton in retail. The **4.0** explores sustainable network management, including trustability and transparency, small scale and better quality process and local materials and local design. In the end, **5.0** presents the last considerations in conclusion.

2 Cotton Production

The cotton plant includes 52 species in the genus *Gossypium* (family Malvaceae). Species of cotton grown for commercial purposes are G. *hirsutum,* G. *barbadense*, G. *arboreum* and G. *herbaceum* [21, 22]. G. *hirsutum* is the main cultivated species and has medium fiber length. G. *barbadense* is the most appreciated as it presents long and extra-long fibers. G. *arboreum* and G. *herbaceum* have short fibers [21].

Cotton exhibits a certain degree of tolerance to salinity and drought, and it is grown in arid and semi-arid regions. However, higher and consistent yield and fiber

quality levels are generally obtained with irrigation or enough rainfall [6]. There are several species of wild cotton in the world. They are found in Australia, Africa, Arizona, Central America, Lower California, Brazil, Mexico and other tropical countries and islands. Because of problems related to their refinement, however, they are not economically feasible to use [6].

Cotton is naturally a perennial plant that is now commercially cultivated as an annual plant in many parts of the world [1]. There are five major types of cotton being grown commercially around the world [23, 24]:

(i) **American Upland** (*G. hirsutum*): the most commonly planted type of cotton in the world, making up about 90% of the world's cotton crop. The multi-branched shrub-like plant may grow 1 to 7 feet (30.5–213 cm) tall, has creamy-white flowers, and produces white fibers up to 1¼ inches (3.2 cm) long. It can be made into many kinds of fabrics, and is used both for heavy canvas and for expensive shirts. It is grown as an annual;

(ii) **Egyptian** (*G. barbadense*): *Menoufi*, the most widely used variety, has exceptionally strong fibers about 1½ inches (3.8 cm) long. It has lemon-colored flowers and long, silky, light-tan fibers. It is made into clothing, balloon cloth, typewriter ribbons, and other fine fabrics;

(iii) **Sea-Island** (*G. barbadense*): It is now grown primarily in the West Indies. One of the most valuable and costly kinds of cotton is silky fibers about 1¾ inches (4.5 cm) long that can be made into very high-quality textiles. The plant has brilliant yellow flowers and white lint. However, it is expensive to raise because it grows slowly and has a low yield and small bolls. Technically, Sea-Island is closely related to Egyptian cotton, but growers consider it a separate kind of cotton because of its different fiber characteristics;

(iv) **Asiatic** (*G. arboreum*): grown mainly in China, India, and Pakistan. It has short, coarse, harsh fibers, and low yields. It is used for blankets, padding, filters, and coarse cloth.

(v) **American Pima**: a hybrid derived from Egyptian and American Upland cottons. It is the only variety of long-fiber cotton grown in commercially significant quantities in the American continent (especially in the United States and Peru).

'Mocó' cotton (*Gossypium hirsutum* r. marie galante Hutch) is grown in Northeastern Brazil, but its origin is unknown. The hypothesis is the mocó cotton lineage consists of several lineages rather than one, and that the 'marie galante' variety is one of them [25]. It presents great adaptability to semi-arid conditions [26]. It is also known as **'Seridó' cotton**. In this case, the name derives from the region of Rio Grande do Norte (state of Northeastern Brazil), which is the natural habitat of the mocó. This name can be used to identify the plant or even the long fiber that is obtained in this micro-region with the cultivation of mocó [27, 28].

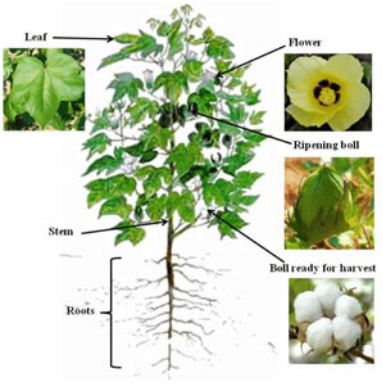
The various kinds of cotton plants resemble each other in most ways; however, they differ in such characteristics as the color of flowers, character of fibers, and time of blooming. In addition, some varieties grow best on irrigated land. Some have

lint 1¾ inches (4.5 cm) long, and others have lint only ½ inch (1.3 cm) long. Some varieties have stronger fibers than others. And some are easier to harvest by machine than others [6].

The diameter of the elementary fiber is about 15–25 μm and the length of cotton fiber is about 10–50 mm. Waxes and fats present on the surface of the fiber make it smooth and flexible. Cotton fibers are characterized by small elongation what ensures that the clothing will not change its shape during use. Cotton is also used for technical applications (industrial, medical, etc.) and interiors. In this last case, the best examples are highly absorbent bath towels and robes, upholstery material, household textiles, such as dishcloths, dusters, bed linen, tablecloth, handicraft, roller blinds, curtains, pillows, etc. Also, cotton is widely used in blends with other natural and man-made fibers [29]. Cotton has many positive characteristics such as versatility, comfort, color retention, absorbency, strength and durability [1].

In cotton cultivation, as the plant grows, flowers are formed in a vertical as well as horizontal direction. Shedding of fruit forms, particularly buds, could occur due to many complex factors, including meteorological, physiological, entomological, and nutritional. The cotton plant cannot retain all flower buds and convert them into bolls and retains only as many bolls it can afford to feed (Fig. 1a). By weight, seed cotton is composed of roughly one-third cotton lint and two-thirds cottonseed [20].

Then it splits open, showing four or five *locks* (groups of 8 to 10 seeds with fibers attached). The open-dried boll, which holds the fluffed-out cotton, is called the *bur*. An average boll will contain nearly 500,000 fibers of cotton, and each plant may bear up to 100 bolls. When fully matured, cotton bolls are picked and transported for processing, leaving the remaining plant as field trash. During the refining process or ginning of the harvested cotton, impurities are removed from the cotton fibers and are recovered as a processing by-product (CGT). From germination and emergence



(a)

STAGE	PERIOD
Planting to emergence	4 to 10 days
Emergence to first true leaf	8 days
Emergence to second true leaf	9 days
Second true leaf to pinhead square (seventh node)	18 to 21 days
Pinhead square to matchhead square	9 to 10 days
Matchhead square to first one-third grown square	3 to 6 days
First one-third grown square to first white bloom	12 to 16 days
First white bloom to first open bolls	40 to 60 days
Harvest bolls set on first four weeks of blooming	96%

(b)

Fig. 1 **a** Cotton plant, the flower, boll and fiber [30]; **b** Average growth and fruiting period of the cotton plant [30]

of shoots to flower bud and peak flowering to boll development and bursting (Fig. 1b) [23, 24, 30].

Requirements of the cotton crop [31] (i) High temperature (ideally 30 degrees); (ii) Long vegetation period; (iii) Ample sunshine; (iv) Dry climate; (v) Min. 500 mm rainfall or irrigation; (vi) Deep soils; (vii) Heavy clay soils, ideally black soils; (viii) No waterlogging; (ix) Strong root growth in first two weeks; and (x) Natural bud shedding (only approx. 1/3 of flowers develop bolls).

During the refining process or ginning of the harvested cotton, impurities are removed from the cotton fibers and are recovered as a processing by-product. By-products of cotton include the edible oil gained from the seeds, and the seed cakes and husks are used as fodder and manure [32].

The production begins with the farmer, who grows cotton and harvests the lint (fiber) from the bolls of the plant [9]. The lint is separated from the seed using a cotton gin, a ginning process, and it is sold to spinners, who produce yarn (ICAC, 2010). Textile manufacturers transform yarns into the fabric, by knitting or weaving, and applying dyes and finishes [10]. In the final stage, end products (garments, home textiles, etc.) are made from fabrics [33, 34]. Cotton has many positive characteristics such as versatility, comfort, color retention, absorbency, strength and durability [1]. A summary of the complete process is presented in Fig. 2.

Cotton fiber is the most commonly utilized natural fiber in the textile industry. It is mainly used in spinning to produce ring or open-end yarn for weaving and knitting applications [36]. The annual production of cotton fiber is about 26 million tons [37]. At the same time, cotton consumes more pesticide than any other crop; it is estimated that 25% of the worldwide use of insecticide and 10% of pesticide use is accounted for by cotton cultivation [38].

The excessive use of agrochemicals is one of the main environmental problems related to the cultivation of cotton globally, the reason to seek to modify cultivation patterns and alternative methods of pest control that propitiate the sustainability of the agricultural system [39, 40]. The use of toxic substances to target and dye the cotton in the finishing stage is another problem of the cotton chain [40, 41].

The cotton textile and clothing industry is a complex and multi-tiered system consisting of cotton cultivation and harvesting, fiber production, yarn manufacturing, fabric preparation, fabric processing that includes bleaching and dying sub-processes, and fabrication of the final fabric product. An array of environmental concerns is associated with this sector, the most significant of which are issues related to the

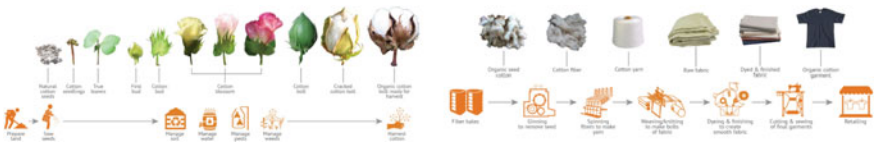


Fig. 2 Field to Fashion: cotton development and general process of transforming seed cotton from the farm into final garment [35]

use of agrochemicals in the cultivation of cotton and water, energy and chemical consumption in the fabric processing stage [42, 43].

The situation is further complicated since some of the leading cotton-producing governments have begun to reduce the size of cultivated cotton due to the severe shortage of water resources—the cultivation of cotton requires huge amounts of water, consuming 2.6% of the global water supply [42]. Moreover, the strain on agricultural land is further increased due to the terrible increase in the population size [44].

2.1 Cotton in the World

The world cotton trade generates around USD 12 billion annually and involves more than 350 million people in its production, from farms to logistics, ginning, processing and packaging [45]. According to the *Instituto de Economia Agrícola* ("Institute of Agricultural Economics") (2020), in 2019, 35 million hectares were planted, with a production of 25 million tons of lint cotton in the world. Cotton is planted in more than 60 countries, being present on five continents [45]. The forecast for the 2019/20 harvest is 26.23 million tons of cotton [46].

Many conventional cotton farmers in developing countries are in a crisis due to decreasing soil fertility, increasing production costs, resistant pests, or low cotton prices. In this scenario, an increasing number of farmers turn to organic cultivation to restore soil fertility, reduce production costs, or get a better price for their certified organic harvest [31].

The livelihood of 17 million people in India depends on cotton farming. The Indian cotton textile industry contributes 38% of the country's export earnings. In some African countries like Burkina Faso, Mali, and Benin, cotton plays an even more dominant role in agricultural exports. World market cotton prices fluctuate to a great degree and have come down considerably over the last two decades. According to Oxfam and other NGOs, this is partly due to high farm subsidies in the US [21]. This scenario mostly considers the main countries in cotton production and exports 2018–2019 and 2020 (Table 1).

