Socioeconomic and Environmental Aspects of the Production of Silk Cocoons in the Brazilian Sericulture

Silvia Mara Bortoloto Damasceno Barcelos, Rodrigo Salvador, Graça Guedes, Eliane Pinheiro, Cassiano Moro Piekarski, and Antonio Carlos de Francisco

Abstract Sericulture is extremely important in the socioeconomic context in Brazil. The country is the fifth largest silk producer in the world, and the silk produced in Brazil is internationally recognized for its quality. Nonetheless, sericultural activities have direct impacts on the silkworm rearers (sericulturists) and are also responsible for environmental impacts, caused by the exchanges of energy and material between the natural environment and the technical/technological environment. Based on that, this exploratory and qualitative study aimed to identify the aspects that affect the (i) socioeconomic and (ii) environmental conditions of silk cocoon production in Brazilian sericulture. Two surveys were designed to collect information on the socioeconomic and environmental aspects of sericulture. The data sets collected through surveys were treated using the NVivo software tool. The results present the socioeconomic and environmental aspects of the production of silk cocoons, and what measures could improve these conditions in order to provide a better quality of life for sericulturists and to improve the relationship of sericulture with the environment in order to guarantee continuity of the activity. In general, the results show that sericulture proved to be ahead of many other cultures with regard to socioeconomic aspects, as it is an alternative to the diversification of small rural properties, generating monthly income for families in rural areas. In addition, there is evidence of efforts to make sericultural activities less impacting on the environment.

Keywords Sericulture · Cocoon production · Silk cocoon · Silk · Socioeconomic aspects · Environmental aspects · Bioeconomy

S. M. B. D. Barcelos (✉) · E. Pinheiro
Universidade Estadual de Maringá (UEM), Cianorte, Brazil
e-mail: smbdamasceno@uem.br

R. Salvador · C. M. Piekarski · A. C. de Francisco
Universidade Tecnológica Federal do Paraná (UTFPR), Ponta Grossa, Brazil

G. Guedes
Universidade do Minho, Guimarães, Portugal

M. Á. Gardetti and R. P. Larios-Francia (eds.), *Sustainable Fashion and Textiles in Latin America*, Textile Science and Clothing Technology,
https://doi.org/10.1007/978-981-16-1850-5_1

1 Introduction

The fashion and textile industry is extremely important for the socioeconomic context in Brazil, accounting for an average production of 1.2 million tons of textile products, absorbing 1.5 million direct employees, and being the second largest employer in the manufacturing industry [1]. The socioeconomic importance of the textile and fashion chain in Brazil can be seen in the turnover of US$ 48.3 billion, with just over US$ 1.2 billion being the results of the export of almost 665 thousand tons of textile products, only in the first quarter of 2020. In the specific case of the export of textile yarns and fibers, focusing on silk, Brazil exported 144 tons, in the same period, obtaining a turnover of US$ 7,586 million [2].

Focusing on the sericulture (cultivation of silkworms to produce silk), Brazil is the world's fifth largest silk producer [24], where the state of Paraná is responsible for 84% of the country's production, representing 2,533 tons of green cocoons. The silk produced in Brazil is internationally recognized in terms of the quality of fibers and for its sustainable economy [23], making the Brazilian silk greatly demanded worldwide by fashion designers [3]. However, such volume and importance of the production of silk also raise environmental and socioeconomic awareness over the activity.

In the current context of the textile/fashion value chain, where there is a need for a paradigm shift toward less environmental and socioeconomic impacts, silk is a product of increasing importance. Silk is a renewable raw material with low environmental impacts, in addition to its exceptional characteristics related to thermophysiological comfort and touch [7, 19].

The cultivation of mulberry trees and the rearing of silkworms comprise the two main activities performed by the sericulturists (who are the silkworm rearers), mainly done in small rural properties, characterized by family labor, providing them with a monthly income throughout the nine-to-ten months a year, using a small piece of land [30]. The socioeconomic aspects and the relatively low environmental impacts of the activity contribute to Brazil's sustainable development [10]. Sericulture is an agroindustrial activity and requires relatively small investments and simple technology, thus being considered a booster of family businesses in rural areas.