Commodity prices are primarily driven by supply and demand. Aspects such as fiber quality (staple length, strength, color, leaf grade, trash content, etc.) also play a part. Other price influencers and considerations include stocks and subsidies, logistics, transportation and warehousing, trader costs, currency conversions and insurance. Agricultural policies and strategies applied by some of the main producer countries (China, India, Brazil and the USA) influence the market, as have environmental factors and competition from other commodities. The prices of competing crops influence farmers' decisions about what to grow. Higher prices for crops such as corn and soybean obviously make those crops more attractive to farmers—and, as a result, can displace cotton production and drive up prices. Additionally, of course, there is competition between fibers and, with polyester being so competitive in price, for example, the price of cotton is impacted [48, 49].

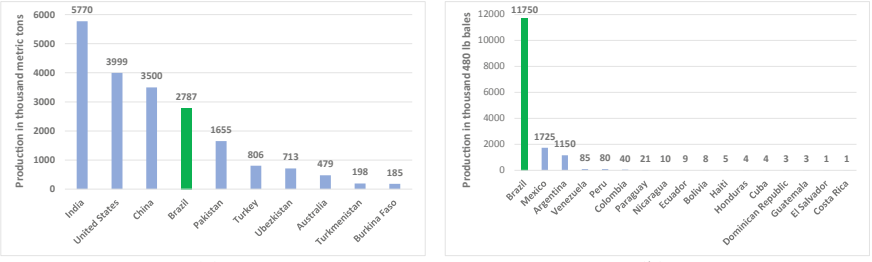
Table 1 Main countries in cotton production and exports 2018/19, May 2019/20 and May 2020/21 [47]

World cotton production				World cotton exports			
Million 480 lb bales		2019/20	2020/21	Million 480 lb bales		2019/20	2020/21
	2018/19	May	May		2018/19	May	May
India	25.8	30.5	28.5	US	14.8	15.0	16.0
China	27.8	27.3	26.5	Brazil	6.0	8.6	9.0
US	18.4	19.9	19.5	India	3.5	3.2	4.5
Brazil	13.0	13.2	12.0	Greece	1.4	1.4	1.5
Pakistan	7.6	6.2	6.3	Benin	1.3	1.2	1.3
Rest of World	26.1	25.6	26.2	Rest of World	14.2	10.6	10.7
World	118.7	122.7	119.0	World	41.1	40.0	42.9

The international market trends for cotton in 2020 reflect upward factors: the possible commercial agreement between the USA and China; good volume exported by US respect the gathered from the 2019/20 harvest; and diminishing in the area to be planted in the US. And the downward factors: estimated global productive surplus for the 2019/20 and the 2020/21 harvests; trade war between the USA and China; coronavirus and its effects on the economy; and oil prices at very low levels. In this way, considering the decrease in global consumption, the expectation is that the prices will remain under pressure along 2020 year [47, 50].

2.2 *Cotton in Latin America*

In Latin America, the three main cotton-producing countries are Brazil, Mexico and Argentina, followed by Venezuela, Peru, Colombia and others [51].



(a) (b)

Fig. 3 **a** Cotton production by country worldwide in 2018/2019 (in 1,000 metric tons) [52], **b** Cotton production in selected Latin American and Caribbean countries in 2018 (in 1,000 480-lb bales) [51]

Complementing the data in Table 1 (2017–2018), Fig. 3a shows the world's leading cotton-producing countries in the period of 2018/2019.

Meanwhile, taking into account the cotton production in Latin America in the same period (Fig. 3b), Brazil stands out as 1st in the region, far surpassing other countries in the region [51, 52].

However, these data are about cotton production in general, which neither highlight the historical importance of cotton production in Latin America or the importance of specific cotton cultivations (Pima, organic, natural colored, etc.) in this region, for which a more detailed approach will be made forward in this text.

2.3 Cotton in Brazil

The second half of the 90 s marked the migration of the cotton crop from the traditional production areas in the semi-arid to the Brazilian Cerrado biome [53]. In 1997, the first producers' association was created in Mato Grosso state, AMPA (Matogrossense Cotton Producers' Association). Later in 1999, it was created the Brazilian Association of Cotton Producers (ABRAPA). In the same year, they were also created important states associations, in São Paulo, Minas Gerais, Goiás and Mato Grosso do Sul. And in the next year, in the states of Bahia, Parana and Maranhão. In 2001, the Brazilian cotton market was self-sufficient, supplying 100% of the textile industry demands, producing around 900 thousand tons per crop [5]. Brazilian fiber production is now characterized by high agroindustry scale, mechanization, analyses and fiber classification considering international standards, traceability system, environmental certification (**BCI—Better Cotton Initiative**).[1]

Brazil has achieved and maintains the productivity in cotton crops under the rainfed system, which is called cultivation without irrigation [32]. In the 2016/2017 harvest, of the 940 thousand hectares planted, only 40 thousand (4.3%) were irrigated. In the general ranking of productivity, the country ranks fourth, with 1,600 kg of feather per hectare, behind Israel, which harvested 1.76 thousand kilos, but irrigates 100% of its areas, Australia (1.74 kg/ha), where irrigation reaches 95% and China (1.66 kg/ha), which has 80% of the crops dependent on the artificial addition of water [56]. Mato Grosso is also the largest cotton producer in the country, accounting for about 70% of Brazilian cotton production. The national average is around 1.5 tons per hectare, while the United States produces an average of 0.8 tons per hectare. However, the country has great potential to be improved [57].

[1] According BCI, the Better Cotton Standard System is a holistic approach to sustainable cotton production which covers all three pillars of sustainability: environmental, social and economic. Each of the elements—from the Principles and Criteria to the monitoring mechanisms which show results and impact—work together to support the Better Cotton Standard System, and the credibility of Better Cotton and BCI. The system is designed to ensure the exchange of good practices, and to encourage the scaling up of collective action to establish Better Cotton as a sustainable mainstream commodity [54, 55].

The success of the corporate system implemented in the Cerrado biome is based largely on the intensive use of modern agricultural inputs, mechanized operations, use of skilled labor, and access to large buyer markets in Brazil and abroad. This model involves higher production costs and the need for scale, encouraging cotton production on large farms. As a result, around 90% of Brazilian cotton is produced on properties with an area equal to or greater than 1,000 hectares [32]. Cotton farmers in the Cerrado, in general, have good access to domestic and foreign markets, a result of the high quality of the fiber produced, the creation of sales coops, the strong performance of agricultural commodity trading companies, and the professionalism with which they meet deadlines and comply with legislation [57, 58].

Due to its agronomic characteristics of adaptation to the region's climatic conditions, the small-scale familiar cotton crop, its historical-cultural value and, mainly, economic, established and gained prominence in family agriculture in the semi-arid region of Brazil. However, throughout history, cotton has gone through ascension, crises and declining production and productivity. In summary, one can attribute the reasons that led to the decline of cotton production: (i) non-conservative crop management (ii) government policies of low and price variations; (iii) occurrence of extreme droughts; and (v) the advent and spread of the boll pest (*Anthonomus grandis* Boheman) [39, 40].

There are alternative production systems practiced by family farmers, or even by small- and medium-scale growers, aimed at exploiting niche markets, among which are: production of colored cotton, organic cotton, and agroecological cotton. These systems are of major social importance and have received growing support from government policies and companies in the textile and apparel sectors that operate in niche markets. These types of products are highly valued [32]. However, market access is a major challenge for small- and medium-scale growers.

Presenting both cotton scale productions, Fig. 4a indicates the states and its production volume in Brazilian states in 2017 for *G. arboreum* and Fig. 4b, for *G. herbaceum.*

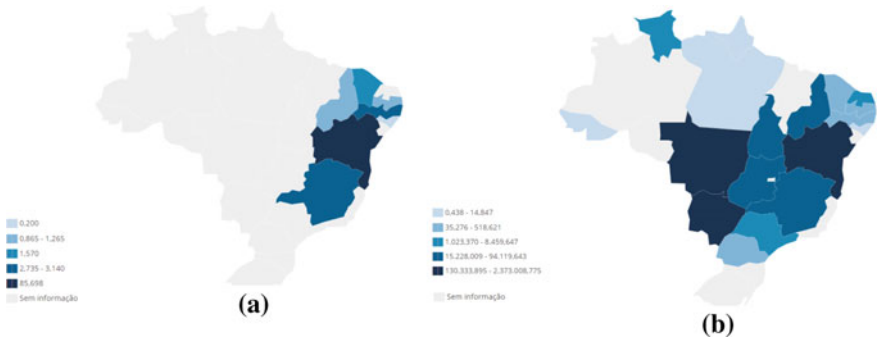


Fig. 4 Volume of Cotton Produced in Brazilian States in 2017: **a** G. *arboretum* (96,225 tons and 135 establishments) [59]; **b** G. *herbaceum* (3,664,808,060 tons and 3,081 establishments). On the left side of each map, the tons amount scale [59]

The cotton fiber obtained in Brazil is marketed in more than 40 countries and can be considered one of the best in the world. Despite the great national production, Brazil is still an importer of cotton fiber. This is because most of the fiber produced in the country is medium in size, and the textile industry still lacks reasonable amounts of longer fibers. The longer fibers allow manufacturing of lighter fabrics, which according to the analyst, are a trend. The new challenge of the Brazilian cotton sector is to produce enough fine or extra-long fibers, thinner and more resistant, that generate lighter fabrics that please consumers [32].

There is a growing demand for products and services generated without aggression to the environment and respect to the worker's dignity. In 2010, ABRAPA implemented BCI in Brazil. BCI is an international organization aimed at improving good production practices, fair working relationships and the transparency and traceability of cotton in the market. Following the same line, ABRAPA created the Brazilian Responsible Cotton (ABR) program in 2012, –81% of Brazilian producers are ABR certified nationwide, and 71% also have the international seal BCI. Brazil supplies 30% of all the BCI cotton in the world. Brands such as Adidas, Nike, Levi Strauss and Co, and C&A are some of BCI's most influential partners [54].

BCI cotton has been used as an answer to the sustainability challenges of the traditional cotton culture. The model represents an advance, especially in terms of social and labor rights aspects. However, it deserves criticism regarding the maintenance of the use of agrochemicals and transgenic seeds, in a similar way to conventional cotton [60].

2.4 Fiber Characteristics and Quality

2.4.1 Fiber Characteristics

A large number of literatures are available on the characterization of cotton fibers. Cotton fiber is composed mostly by cellulose (82.7%), and minor fractions of hemicellulose (5.7%) and wax (0.6%), among other constituents [19]. The cellulose in cotton fibers is also of the highest molecular weight among all plant fibers and highest structural order, i.e., highly crystalline, oriented and fibrillar. Cotton, with this high quantity and structural order of the most abundant natural polymer, is, not surprisingly, viewed as a premier fiber and biomass [61].

The cross-sectional view of cotton fiber is kidney-shaped (Fig. 5a, b). The cross-section tends to indicate the relative dimensions of the lumen and fiber walls [62]. The cotton walls are constituted by various layers with different cellulose structural orders [63], as presented in Fig. 5c.

The fibers are classified according to their length. Lower if smaller than 22 mm. Averages, if measured from 28 to 34 mm. Long above 34 mm. The good length of the cotton fiber helps in the easier spinning into a smoother, stronger yarn. Yarn quality parameters such as evenness, strength, elongation and hairiness are correlated to the length of cotton fibers. Spinning parameters depend on the length of cotton

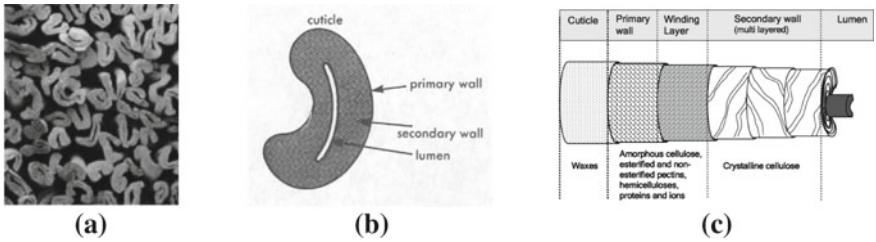


Fig. 5 Cotton fiber: **a** cross-section of raw cotton [64]; **b** macro structure [64]; **c** schematic representation of mature cotton fiber showing its various layers [63]

fibers, which results in a more comfortable, more durable, more attractive fabric and garments [62].

Murugesh et al. [19] research characterized organic and conventional cotton fiber properties, such as the surface morphology, surface chemical and elemental composition, internal chemical composition and architecture. The main properties pointed by them are: fiber length (10–50 mm); diameter (10–27 μm); moisture regain at 65% R.H. (8.5%); elongation strain to failure (7%); dry tenacity (0.3–0.5 N/tex) and flammability limiting oxygen index (LOI) (17–19%).

2.4.2 Fiber Quality

The quality of the cotton is evaluated according to the length of its fiber, following the fineness, color and purity. The classification of fiber quality is also made according to the resistance test, uniformity of length, and the relationship between maturity [62].

The mix of perennial crop and annual growth habits contribute to the variability in cotton lint quality. The amount of sunlight, day and night temperatures during growth, variety and agronomic inputs are responsible for year-to-year variations in quality. Fiber properties have been studied since the early 1900s, but electronic and physical sciences have been employed in measuring quality parameters only since the 1950s. High Volume Instrument (HVI) is a machine for measuring quality characteristics in cotton, to reduce the time required to measure fiber properties [20]. HVI was adopted in Brazilian labs following an international standard, in 2003, supporting production and chain rastreability and fiber quality control [5].

The main HVI determinations include [65]:

Fiber Length—the average length of the longer one-half of the fibers (upper half mean length). It is reported in both 100ths and 32nds of an inch.

Length Uniformity—the ratio between the mean length and the upper half mean length of the fibers and is expressed as a percentage.

Fiber Strength—reported in terms of grams per tex. A tex unit is equal to the weight in grams of 1,000 m of fiber. Therefore, the strength reported is the force in grams required to break a bundle of fibers one tex unit in size.

Micronaire—a measure of fiber fineness and maturity (μg/in). An airflow instrument is used to measure the air permeability of a constant mass of cotton fibers compressed to a fixed volume.

Color Grade—The color grade is determined by the degree of reflectance (Rd) and yellowness (+b) as established by the official standards and measured by the HVI. Reflectance indicates how bright or dull a sample is and yellowness indicates the degree of color pigmentation.

Trash—a measure of the amount of non-lint materials in the cotton, such as leaf and bark from the cotton plant. The surface of the cotton sample is scanned by a video camera and the percentage of the surface area occupied by trash particles is calculated.

The complementary classer determinations include [65]:

Leaf Grade—a visual estimate of the amount of cotton plant leaf particles in the cotton. There are seven leaf grades, designated as leaf grade "1" through "7", and physical standards represent all. Also, there is a "below grade" designation which is descriptive.

Preparation—describe the degree of smoothness or roughness of the ginned cotton lint. Various methods of harvesting, handling, and ginning cotton produce differences in roughness or smoothness of preparation that sometimes are very apparent.

Extraneous Matter—any substance in the cotton other than fiber or leaf. Examples of extraneous matter are the bark, grass, spindle twist, seedcoat fragments, dust, and oil.

The measurement units, values and classifications for all the determinations expressed above are provided by USDA and replied by many other institutions related to cotton production and trade [65–68].

Specifically, about the color grade, it is determined by the degree of reflectance (Rd) and yellowness (+b) as established by the official standards and measured by the HVI. Reflectance indicates how bright or dull a sample is and yellowness indicates the degree of color pigmentation. A three-digit color code is used. The color code is determined by locating the point at which the Rd and +b values intersect on the Nickerson-Hunter cotton colorimeter diagram for Upland cotton. The color of cotton fibers can be affected by rainfall, freezes, insects and fungi, and staining through contact with soil, grass, or the cotton plant's leaf. Color also can be affected by excessive moisture and temperature levels while cotton is being stored, both before and after ginning. As the color of cotton deteriorates due to environmental conditions, the probability of reduced processing efficiency is increased. Color deterioration also affects the ability of fibers to absorb and hold dyes and finishes. There are 25 official color grades for American Upland cotton, plus five categories of below grade color, as shown in the tabulation below. USDA maintains physical standards for 15 of the color grades. The others are descriptive standards (Table 2) [65–67].

Classification procedures for American Pima cotton are similar to those for American Upland cotton, including the use of HVI measurements. The most significant difference is that the American Upland color grade is determined by instrument measurement, while highly trained cotton classers still determine the American Pima

Table 2 Color Grades of Upland Cotton [65, 67]

	White	Light spotted	Spotted	Tinged	Yellow stained
GM (Good Middling)	11.1[b]	12	13	–	–
SM (Strict Middling)	21.2[b]	22	23[a]	24	25
M (Middling)	31.3[b]	32	33[a]	34[a]	35
SLM (Strict Low Middling)	41.4[b]	42	43[a]	44[a]	–
LM (Low Middling)	51.5[b]	52	53[a]	54[a]	–
SGO (Strict Good Ordinary)	61.6[b]	62	63[a]	–	–
GO (Good Ordinary)	71.7[b]	–	–	–	–
BG (Below Grade)	81	82	83	84	85

[a]Physical standards for color grade only;
[b]Physical standards for color grade and leaf grade; All others are descriptive

color grade. Different grade standards are used because the color of American Pima cotton is a deeper yellow than that of Upland. Also, the ginning process for American Pima cotton (roller ginned) is not the same as for Upland (saw ginned). The roller gin process results in an appearance that is not as smooth as obtained with the saw ginned process. There are six official grades (grades "1" through "6") for American Pima color and six for leaf. All are represented by physical standards. There is a descriptive standard for cotton, which is below grade for color or leaf. A different chart is used to convert American Pima fiber length from 100ths of an inch to 32nds of an inch [65, 68].

The quality of fibers and their properties correlate with the textile process and product development. The length characteristics, for example, mean the longer the fiber is, it will enhance the machinery production. Resistant fibers will influence the textile softness. Also, the fiber color uniformity and cleaning will influence processes quality and costs. The micronaire index measuring fiber maturity and density, will indicate that the fibers with low value and high maturity will be more resistant and longer. The more the yarn is long and homogeneous, the high its quality [64].

2.5 Colored Cotton

Naturally colored cotton was cultivated by the Incas from 4500 B.C., then later by other peoples in the Americas, Asia, Africa and Australia [3, 69, 70]. The growing demand for organic products generates interest in this crop because it does not require dyeing [21, 62]. More than 39 wild cotton species with colored fibers have already been identified. In most of these primitive species, cotton has colored fibers, mainly in brown. However, colored cottons in shades of green, yellow, blue and gray have already been described. These cottons, for long periods, were discarded by the global textile industry and their exploitation in several countries was even banned because they are considered as undesirable contamination of normal white cottons. These

colorful types have been preserved by native peoples and in cotton collections in several countries [69].

Naturally colored cottons are considered environmentally friendly because they have many insect and disease-resistant qualities, are drought and salt tolerant and do not have to be dyed artificially. Colored cottons have been grown successfully with organic farming methods [62].

Although the organically grown naturally colored cotton is more expensive than traditional varieties, it is being exploited in relatively small but potentially lucrative market niches, similar to the 'organic food' and 'fair trade' markets. One niche is the sales of clothing in the local tourism sector; another one is children's clothing which parents do not want their children to be exposed to any chemical process-based clothing; and generally, consumers who desire to support healthy and ethical new-growth businesses [70].

In Brazil, cotton plants, in cream and brown tones, were collected in mixtures with cultivated white cottons, of the species *G. barbadense* L. and *G. hirsutum* L., Marie Galante Hutch variety, known as arboreal cottons. Since 1989, EMBRAPA (Brazilian Company of Agricultural Research) has begun to study the formation of genetic crosses to improve the raw material. The investments in production meant the resumption of the cotton crop in the northeastern semi-arid region, which had practically disappeared due to the beetle. Colored fiber has a market value of 30% to 50% higher than white cotton fibers. The colored cotton developed by EMBRAPA is considered ecologically correct, since it eliminates the process of dyeing, one of the most polluting of the textile industry [71].

To date, five cultivars BRS 200, BRS Verde, BRS Rubi, BRS Safira ("sapphire") and Topázio ("topaz") have been presented commercially (Fig. 6a, b).

Also, clothes made with this material can be used without problems by people allergic to dyes. Another quality of these seeds lies in the fact that they can be planted in dry regions and use less pesticides, that there are not many pests that attack this variety [62]. Cotton occurs naturally in white, brown, green colors, varying in a range of shades. The colored lint is shorter in length. Lack of sufficient sunlight affects the ability of a genotype to express its color. Colored cotton lint varieties have the same agronomic management requirements as white ones (Table 3) [20].

The production of colored cotton on a commercial scale began only in the first half of the 2000s [21, 73].

2.6 Cotton Certifications

With the growth in demand for organic products, it was necessary to create mechanisms for the certification of such products, based on standards that regulate production, processing and marketing [74]. This socio-environmental certification is fundamental for sustainable agricultural promotion, and it generates product differentiation with sustainable management, thus ensuring that the product consumed comes from ecological management and that there is no incentive to degrade natural resources

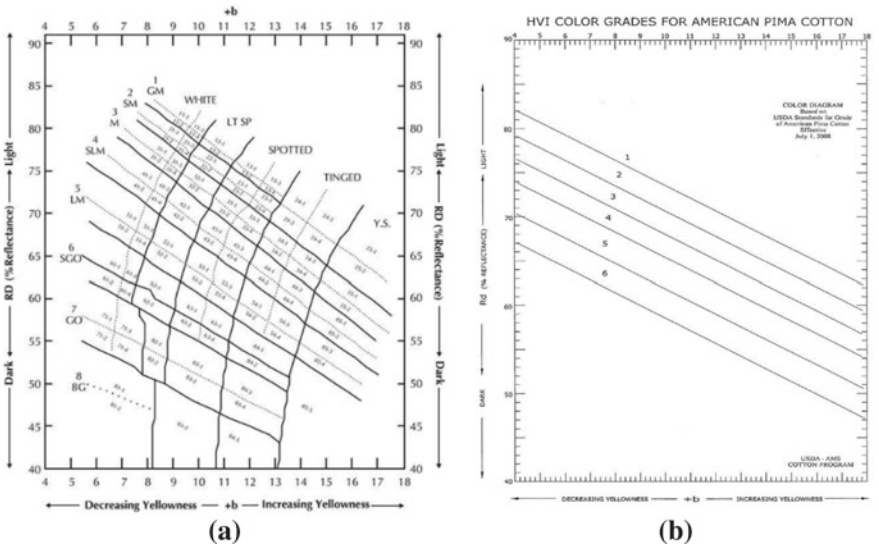


Fig. 6 **a** HVI color chart plotting of the distribution of reflectance (Rd) and yellowness (+b) for American Upland cotton. It includes color grades for white, light spotted, spotted, tinged and yellow stained cotton [65]; **b** HVI Color Chart for American Pima Cotton [67]

Table 3 Color inheritance of cotton fiber and geographical origin [21, 67, 72]

Gene symbol	Fiber color	*Gossypium* species	Region
Ld^{1k}	Khaki	Arboreum and herbaceum	Africa and Asia
Lc^{2b}	Light brown	Arboreum and herbaceum	Africa and Asia
Lc^{2k}	Khaki	Arboreum and herbaceum	Africa and Asia
Lc^{2M}	Medium brown	Arboreum and herbaceum	Africa and Asia
Lc^{2v}	Slight brown	Arboreum and herbaceum	Africa and Asia
Lc^{3B}	Light brown	Arboreum and herbaceum	Africa and Asia
Lc^{4k}	Khaki	Arboreum	Asia
D^{w}	Off white	Raimondii	America
Lg_1	Green	Hirsutum	America
Lc_2	Brown	Hirsutum	America
Lc	Brown	Barbadense, darwinii and tormentosum	America

[75]. Furthermore, the main aim of the certification processes is to maintain the integrity of the organic nature of the fiber as much as possible. Regulations are important because they standardize criteria for organic production and post-harvest handling/processing that facilitate domestic and international trade [8].