Sericulture is essentially important in improving the quality of life of the sericulturists and their families, in the Brazilian economy, and especially in the economy of Paraná, the state that concentrates the largest production of silk cocoons in the country [11]. Moreover, sericulture can help keep the rural population employed, preventing migration to large cities and guaranteeing paid employment. It requires small investments and provides the raw material for the textile industries. In this sense, Brazilian silk is an agent of economic and social transformation, strengthening small municipalities, cities, and sustainable communities in Brazil [3]. Nevertheless, although seemingly simple, both the cultivation of mulberry trees and the rearing of silkworms require the use of chemicals, which might bring negative impacts to both human health and the environment, on top of requiring from sericulturists long labor-intensive working hours.

Most of the studies addressing sericulture and silk production in the world that can be found in the existing literature address the context of Asian countries. Moreover, existing studies are usually focused on production processes, production costs, and productivity. Therefore, there is a lack of studies on the socioeconomic and environmental aspects of sericulture in the context of the textile chain, especially in Brazil, as many studies that refer to silk and its production processes do not reflect the production reality of Brazilian silk [11].

In light of the aforementioned, this chapter sought to answer the following research question: what aspects of silk cocoon production affect the socioeconomic and environmental conditions of sericulture in Brazil? Therefore, the objective of this chapter is twofold: identify the aspects that affect the (i) socioeconomic and (ii) environmental conditions of the silk cocoon production in Brazilian sericulture.

2 Background

2.1 Global Scenario of Silk Production

As a natural fiber, silk is a fibroin secreted by the silkworm in the form of a continuous filament, which forms the cocoon. This continuous filament is of great commercial importance. Its natural properties make silk unique, besides having natural luster and exceptional characteristics related to thermophysiological comfort and touch [25].

Many types of silkworms have been reported to be used in silk production. There are silkworms that are reared outdoor such as *Antheraea assamensis* (fed on *Persea bombycina* or *Litsea monopetala*, which are non-mulberry trees), and some that are reared indoor, such as *Samia cynthia* (fed on *Ricinus communis*), *Bombyx textor*, and *Bombyx mori* (fed on *Morus* trees) [28, 31, 44]. Moreover, there are five types of silk of commercial importance obtained from different species of silkworms, with the main one being a mulberry-silkworm [9].

The various types of silk have diverse applications in different sectors, such as luxury clothing, haute couture, furniture, upholstery, carpets, sewing, knitting, and embroidery [25]. Silk has excellent mechanical properties when tested as a biomaterial, and has shown to be biodegradable and compatible with cell interaction, in addition to being used in technical applications in filters (of different types), membranes, paper, textiles, leather, in the field of biosensors, and in the medical and biomedical sectors [7]. The use of silk in those and various other areas such as nutrition, cosmetics, biomaterials, bioengineering, pharmaceuticals, automobile manufacturing, home building, crafts, and arts contributes to the increase in the global demand for silk [8].

Silk production is widespread in 60 countries worldwide, 90% of which is concentrated in Asia and, more recently, in Brazil, whose production is 100% of mulberry silk [24]. The greatest silk producers in the world, considering production volume,

are China, India, Uzbekistan, Thailand, Vietnam, and Brazil; Brazil being the only producer of silk yarn on a commercial scale in the West.

In the global textile scenario, silk represents only 0.2% of the textile market. However, through sericulture, China employs around 1 million workers, India employs 7.9 million people, Thailand employs 20,000 families, and Brazil generates jobs for 2,310 families. Still in this scenario, the main world consumers of silk are the USA, Italy, Japan, India, France, China, United Kingdom, Switzerland, Germany, United Arab Emirates, Korea, Vietnam, among others [20, 23, 24].

Sericulture is considered extremely important in the fight against poverty since it prevents the migration of families from rural to urban areas, and it is also an employment opportunity for the rural population in several developing countries, Brazil being a good example [36]. Therefore, it is observed that silkworm rearing can be a lucrative activity for rural livelihoods [39].