In 2018, the global cultivation of organic cotton grew by 10% compared to 2017 [7]. Although organic cotton production worldwide is still small the demand for

the product only grows [76]. To produce and sell organic cotton, it is necessary to follow the principles of organic production, certifying the production systems. The organic certification is the guarantee that the producer has followed norms/standards for organic production, and in this way, it can be called an organic product. Products labeled as green, agroecological, biodynamic, ecological or sustainable, which have not undergone an organic certification process, cannot be called an organic product [77].

The organic conformity assessment is a systematic process, composed of pre-established rules and standards, which undergo monitoring and evaluations, promoting security and guarantee that a product, process or service, meets the requirements determined in the rules and regulations. The conformity assessment involves the following activities: selection of standards or regulations, collection of samples, carrying out laboratory analyzes, carrying out inspections, carrying out audits and product traceability [78]. Furthermore, a three-year transitional period from conventional to organic cotton production is required for certification [42].

These certifications are made by public or private agencies, and are important to discourage possible opportunistic actions [79], in addition to ensuring the integrity and origin of the product, so only certified products contain a guarantee of organic property.

According to the IFOAM—International Federation of Organic Agriculture Movements [80], "there are two different kinds of organic farms in the world (1) Certified organic farms producing for a premium price market and (2) Non-certified organic farms producing for their own households and for local markets". Organic production takes place in more than 180 countries; of this total, only 87 countries have their own regulations [81], with Brazil among these countries. In each country or region,, organic cotton is subject to organic production laws, such as Organic Regulation No 834/2007 in Europe, USDA National Organic Program (NOP) in the United States, and the National Organic Production Program (NPOP) in India [60]. Also, in organic agriculture, international standards and certificates exist, such as specific standards such as ISO 9000, ISO 14,000 [82].

The Brazilian Organic Law, Law No. 10,831/2003, was sanctioned in 2003, is regulated in 2007, through the publication of Decree No. 6,323/2007. The Ministry of Agriculture, Livestock and Supply is the supervisory body. The Brazilian legislation regulates two certification mechanisms, which are: Audit Certification or Third-Party Certification and the Participatory Guarantee System or Participatory Certification or **Participative Guarantee System (PGS)**.[2] Brazil was the pioneer country in participatory certification, being a world reference [77].

The Participative Guarantee System, together with the certification by external audit, composes the Brazilian System of Evaluation of Organic Conformity (SisOrg) [84].

[2] Participatory Guarantee Systems (PGS) are an alternative to third party certification. As per IFOAM—Organic International's definition, PGS are locally focused quality assurance systems that certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange. IFOAM—Organics International has a list of recognized PGS programs [83].

Participatory certification is a process that involves knowing how to produce, managing production and marketing and registering all information, a process that, for many, is complex and demands support [85]. It is a system composed of commissions and councils, with the mandatory effective and direct participation of producers interested in certification, with the participation of technicians and employees. In order for the Participatory Guarantee System to carry out certification activities in the production systems of its members, it is necessary to accredit a **Participatory Organism for the Evaluation of Organic Conformity** (OPAC) in the Ministry of Agriculture, Livestock and Supply [84]. (MAPA). The mechanisms of evaluation of organic conformity have the as main objective to certify the quality of organic products to consumers [77]. The OPAC is a legally constituted association with an ethics council, which assumes the formal responsibility for the set of activities, attesting to whether the products and producers meet the requirements of the organic production regulation. After the MAPA accreditation, OPAC may authorize the producers controlled by it to use the Standard of the Brazilian Organic Conformity Assessment System and become responsible for launching and keeping up to date all the data of the production units it controls, in the National Register of Organic Producers and in the National Register of Productive Activities, so that information is available to society [84].

Certification by external auditing is carried out by independent third-party organizations, which ensure compliance with organic production procedures—provided for in international standards and legislation. Despite the importance of certification in expanding the production and marketing of organic products in Brazil attesting to the credibility of the product, certification by external auditing has high costs; it is often not feasible for the family farmer [84].

Audit certification is a private service carried out by contracting services from certifying companies. The certifying companies follow the standards of the countries in which they operate, utilizing the standards from IFOAM and of ISO Guide 65, which are internationally recognized references [77].

According to Ferraz [60], there are various others standards and certifications for classified cotton called by Textile Exchange as “Preferred Cotton” (cotton that is ecologically and or socially progressive because it has more sustainable properties compared to other conventional options). The organization, “Preferred Cotton” (pCotton) includes: Recycled, Organic, Fair Trade, CmiA, Better Cotton (BCI) and its equivalences.

Also, there are initiatives aimed at certifying recycled cotton. In order to ensure the production model, origin and traceability, there are some types of standards and certifications, legally defined as external audit models.

In Brazil, organic cotton is attested by auditory certification (carried out by private companies: IBD Certifications and ECOCERT Brazil). The PGSs in the Northeastern Semi-Arid are: *Rede Borborema de Agroecologia* (“Borborema Network of Agroecology”), ACEPA, ACEPI, APASPI, ACOPASA and ECOARARIPE.

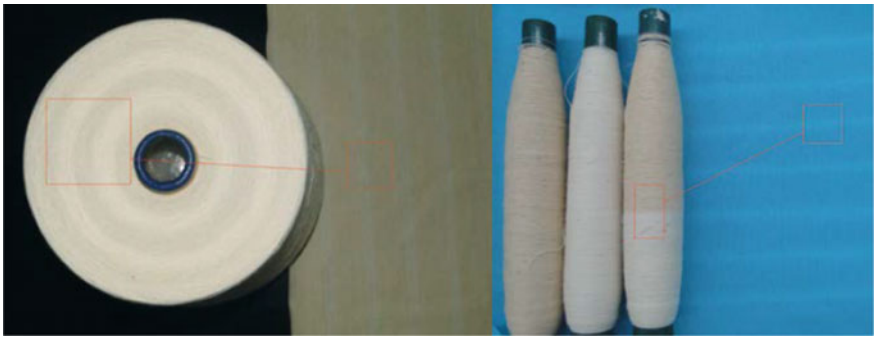


Fig. 7 Example of yarns and textiles with color variation [63]

In addition, some companies and farmers' associations also employ **GOTS**[3] and **Fair Trade**[4] certifications. For example, the family farmers of the Association for Educational and Cultural Development of Tauá (ADEC), located in Ceará state (Brazil), certifies cotton by IBD Certification and has the Fair Trade certification. On the other hand, the OCC (Organic Cotton Colors) company, does not require organic cotton certification, but certifies its manufactured products by GOTS certification.

2.7 Characterizing Production Systems

In Brazil, the conventional crop is characterized as using machinery and agroindustry systems for scale production in extensive areas (Fig. 7).

The organic crop is characterized as small properties (Fig. 8a), family farming and manual activities such as planting and harvest [88]. Since the organic system was labor-intensive, it was more attractive for producers with smaller areas of cultivation, especially in a context of production with the predominance of family farming, where the hiring of temporary or permanent labor is very scarce [60].

[3] GOTS Certification is an internationally accredited certification by the Global Organic Textile Standard (GOTS). It guarantees the organic quality of textiles, starting from the harvest of the raw material, passing through all stages of textile processing, from fiber to finished product. It aims to guarantee the process traceability, evaluating the reduction in the use of chemicals, energy and social and economic relations [86].

[4] Fair Trade Certification: it is an international certification, accredited by the International Federation of Alternative Trade (IFAT) with the mission "to improve the livelihoods and well being of disadvantaged producers by linking and promoting Fair Trade Organizations, and speaking out for greater justice in world trade" [87].

Fig. 8 **a** Colored Cotton BSB Rubi from EMBRAPA Cotton (Authorship); **b** From left to right, white color lint, BRS 200, BRS Green, BRS Rubi from EMBRAPA Cotton [70]

2.8 Characterizing Producers

According to Ref. [89], the size of the area, the rural properties are classified in:

- *Minifundio*—is the rural property with an area less than 1 (one) fiscal module;
- *Small Property*—the property of area between 1 (one) and 4 (four) fiscal modules;
- *Average Property*—the rural property of area greater than four (4) and up to fifteen (15) fiscal modules;
- *Large Property*—the rural property of the upper area 15 (fifteen) fiscal modules.

To the Brazilian Ministry of Agriculture and Supply [90], small holders and family agriculture (Fig. 8b) in Brazil is characterized as using the family's own labor force in rural economic activities in an area of maximum 4 fiscal modules predominantly, having a minimum family income originating from rural economic activities in their establishment and/or enterprise; and driving the establishment with the family. Family farming is an important segment for the development of Brazil. There are approximately 4.4 million farm families, representing 84% of Brazilian rural establishments. For the economy, it represents 38% of the gross value of agricultural production and the sector accounts for seven out of ten jobs in the field. It is productive since it is responsible for producing more than 50% of the food supplies of Brazilian "cesta básica" (set consisting of basic food products consumed by a family per month), being an important instrument of inflation control [91].

Enhancing smallholders' capabilities [10, 92]:

- *Training*: The provision of farmer training enables farmers to improve their production capacity and productivity and their abilities to meet the quality standards demanded by international supply chains.
- *Information Systems*: Providing smallholders with access to information and communications can help them make decisions and reach new or more beneficial markets. Market information is crucial for good decision-making.

- *Financial Services*: Access to finance has been identified as a major issue for small farmer inclusion. There is a growing need to facilitate and adapt financial products for small farmers, such as access to loans, crop finance, and crop insurance advances.
- *Social Entrepreneurship*: Social entrepreneurship aims to improve smallholders' inclusion by providing entrepreneurial opportunities within the supply chain. Several authors identify the relevance of entrepreneurs within farmer organizations who might bridge the gap and coordinate small farmers and market actors [93, 94]. Entrepreneurs are more likely to try new technologies and methods and can be triggers for innovation.

According to DataSebrae [95], referring to the first quarter of 2018, the highest proportion of rural producers is between 45 and 55 years of age, representing 26.3% of the total. Next are those who are between 55 and 65 years old (20.5%). On the other hand, the younger rural business owners, who are up to 25 years of age, are the minority. They represent only 6.7% of the total. Also, they affirm [95]:

- Personnel employed in agricultural establishments: 15,036,978 people.
- In the case of agricultural establishments: 5,072,152 establishments.

3 Organic Cotton

Organic cotton is grown without the use of any synthetically compounded chemicals (i.e., pesticides, plant growth regulators, defoliants, etc.) and fertilizers are considered 'organic' cotton [96]. The production of cotton using organic farming techniques (Fig. 9) seeks to maintain soil fertility and to use materials and practices that enhance the ecological balance of natural systems and integrate the parts of the farming system into an ecological whole [97].

Organic cotton cultivation is reported in the following countries: Africa: Benin, Burkina Faso, Egypt, Mali, Mozambique, Senegal, Tanzania, Togo, Uganda, Zambia, Zimbabwe. Asia: China, India, Kyrgyzstan, Pakistan. South America: Argentina, Brazil, Nicaragua, Paraguay, Peru. Middle East: Turkey, Israel. Europe: Greece. The USA and Australia [98]. The main producers of organic cotton are India, China, Kyrgyzstan, with India alone accounting for 56% of the global production [99]. While African organic cotton Sourced from six different nations holds a 4% share [99].

Surface morphology and surface chemical composition of both the organic and conventional cotton fibers are similar [19].

Production support comes considerably from financial institutions, local banks, donors and governments and NGOs [11]. Intermediate stakeholders, as transnational and local environmental NGO networks 'Solidaridad' and 'Helvetas', are important instruments in the construction, maintenance and transformation of the organic cotton network [10]. They enable services such as training, storage facilities, logistics, insurance and financial services, marketing, technical support and the supply of

Fig. 9 Organic color cotton clothing from "Flávia Aranha" Brazilian fashion brand, employing cotton cultivated in Paraiba state—Brazil [73]

seeds and inputs [10]. International institutions, such as Textile Exchange, also play an important role in financing capacity building in farmers' groups, acting as an agent in cotton marketing, promoting international events and publishing information [9].

Proponents of organic cotton and those who market organic cotton products promote the perception that conventional cotton is not an environmentally responsibly produced crop [99]. Some of the reasons used to support they contend that traditional cotton production greatly overuses and misuses pesticides/crop protection products that have an adverse effect on the environment and agricultural workers and conventionally grown cotton fiber/fabrics/apparel has chemical residues on the cotton that can cause skin irritation, and other health-related problems to consumers. Organic cotton production is not equivalent to sustainable—either organic or conventional cotton production practices may be sustainable [100].

With its tiny market share, organic cotton represents a viable option and a lucrative niche for many small-scale farmers in developing countries, in particular, due to attractive price premiums. However, these premiums may encourage more and larger producers to enter the market [101]. The aim is not to compare conventional and organic cotton value chains but to provide the necessary reference to understanding the context of emergence and the dynamics within the organic cotton network [9].

3.1 Sustainable Agriculture

Growing demand is forcing the conversation on reconciling economic growth with environmental sustainability. Local scaled decisions include but are not limited to the following: farm design, crop allocation, adoption of equipment and infrastructure, landscape planning, and groundwater management [43].

Analyzing the many definitions of Sustainable Agriculture, it can be found two that are most frequent, maybe the most accepted internationally, the one elaborated by FAO (United Nations Food and Agriculture Organization) [102] and the other by NCR (National Research Council) [103]. These two, complement each other, probably because there is still no consensus about Sustainable Agriculture definition.

The concept of Sustainable agriculture in farming means meeting society's present food and textile needs, without compromising the ability of current or future generations to meet their needs. Sustainable agriculture is not a set of unique practices, but rather an objective: to achieve a productive system of food and fibers that; increase the productivity of natural resources and agricultural systems, allowing producers to respond to demand levels engineered by population growth and economic development; produce healthy, wholesome and nutritious foods that enable human well-being; ensure a sufficient net income for farmers to have an acceptable standard of living; to invest in increasing the productivity of soil, water and other resources; and meets community standards and expectations [104].

Practitioners of sustainable agriculture seek to integrate three main objectives into their work: a healthy environment, economic profitability, and social and economic equity. Every person involved in the food system—growers, food processors, distributors, retailers, consumers, and waste managers—can play a role in ensuring a sustainable agricultural system [104].

Wide-scale transformation promoting sustainable agricultural production in the tropics will be crucial to global sustainability and development. Although contemporary agricultural production has increased alongside international demand, it has resulted in extensive changes in land cover, often at the expense of tropical forests and other native habitats. Conservation and development professionals from civil society, private foundations, multilateral and specialized international agencies, along with academic organizations and, increasingly, the private sector, have cited the urgent need to transform tropical agricultural production to meet current and future food needs without compromising environmental, economic, and sociocultural outcomes for present and future generations [105].

3.1.1 Agroecology

The term 'Agroecology' was first time coined in the scientific publication by Bensin [106, 107] and recently reaffirmed by Gliessman [108] and Warner [109]. The scientific discipline uses ecological theory to study, design, manage, and evaluate sustainable agriculture systems that are productive and resources conserving. Drawing on

the natural social sciences, agroecology provides a framework for assessing four keys (productivity, resilience, sustainability and equity). Hence its importance is greatly realized by the dominant food policy and agricultural research bodies around the world [108, 110–112].

3.1.2 Organic Agriculture

The concepts of organic agriculture were developed in the early 1900s by Sir Albert Howard, F. H. King, Rudolf Steiner, and others who believed that the use of animal manures (often made into compost), cover crops, crop rotation, and biologically based pest controls resulted in a better farming system [113].

"Organic agriculture is a holistic production management system that promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, considering 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 [114].

The latest statistics reveal that Australia now has more certified organic agriculture hectares than the rest of the world put together. Organic agriculture is reported from 181 countries. Australia reported 35,645,038 certified organic hectares and the world total is 69,845,243 hectares. The development and growth of organics in Australia have always been driven by two factors, ideology and the market. Australian organics has received scant support from government and institutions, often being ignored and sometimes derogated [115, 116].

It is possible to say that all definitions express the need to establish a new productive pattern or system, that uses natural resources more rationally and maintains productive capacity in the long term. The word "sustainability" is known worldwide and its use in many sectors of the economy has been increasing. However, there is no consensus about its real concept. Therefore, a single, globally agreed definition of the terms "sustainability", "sustainable development" or "sustainable agriculture" is inadequate [117].

3.2 Organic Cotton in the World

In the cultivation of organic cotton, chemical fertilizers, synthetic pesticides, genetically modified seeds, chemical growth regulators, and chemical defoliants are prohibited [60, 118, 119].

Although 19 countries produce organic cotton, only seven of them (India, China, Turkey, Kyrgyzstan, Tajikistan, USA and Tanzania) represent 98% of the total production. India has the largest share, with 47% of global production. Evidence from India, the USA and Turkey shows that, if supported by good science, high yields

of more than 1,000 kg per hectare can be obtained. Current global average yields are low, 375 kg of feather per hectare. Property yields may actually be higher due to intercropping with other crops produced organically, different from monoculture on conventional properties [35].

The demand for organic cotton is constantly growing, as more and more buyers are looking for high-quality cotton, produced according to strict environmental and social standards. The increase in responsible consumption, involving social, environmental and economic issues, led to strong market growth, increasing the demand for organic cotton. By using organic cotton in their products, buyers are promoting a more ecologically sustainable social production cycle, contributing to the Sustainable Development Goals (SDGs) achievement, giving greater credibility to the sustainable activities carried out by your company. The continuous expansion will depend on overcoming challenges: technologies appropriate to organic production systems, the need for progressive increments in areas of arable land under organic management to meet growing consumption, the standardization of certification criteria and the great concentration of world demand for consumption [35, 60, 118–120].

3.3 Organic Cotton in Latin America

In Latin America, the production of organic cotton takes place in Peru, Brazil and Argentina, mainly being carried out by family farmers. According to the report of the Organic Cotton Market of the Textile Exchange (2019), the 2017/18 crop represented 0.29% of the global production of organic cotton. It counted with the participation of 1,172 farmers, and the planted area was 1,300 hectares of land, where 526 tons of feathered organic cotton were produced [35].

Peru is the largest producer of organic cotton in Latin America and its production is responsible for 2.3% of the overall cotton production in the country. Brazil is the second, and Argentina occupies third place in the production of organic cotton [35].

The organic certification adopted by farmers is done through certification by auditory and through the Participatory Guarantee System. Some companies and farmers' associations access other types of certification, such as Global Organic Textile Standard (GOTS) and Fair Trade.

Production is supported and monitored by the following institutions:

- Bergman Rivera Service Company—located in Peru;
- SoCiLa Non-profit—located in Colombia;
- Stay True Social Enterprise—located in Argentina;
- EMBRAPA Cotton, ESPLAR, EMPAER, Textile Exchange, Renner Stores Institute, Food and Agriculture Organization of the United Nations (FAO/WHO), Laudes Foundation, DIACONIA, ASPTA and Sustainable Fashion Lab—all located in Brazil.

In Latin America, cotton production is being encouraged through the actions of the *Projeto + Algodão* ("Project + Cotton"), which has been developing actions since

2013. The project is a partnership between FAO, the Brazilian government and seven other countries in Latin America and the Caribbean (Argentina, Bolivia, Ecuador, Colombia, Paraguay, Peru and Haiti), which were organized through Trilateral South-South Cooperation. One of the project's objectives is to achieve SDG targets, which could be a strong ally in organic cotton production in the near future [121].

3.4 Organic Cotton in Brazil

Organic production began around the 1940s, arriving in Brazil around 1989 [74]. Cotton is a plant that resists drought, so it is an option for planting in semi-arid regions, which generally do not have many alternatives for the population in rural areas of income generation. Besides its resistance, in cotton, almost everything is used; the seed and fiber are the most relevant, representing around 65% and 35% of production weight, respectively [122].

In Brazil, the cultivation of organic cotton, whether white or naturally colored, is produced through agricultural cooperatives and/or small farmers due to the needs of the management itself. The technical limitations end up including small farmers in the production chain, thus generating gains and social inclusion [123]. In addition to economic gains, there is also an improvement in life quality, health and well-being. In the environment, it is important to highlight the value of biodiversity, in addition to the non-use of water, since the water coming from the rains is sufficient to irrigate the plantation and since there is no use of pesticides, there is also no environmental contamination [82].

The production of organic cotton in Brazil is made by small producers in a scheme of family labor. The production of organic cotton in Brazil, carried out by family farmers, is concentrated in the semi-arid Northeast (Paraiba, Piaui, Pernambuco, Rio Grande do Norte and Ceará). The states of Alagoas and Sergipe are also producing; however, their areas are transitioning. Among the Northeast states, only Paraiba and Ceará produce white and colored organic cotton. In the state of Mato Grosso Sul, family farmers work with the production of colored organic cotton.

The data presented below are from the Organic Cotton Market Report—Textile Exchange [83]:

- Planted area: 619 ha, of this total amount, 358 ha PGS certified;
- Number of family farmers: 930, out of this total, 700 PGS certified;
- Organic cotton production: 22 tons, of this total value, 13 tons PGS certified;
- Area planted in the process of organic transition: 318 ha; of this total, 30 ha are under the responsibility of the PGS.

In this way, in the agricultural aspect, the management adopted for cotton crops in large areas is practically established. Still, the main challenge for organic cotton production is to put into action more researches with cotton-organic/agroecological management [53].