Silk production also raises political and economic interests around the globe (see [32, 42]), greatly because silk production is concentrated in a few countries. International cooperation efforts have been launched in order to achieve better production and distribution of silk, mainly in Eurasia. Inter and intranational efforts contribute not only to political and economic agreements but also to technology and innovation exchange [42, 49].

Different levels of technicality can be found in different countries and different areas, which contribute to the varied quality of silk produced around the world. This permeates the feed production (silkworm feed, silkworm rearing and cocoon production, and yarn manufacturing). In Brazil, for instance, the level of technicality in the cultivation of mulberry trees (silkworm feed) and cocoon production is majorly supervised by the yarn manufacturer [12]. In other countries, though, this might be left at the sericulturists' discretion, which influences standardization, mainly in outdoor rearing.

Silk production also results in byproducts. The main product of all this process is the silk thread; however, portions of silk that are unreelable or tainted can be used to produce exquisite silk products [12], and the pupae, which is considered edible in a few markets [35].

2.2 Silk Production in Brazil

Silk production, as a sericultural activity, was introduced in Brazil in the nineteenth century, specifically in Rio de Janeiro. The first Brazilian silk industry was installed in the municipality of Itaguaí, the Imperial Companhia Seropédica Fluminense [38]. In the twentieth century, sericulture was established in the state of São Paulo, and later in Paraná [15, 38]. However, it was from the 1970s that sericulture began to spread in Paraná through the installation of factories and other investments [13, 15].

Until 1980, the national silk production was concentrated in São Paulo [14]. A few years later, in 1985, Paraná surpassed the production of other states, becoming the largest national producer of green cocoons [34]. The local climate was a factor

that favored the rearing of silkworms in the region of Paraná, in addition to incentives from the State government, making resources available to small producers [14].

Paraná faced a 46% drop in 2007, followed by an additional fall of 8% in 2010 in the production of green cocoons [14]. After this period of recession, it recovered due to the resumption of world demand for silk yarn, since most of Paraná's silk production was exported to countries such as Vietnam, France, Italy, and Japan [20].

The region known as the Silk Valley is located in the northwest region, with the highest cocoon production in Paraná, formed by 29 producing municipalities [20]. In addition, projections indicate that Paraná has the potential to increase its production by 50% in the coming years, where the intention is innovating to produce more on smaller properties [4, 17].

Silk production has been thriving in Brazil through its profitability, as a way to settle families in the countryside [22]. Sericulture is an activity that requires human, technical, and material resources and can optimize sustainable local, regional, and even the country's development [16], considering primarily its social aspects, followed by low environmental impacts [33].

Sericulture in Paraná is essentially developed by small and medium-sized farmers with family labor; and with the increasing mechanization of the activity, many producers continue investing in sericulture, due to the reduction of manual labor. The new technologies introduced in the sector aid the development of the activity [22], however, the technologies still need to reach the majority of silkworm rearers.

Brazilian silk production, in the 2016/2017 harvest, reached the figure of 2,968,849.61 kg of cocoons, where Paraná alone represented 83.28% of such production with 2,471,959.16 kg, followed by São Paulo with 349,312.95 kg and Mato Grosso do Sul with 147,577.50 kg, which were sold to the only spinning company in Brazil, Bratac [18].

2.3 Socioeconomic Impacts of the Silk Cocoon Production

Sericulture comprises two main activities, the cultivation of mulberry trees and the production of silk cocoons [30]. In this activity, sericulturists are susceptible to the dynamic international market, where the price of their products is subject to fluctuation and uncertainty, considering that 90% of the production of Brazilian silk is destined for exports [37].

The production of silk cocoons is important in the socioeconomic development of a given location, improving the quality of life of families in small rural properties, in addition to contributing to the generation of jobs, income, and taxes [30]. However, the majority of sericultural activities still comprise mostly manual labor, requiring exhaustive physical effort, in addition to some activities causing harm to workers' health. Among the possible problems, one can mention physical tiredness, body aches, health problems, reduced hours of sleep, psychological pressure, stress, contact with toxic chemicals, long working hours, night shifts, risk of accidents

involving fire and snakes, and environmental degradation caused by pesticides and other chemicals [37].