Table 4 Advantages of growing organic cotton compared with conventional farming [85]

	Conventional cotton	Organic cotton
Environment	Pesticides kill beneficial insects	Increased bio-diversity
	Pollution of soil and water	Eco-balance between pests and beneficial insects
	Resistance of pests	No pollution
Health	Accidents with pesticides	No health risks from pesticides
	Chronic diseases (cancer, infertility, weakness)	Healthy organic food crops
Soil fertility	Risk of declining soil fertility due to use of chemical fertilizers and poor crop rotation	Soil fertility is maintained or improved by organic manures and crop rotation
Market	Open market with no loyalty of the buyer to the farmer	Closer relationship with the market partner
	Open market with no loyalty of the buyer to the farmer	Option to sell products as 'organic' at higher price
	Dependency on general market rates Usually individual farmers	Farmers usually organized in groups
Economy	High production costs	Lower costs for inputs
	High financial risk	Lower financial risk
	High yields only in good years	Satisfying yields once soil fertility has improved

Besides that one related to the agricultural activity, many other actors are involved in the organic cotton chain in Brazil, constituting a network. The main actors and respective roles of this organic cotton network in Brazil are summarized in Table 4.

One of Brazil's firsts organic cotton network dynamics includes the French shoes' brand named "Veja". Since its beginning, Veja has been signing one-year contracts with farmers' associations and setting a market price per kilo of organic cotton. Veja also pre-finances the harvest up to 50% and pays a premium per kilo of cotton produced that associations must use to develop community projects. The agricultural approach farms use based on mixed farming provides food independence and maintains nutrient balance in cultivated land (agroecological practices). These families are in rural communities and cultivate cotton together with other crops such as beans, corn, sesame, manioc (cassava), sunflower, and pumpkin in areas of maximum of two hectares. They benefit from regenerating the land, producing food and commercializing diverse products. In 2018, more than 23 tons of agroecological cotton was bought by Veja directly from seven different associations in northeast Brazil. This cotton was cultivated by 259 families [124].

The second dynamic and very important one is this one initiated by "Laudes Foundation", "Embrapa Cotton" and "Diaconia". The objective of the Program "Agroecological cotton cultivated in consortium with food crops" is the expansion of organic cotton supply network. At the beginning of this project, in 2017, 2 tons of organic

cotton was produced and 80 smallholder farmers were involved. This number has significantly increased with the expectation of 50 tons to be produced in 2019 and more than 900 farmers producing cotton. This increased productivity has a lot to do with the intensive capacity-building for agroecological intercropping management and processing. Another objective is to guarantee women's effective participation and recognition in both agricultural activities and political organization. More than 160 women have taken on leadership positions in their communities in these three years of the project. This program has also strengthened OPACs to obtain the certificate of organic compliance and consolidate the producers' network and autonomy. There is an important role undertaken by "Laudes Foundation", which relates to the participation in negotiation between representatives of OPACs and potential buyers of cotton. Besides strengthening local farmers' collectives, the Program also aims to create a regional network to promote collective actions. With a focus on income generation, development of family-based social organizations, conservation of natural resources, and introduction of smallholders into fair trade and the organic market, the initiative will benefit at least 1,000 families by the final of 2020. The main buyers of the organic cotton produced are the brands Veja and "Organic Cotton Color" [125–128]. Laudes Foundation has also been working with ESPLAR and Embrapa Cotton to expand the production of Mocó (*G. hirsutum* subsp. marie gallant) organic cotton supply (long and resistant fiber) in Ceará State [53].

The third dynamic is called "Institute Casaca de Couro" (in reference to the Caatinga singer bird *Pseudoseisura cristata*). The Institute is formed by Coopnatural, EMBRAPA Cotton, EMPAER, Norfil and other organizations. Their partnership includes actors that understand the organic cotton reality in Paraíba state (Brazil), offering technical support to the small producers and its families and straightening the dialog with the textile industry, considering the increase of organic cotton fabrics production. The main aim is to support local communities, the environment, and the development of Caatinga Biome (the driest area of Brazil), including the cultivation of native plant species for coloring the produced cotton clothes [129, 130].

The fourth is organized by company "Natural Cotton Color", which commercializes textiles and produces and commercializes clothes and bags, mainly for exportation. The company is connected with family farmers from the "Margarida Maria Alves community" in (Juarez Távora, Paraíba state, Brazil) and also works with natural colored cotton [124].

Figure 10 overlooks the process from farm to clothing in the regions cited above.

3.5 Motivations and Constraints of Organic Cotton

Whereas speaking about smallholder organic cotton farmers in developing countries, the following motivations are stated as the most important ones: (i) to improve the fertility of the soil (softer soil, greater absorption of water, better water holding capacity, healthy crops); (ii) to reduce the production costs and thus the financial risk; (iii) to get a better price for the cotton (organic premium); (iv) to get rid of the

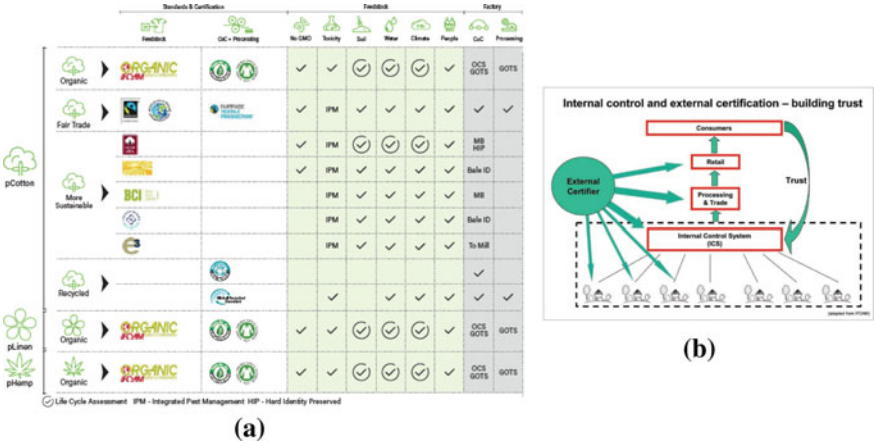


Fig. 10 **a** Cotton standards and certifications [83]; **b** Internal and external control in an organic cotton project (adapted from IFOAM) [27]

negative effects of conventional farming: declining yields, the resistance of pests and diseases, health hazards of chemicals; (v) to improve the profitability of the farm in the long run [98].

However, various issues hinder the adoption of organic cotton production. These include production problems, particularly insect and weed control, and marketing problems, particularly price variability and unstable, underdeveloped markets, crop rotation problems, lack of organic cotton marketing information, and organic certification issues. One of the most important aspects of organic cotton production and expansion requires improvement in marketing and market linkages between cotton producers and international organic cotton buyers, including access to market information distribution channels. Improvements in all these areas are needed to promote organic cotton properly [100]. Some challenges are also linked with lack of information on cost of production and production methods, lack of work force and tax incentives, unstable market, development of new markets and international certification issues [41, 60]. Table 5 summarizes the main topics.

In this way, complementing the literature information, motivations and restrictions (challenges) for planting organic cotton and its consortia observed by the present authors are highlighted in Table 6.

Furthermore, from the textile and clothing perspective, there is a lack of publicly available data on more sustainable cotton as well as a need for consistent uptake production reporting. Greater transparency and coordination between standard organizations would support by providing the sector with clear indications of market demand and understanding where the bottlenecks are in the supply chain. Thus, companies have numerous concerns about more sustainable cotton supply chains, including issues such as the disconnection between harvest and production times combined with the unavailability of stocks; the challenge of adapting to new suppliers and different business practices, and; the lack of supply of certain qualities of cotton

Table 5 Motivations and restrictions (challenges) for planting organic cotton and its consortia (Authorship)

Motivations	Restrictions (challenges)
Improving food security, family health, and the economic situation that organizes property income	The need for a closer relationship between farmers and purchasing companies to accordance the organic market related to production processes in the field
The women participation in organic cotton production in agri-food consortia in developing countries is more frequent due to the non-handling of dangerous chemicals. The access to training and financial income for women has a positive impact on their social autonomy	The improvement of the organic certification process to comply with laws and regulations related to organic products and processes
Young people have the opportunity to participate effectively in the productive actions of the property. The production of organic cotton in agri-food consortia has a positive impact on their financial independence and activates the process of rural succession	Difficulty in accessing organic inputs such as bioinsecticides and seeds with organic certification
The diversified cultivation with the use of natural fertilizers and pesticides, let the environment clean and balanced, where groundwater and water reservoirs are free of chemical contaminants. The biodiversity of the property systems and subsystems is improved	Expansion of the market for machines and implements adapted to production systems combined with field activities and processing of organic products. The prices of machines and implements are most often incompatible with the reality of small cotton producers
Enabling the organization of their participatory certification institutions, generating autonomy in the commercialization process	Access to a market with a fair price and compatible with the organic quality of the other products of the agri-food consortia

Table 6 Comparison of production cost between conventional, BCI, fair trade, organic and organic-fair trade for a T-shirt [48]

	Conventional Cotton		Better Cotton Initiative			Fair Trade Cotton			Organic Cotton			Organic-Fair Trade Cotton		
	USD/kg	B/down	USD/kg	B/down	Differential	USD/kg	B/down	Differential	USD/kg	B/down	Differential	USD/kg	B/down	Differential
Seed cotton price farm gate	0.61	6.4%	0.62	6.1%	2.0%	0.67	5.9%	8.9%	0.64	5.6%	4.0%	0.69	5.8%	12.9%
Ginning, baling, transportation, handling & seed recovery	0.84	8.8%	0.94	9.2%		1.03	9.1%		0.96	8.4%		1.08	9.2%	
Fiber price ex mill	1.45		1.56		7.7%	1.70		17.0%	1.60		10.4%	1.77		22.4%
Spinning, packing, transportation & margin	1.50	15.8%	1.55	15.2%		1.61	14.2%		1.57	13.7%		1.65	13.9%	
Yarn price ex mill	2.95		3.11		5.6%	3.31		12.3%	3.17		7.5%	3.42		16.2%
Knitting, dyeing, finishing, loss, transportation & margin	1.47	15.5%	1.50	14.7%		1.54	13.5%		1.51	13.2%		1.56	13.2%	
Fabric price	4.42		4.61		4.4%	4.85		9.6%	4.68		5.9%	4.98		12.7%
Certification & traceability		0%	0.06	0.6%		0.15	1.3%		0.15	1.3%		0.15	1.3%	
Total fabric price	4.42		4.67		5.7%	4.99		13.0%	4.83		9.3%	5.13		16.1%
Fabric usage per t-shirt @ 13% fabric usage	**0.57**		**0.61**			**0.65**			**0.63**			**0.67**		
Standard marking	0.03	2.2%	0.03	2.2%		0.03	2.0%		0.03	2.0%		0.03	1.9%	
Accessories / printing	0.28	23.0%	0.28	21.3%		0.28	19.2%		0.28	19.1%		0.28	18.4%	
Packing	0.11	8.6%	0.11	8.0%		0.11	7.2%		0.11	7.2%		0.11	6.9%	
Cutting, making & trimming	0.24	19.7%	0.24	18.3%		0.24	16.5%		0.24	16.4%		0.24	15.8%	
Integrity, certification & traceability			0.06	4.5%		0.16	11.1%		0.19	13.1%		0.21	13.6%	
FOB price per t-shirt	**1.23**	**100.0%**	**1.33**	**100.0%**	**7.7%**	**1.48**	**100.0%**	**19.6%**	**1.48**	**100.0%**	**20.3%**	**1.54**	**100.0%**	**24.6%**

or from preferred locations. Brands and retailers have a crucial role to play as they can pull the sector toward greater sustainability by demanding and sourcing more sustainable cotton [16].

3.6 Market Potential

Market demand for textiles made from organic cotton mainly exists in Europe, the USA, Canada, Japan and Australia [7]. Some large companies become involved with organic cotton textiles in order to improve their corporate image with respect to environmental and social accountability. The main reasons for consumers to buy textiles made out of organic cotton are: To reduce the risk of skin irritation and allergies; To protect the environment from toxic chemicals; To support sustainable agricultural production in the country where the cotton is grown; To ensure that the farmers in developing countries receive a fair price [98].

It is important to avoid contamination throughout the entire organic cotton processing chain and separate organic from conventional cotton. As most spinning mills and processing entities process organic and conventional cotton on the same machinery, it is important to separate the cottons and clean the equipment before processing an organic lot. Some labels and brands have certain restrictions on which dyes can be used. Initially, most organic cotton was processed into garments containing 100% organic cotton fiber. Some large garment brands have recently decided to blend a certain percentage (usually 5–10%) of organic yarn into their entire range of articles rather than selling purely organic clothes. This could increase the demand for organic cotton fiber considerably. Companies can communicate to their customers that they support organic cotton farming, which helps them to improve their corporate image [98]. The main organic cotton markets are presented in Fig. 11.

In the future, a number of changes to the cotton production industry are likely to affect the shape and scope of the value chain. It is predicted that the demand for organic cotton will grow substantially in the coming years [10]. This demand is likely to be increasingly met by producers in developing countries, who are now benefiting from better support services, know-how, and the economic and regulatory infrastructure necessary to allow them to shift to organic production [8].

Fig. 11 **a, b** Conventional cotton farming in Brazil for scale production [63]; **c** mechanical harvesting [63]; **d** Conventional cotton crop at Brazilian Cerrado biome [63]; and **e** bales transport [63]

In the event "Brazil Eco Fashion Week" (São Paulo city—Brazil, 2019), the Natural Cotton Color company presented a new denim ("jeans") manufactured with BRS Rubi fibers (Fig. 6b). This product had wide approval at the "Première Vision" (Paris—France), considered the main international textile fair. Besides denim, the company developed other new materials, including a biodegradable elastane and a fabric combining colored organic cotton and silk. This segment tends to grow and have a strong impact on the future market, based on customer demand and the trend toward more sustainable field practices and circular materials [53].

Engagement of stakeholders will motivate them to take ownership of initiatives and improve production and market coordination [131]. Collectivism may be conducive to loyalty and at the same time promote creativity and diversity of solutions. Organic production involves collaboration between network participants in terms of transparency, sharing information on technical and managerial practices, and fair trade and price-related contractual agreements [60].

3.7 Communicating Organic Cotton in Retail

Organic cotton cultivation has been gaining notoriety in recent years and increasing its production in planted hectares and amount of production [132, 133].

As the cultivation of organics has grown, so has the relevance of sustainable issues in production, aiming at sustainable development and practices to curb environmental and social disasters [123]. In this way, sustainable products are beginning to integrate some environmental costs into business practices. In retail, they are beginning to express values to the consumer, not just monetary issues, but also influence cultural thinking [134].

Advertising is considered to be informative and wishful thinking, seen as fundamental for placing new products on the market and increasing sales. However, this requires consumers to be educated about the impacts of clothing production and sustainability, so that attitudes and behaviors can be changed [135].

Flavia Aranha is one of the main clothing brands utilizing organic cotton in Brazil. The brand also works with natural dyes, emphasizing more sustainable processes. It started in 2009, working with natural fibers such as organic cotton, linen, silk and wool. Using fabrics from Natural Cotton Color, an organic cotton chain organized in the state of Paraíba (Brazil) and "Justa Trama", a chain located in the Brazilian states of Ceará, Sao Paulo and Rio Grande do Sul. The brand prefers organic cotton considering the land regeneration potential, soil and water sustainable use.

The company carries the name of the owner and director, Flávia Aranha. According to Flavia "The challenge of organic cotton is not in the technique of cotton cultivation itself. The challenge concerns the perspective of the industry as an all, understanding the materials and the chains. It's a mindset-changing challenge."

The brand uses different communication tolls to engage and educate costumers. The product tag contains a short text explaining about Brazilian plant-based textile fibers and pigments and the sustainable process utilized in production. Also, the QR

Fig. 12 **a** Manual harvest agroecological cotton in the Tiracanga rural settlement, Canindé (Ceará, Brazil) [89]; **b** C&A Foundation´s Sustainable Cotton Program in Brazil - Araripina Community Field Work (Brazil's Caatinga biome) [90, 91]

code inside the clothes has a link with videos explaining the process of the outfit manufacture, showing the fabric, the color, the plant extraction, sewing, etc., and always looking to the most affective and real way to tell these stories. Also, since the first collection, all clothes were packed with organic cotton bags. In the Flavia Aranha store, the brand promotes events and workshops. Nowadays, how to bring the brand experience to the digital platforms is the main challenge (Fig. 12).

According to Magnuson et al. [136], most customers do not know-how their clothes were manufactured. It would be up to the brand to inform them about the production processes and materials used, adding value to the product. Communication in retail and e-commerce becomes essential to prospect and inform new customers about ethics and social-environmental responsibility [137, 138]. In Araújo et al. [139], it is mainly through communication that consumers come to know the identity, value purpose of brands and their products so that they become known in fact and reach their target audience.

4 Sustainable Network Management

The so-called chain processes are the most used to analyze the macro-processes of production in order to ascertain performances, bottlenecks, productive and managerial processes, always to improve efficiency, quality, competitiveness and sustainability [140]. Moving from the language of commodity *chains* to commodity *networks,* Raynolds [141] helps portray the complex network of material and nonmaterial relationships connecting the social, environmental, political, and economic actors enmeshed in the life of a commodity, such as cotton. Understanding how individuals, firms, government authorities, and nongovernmental organizations (NGOs) are involved in economic and social transactions and how network relations shape these different actors both shape and. The network concept is increasingly used in

studies of the horizontal and vertical relations among global manufacturing firms [141].

Many innovative approaches may contribute to delivering sustainability through business models but have not been collated under a unifying theme of business model innovation [142] that could include:

- A system that encourages minimizing of consumption or imposes personal and institutional caps or quotas on energy, goods, water, etc.;
- A system designed to maximize societal and environmental benefit, rather than prioritizing economic growth;
- A closed-loop system where nothing is allowed to be wasted or discarded into the environment, which reuses, repairs, and remakes in preference to recycling;
- A system that emphasizes delivery of functionality and experience, rather than product ownership;
- A system designed to provide fulfilling, rewarding work experiences for all that enhances human creativity/skills;
- A system built on collaboration and sharing, rather than aggressive competition.

Moreover, delivering environmental and social sustainability initiatives such as [142]:

- Employee welfare and living wages;
- Community development: Education, health, livelihoods;
- Sustainable growing and harvesting of food and other crops, minimizing chemical fertilizers and pesticides, water consumption, and top soil erosion;
- Environmental resource and biodiversity protection and regeneration.

In order to generate a sustainable network, improve research, gain credibility and fulfill missions of sustainable processes, several companies join NGOs that aim to promote sustainability through organic products, fair trade, and social responsibility. At this junction, both gain and generate greater confidence in the consumer and added value, since the consumer perceives this junction as beneficial and contributing to sustainability, in addition to improving the lives of the participating communities [143].

Therefore, collaboration is particularly relevant because it represents a chance to improve the chain's competitiveness and farmers' well-being. One of the principles of organic and fair trade funding, which translates into certification rules of transparency and, most pertinently, for fair trade and joint management procedures [144]. Thus, sustainable commodity systems will require participation and cooperation throughout the chain [145].

Glin et al. [9] analyzed the social dynamics that connect actors and practices within the organic cotton network, particularly flows of information and knowledge, trust-building mechanisms, and power relations among actors from production level to global market level. The research of these authors well-described network challenges in Benin, which are apparently very similar in Brazil. Linking small producers to markets and integrating them into value chains is widely recognized as a valuable way to reduce poverty. However, little is known about the precise conditions under

which this is most likely to occur. Smallholders are often illiterate, under-educated, lack management and technical skills, and have poor access to information (about quality, buyer demand and standards). Larger farmers have more bargaining power and better access to capital, information, finance and technology [57].

So, initiated by intergovernmental sustainable development cooperation, a transnational organic cotton network evolved into a hybrid structure, combining private economic actors and domestic and international NGOs. National and international NGO networks opened spaces for value sharing and information exchange and played a brokering role in linking local producers to the global organic cotton market in Europe and vice versa [9].

International conferences and events provided important occasions for establishing linkages between organic cotton promoters and businesses, and they strengthened the organic movement. Trust was a critical factor in recruiting farmers and ensuring their continued participation in the organic cotton production system and in securing the organic profile for European customers (Fig. 13) [9].

As sustainability labeling is gaining momentum in the global apparel industry, opportunities for market expansion are related to the creation of farmer organizations [10, 146, 147]. This will allow small farmers to be more competitive, achieve economies of scale, reduce transaction costs, enhance their bargaining power, improve their market information, access technology, manage common pool of

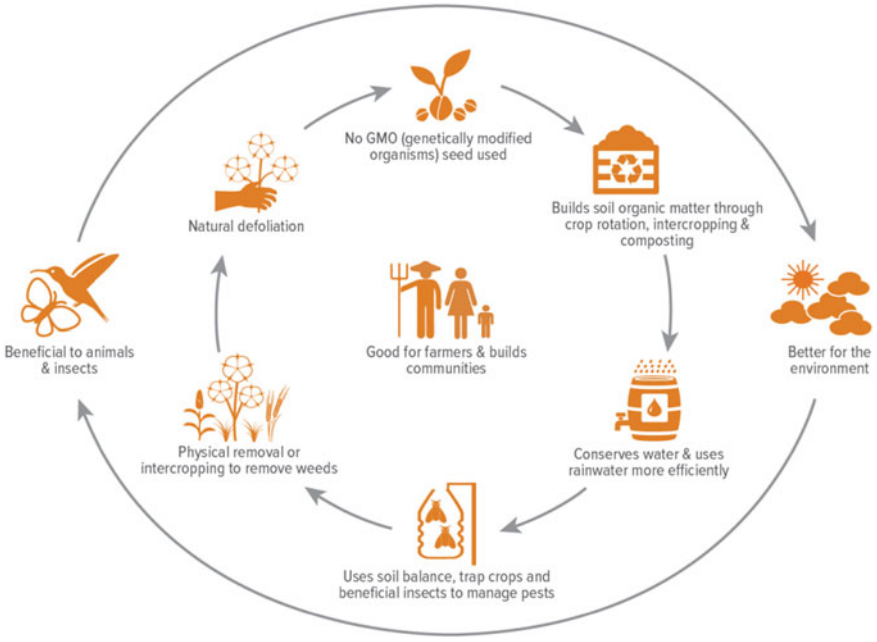


Fig. 13 Organic cotton benefits and main characteristics [31]

resources and reduce certification costs [8]. In this way, considering the various involved actors, the main advantages could be summarized as follows:

- For *farmers*, a range of perceived advantages was found to motivate converting to organic farming, including higher market prices for organic cotton (premiums), reduced costs for agricultural inputs, services provided by support organizations (e.g., access to credit, provision of seeds, marketing support, training), reduced health risks and soil improvements [101]. As many traditional farmers in developing countries are not well educated and lack the channels to share their experiences, many of these costs remain unacknowledged [148]. Potential advantages to cotton farmers, including lower expenses for farm inputs, healthier soils, diverse Sources of income, and higher prices, may be able to offer higher gross margins than conventional cotton farming [11].
- For the *textile and clothing industry*, many factors affect the growth of the organic cotton industry. These include consumer demand for organic products, a recognition by firms of the benefits in terms of sales and profits from the increasing consumer awareness of organic methods, and the institutionalization and regulation of the industry with its attendant reputational benefits [144].
- For *retail*, the market innovation in its production procedures and client's engagement can contribute to communicating to stakeholders the companies practice regarding cultural, social and environmental aspects [136–138, 149]. Opportunities for exports, particularly to the European markets, create further demand pressures on the industry, for environmental improvements including more formal certification [150], expecting to cover more than niche markets.
- For *clients*, considering the growth factors in the organic cotton industry, consumers and the various media have played probably the most important role in raising ethical expectations of business and achieving public visibility of corporate social responsibility issues. Among recent changes in consumer habits and preferences, increased awareness about sustainability is one of the most important elements [14]. Although there are a number of forces encouraging the move to organic production, other forces counteract these. Prices of organic cotton garments are still high to encourage the migration of the mass market to them. There is also, still, a lack of awareness of the consequences of the different production methods [8].

4.1 Trustability and Transparency

Since 2006, many companies have committed themselves in the long term to increase the use of organic cotton, thus enabling new brands and retailers to enter the market [143]. It is important that such companies provide sustainability reports and produce environmentally friendly collections [151].

Any large apparel brand often consists of thousands of suppliers, distributors and retailers [152]. Concerning a global supply chain that employs 58 million people

Fig. 14 Top 10 countries for organic production and certified facilities and top ten users by volume [48]

worldwide [153], this complexity introduces myriad challenges associated with monitoring, reporting, compliance and improving sustainability practices [154].

In the competitive fashion product market, the organic label can generate successful differentiation, promoting and encouraging profitability as well as consumer loyalty [155]. In this case, consumers recognize social values and seek a better quality of life [156]. The motivations of ethical consumers are their concerns about the fair trade, fair remuneration, etc. [157]. With this scenario change, many textile and clothing companies have increased their mindset transformation, toward consumers engagement [158] (Fig. 14).

Multi-stakeholder initiatives, acting beyond commercial interests, can offer guidance and promote network cohesion. The industry united around an agenda for change can drive the needed systemic change and work jointly on disruptive innovation [159]. Collaborative relationships emerge among the actors who can achieve complementary benefits by integrating their functional specializations and building a collective intelligence [160]. In other words, actors are individually intelligent, they are purpose-driven and they can mobilize resources through collaboration [161]. As a consequence, trusting relationships are often depicted as the essence of collaboration [162]. Trust is the outcome of a gradual, coherent and consistent long-term effort (Fig. 15).

As a driver of innovative and sustainable business models in fashion, collaboration refers to adopting a collaborative mindset by all stakeholders involved in a sustainable value network: suppliers, distributors, customers (who often are involved in co-creating initiatives), and even competitors. Collaboration allows the creation of a

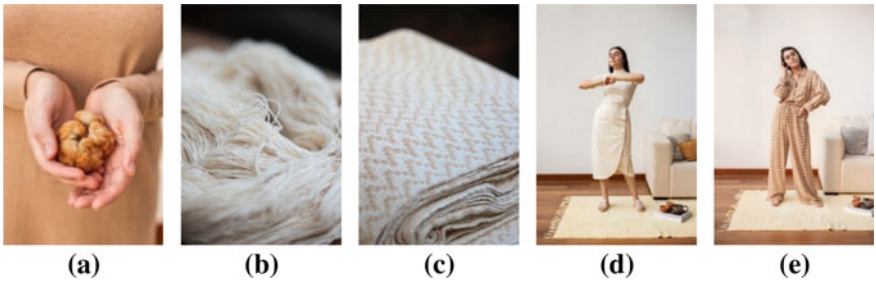


Fig. 15 Flavia Aranha Collection "The harvest", using organic cotton fabrics from Natural Cotton Color and Justa Trama [132]

supporting ecosystem that drives resource and knowledge sharing, promotes sustainable practices, and ultimately allows business model experimentation. As a result, it is critical to relate value creation (key activities, key resources, and key partners), distribution (delivery channels and customer relationship), and potential impacts on cost savings and revenue structure, as many collaboration initiatives involve revenue sharing [14] (Fig. 16).

This process is largely due to changes in consumer needs [163], therefore the transparency of the entire production cycle is essential because it is where the increase of consumer confidence lies [164].

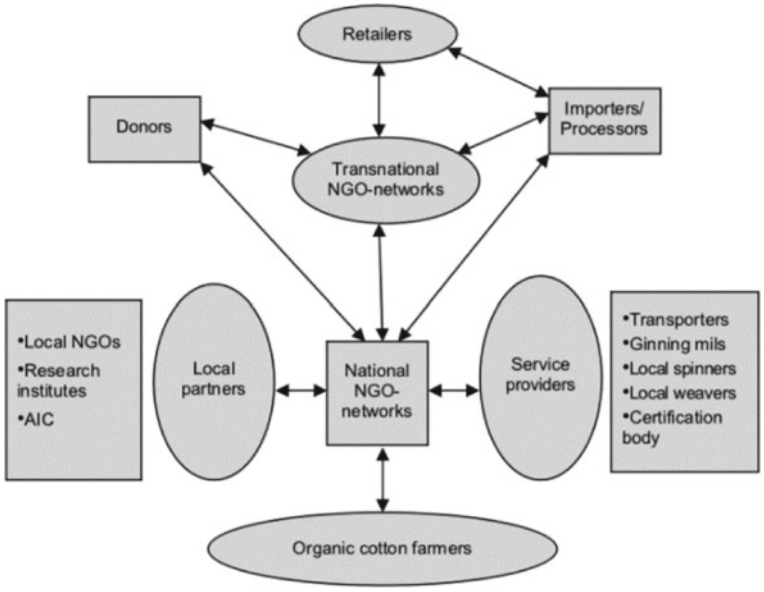


Fig. 16 The transnational organic cotton network [5]

The fashion system is dependent on flows of resources: fiber, chemicals, energy, water, human labor. The global environmental costs and consequences associated with fashion production and consumption are widely documented [165]. Therefore, it is necessary to have a vision of the whole system since several processes are related through the flows of materials, capital and information, always aiming to meet the market demand [140].

4.2 Small Scale and Better Quality Process

There is a growing need for the unique and the traditional. More customers want a one-of-a-kind, natural products, and are increasingly reverting to the idea of quality products. Old crafting techniques are gaining in value. Accordingly, small-scale companies have the ability to be flexible and innovative, which is crucial in order to take the time to create hand-crafted and exclusive designs. They are able to involve their customers, creating emotional value and belonging. Their clients are more likely to feel attached to their purchases and to keep them on the long term [166].

Traditional handicraft does not demean new technologies. They are compatible, as was pointed out by trend forecaster, Lidewij Edelkoort (one of the world's most famous trend forecasters), who believes that the two phenomena enrich one another. When technology provides new material options and smart machinery, the implementation of traditional handicraft techniques to create strong, durable and beautiful designs out of them gets accessible. Increasingly large-scale businesses are outsourcing their innovation to small, highly specialist organizations, which in turn help them to stay ahead of the crowd and remain unique while also spreading awareness and standards [57, 166].

4.3 Local Materials and Local Design

Clothing companies must face challenges posed by demand unpredictability and must adapt to a new, competitive environment [145]. But also increasingly time-based competition and mounting consumer sensibility to social-environmental issues [167], have driven fashion companies to reorganize their supply networks, searching for a new balance between local and global sourcing and production.

Fletcher and Tham [165] detailed their perspectives for the future, based on eight values: (1) Multiple centers, (2) Interdependency, (3) Diverse ways of knowing, (4) Co-creation, (5) Action research, (6) Grounded imagination, (7) Care of world, (8) Care of self.

Multiple centers include diverse ways of knowing; direct experience, practice, indigenous knowledge, artistic exploration, spirituality, and theory, among others. The promotion of multiple centers and interdependency in unison foregrounds specific skills of *collaboration*, *listening*, *dialog* and *linking*. In practice, co-creation

requires a high level of collaboration between all involved which reaches beyond knowledge exchange and generates new ideas and actions. Imagination is a creative living process [165].

Motivating changes in the fashion system is a challenge to sustainability, and great potential since fashion affects the lives of almost everyone on a daily basis and has the potential to be effective in changing intentions, attitudes and behaviors [168].

As a way to add value to their products and meet consumer demand, a new generation of designers is already concerned with sustainable processes and materials. With motivations and information, these professionals seek innovative social and environmental solutions [96].

Sustainable clothing and fashion seem to be not just a trend but a movement toward changing paradigm. Fundamental in the movement, more aware consumers with their demands seem to be increasing. From supporting handcrafts and traditional local communities, using biodegradable and renewable fibers to supporting textile natural dying technics, second-hand clothes and upcycling. Furthermore, companies also began to assess the impact of not acting toward consumers choice in supporting and purchasing more sustainable products and brands [169].

In such a new textiles economy, clothes, fabric, and fibers are kept at their highest value during use, and re-enter the economy after use, never-ending up as waste. Designing and producing clothes of higher quality and providing access to them via new business models would help shift the perception of clothing from being a disposable item to being a durable product. To achieve system change, buy-in to the vision needs to be built across different actors, including industry, government and cities, civil society, and the broader public. None of these groups can do it alone. In particular, ambitious, common, time-bound commitments to the vision are required. The principles of transparency, compliance and sustainability are mandatory for all members and their activities of an organic network to the same degree of responsibility and commitment [170].

5 Conclusion

The fashion system is dependent on flows of resources: fiber, chemicals, energy, water, human labor. The global environmental costs and consequences associated with fashion production and consumption are widely documented. Cotton is one of the primary resources in many industries and with increasing demand rates. The cotton production chain is divided into production, processing, spinning, weaving, confection, and consumption. Therefore, it is necessary to have a vision of the whole system, since several processes are related through the flows of materials, capital and information, always aiming to meet the market demand. In addition, there is a need for increasingly seeking mechanisms to close the life cycle of materials, without leaving aside their nature and concept. The interest in organic cotton production has been increasing every year, yet the production still faces difficulties regarding articulation with the textile and clothing sector and the market. Multi-actors' initiatives and

programs, acting beyond commercial interests, could offer guidance and promote cohesion to the network. Organic agriculture especially together with agroecological practices, has a major role to play in assisting with resource management, such as reducing water demand, diminishing soil erosion, maintaining and enhancing biodiversity. Thus, to persuade a systemic change in the current model of textile production, it is necessary to generate solid connections, educate, and involve the society to build a joint vision of a sustainable and creative economy with financial, social and environmental purpose.

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