The aspects addressed are related to the cultivation of mulberry trees (the only food for silkworms) and the rearing of silkworms. Sericulturists come into contact with herbicides, pesticides, and fertilizers, in the cultivation of mulberry trees, and chemicals such as formaldehyde, chlorine, and lime, in the rearing of silkworms, for the disinfection and control of pests (sheds and grids), as well as contact with fire in the scorching of the grids.

Socioeconomic impacts that directly affect rearers can be observed in the production of silk cocoons, such as freedom of association and collective bargaining, child labor, working hours, forced labor, equal opportunity/discrimination, health and safety (working environment), social benefits/social security, education, and psychological working conditions.

A few aspects of the socioeconomic impacts in the silk cocoon production have been reported in research on silk production in India (see [29, 40, 41, 43]). In Brazil, existing research is generally focused on genetic improvement, the cost of producing silkworms, and cocoon quality and productivity. However, there are several aspects that contribute to the socioeconomic impacts related to the production of silk cocoons in Brazil, which are later addressed in this study.

2.4 Environmental Impacts of the Silk Cocoon Production

On top of socioeconomic impacts, silk production can have significant environmental impacts, especially for the indoor rearing of silkworms, which requires specific conditions such as the cultivation of mulberry trees, in order to feed the silkworms, as well as materials and workforce for feeding them [12], cleaning and disinfecting facilities, on top of specific climate conditions [48] for the development of silkworms.

Impacts can be observed on the environment, such as land use, toxicity (human and ecological—both to water and land), eutrophication (both to water and land), climate change, and human health. Environmental impacts can be considered as the effects on the environment caused by energy and material exchanges between the natural environment (biosphere) and the technical/technological environment (technosphere). These inputs and outputs, from and to the environment, respectively, are environmental aspects. Inputs encompass (e.g.) water, raw materials, and energy. Outputs can be finished products, byproducts, and wastes, including emissions to air, water, and soil.

Inputs and outputs related to environmental aspects have been reported in existing research on the production of silk cocoons, in India [5, 6, 48] and Brazil [12, 22]. Aspects reported in existing research include general statements on their contribution to the impacts of cocoon production. The most complete research on the impacts of silk cocoon production in Brazil thus far seems to be the research of Barcelos et al. [12], who conducted a life cycle assessment (LCA) of the mulberry and cocoon production under Brazilian conditions.

The aspects commonly addressed in existing research are related to the use of mulberry leaves (including, e.g., fertilizers, pesticides, etc.) and the use of chemicals for disinfecting the rearing beds and the sheds. However, there are many more aspects that contribute to the impacts inherent to the production of silk cocoons. Therefore, a mapping of such aspects will be provided later in this chapter.

3 Methods

This study is exploratory and qualitative. Two surveys were designed to collect information on the socioeconomic and environmental aspects of the sericulture in the Silk Valley (a region comprising 29 municipalities) in Brazil.

The information on the socioeconomic and environmental aspects were collected between February and August 2017, and between November 2017 and April 2018, in 15 municipalities within the Silk Valley, being them: Terra Boa, Cianorte, Santa Isabel do Ivaí, Cidade Gaúcha, Tapira, Tuneiras do Oeste, Indianópolis, Rondon, Doutor Camargo, São Manoel do Paraná, Ivaté, Aparecida d'Oeste, Nova Olímpia, Nova Esperança, and Alto Paraná.

The survey on the socioeconomic aspects was answered by 69 sericulturists (silk cocoon producers), and the data collection was given via a structured questionnaire. To build the socioeconomic survey, the aspects in the guidance for assessing and managing the social impacts of projects [47], EVALSED: The resource for the evaluation of Socio-Economic Development [21], guidelines for social life cycle assessment of products [45], and the methodological sheets for subcategories in social life cycle assessment (S-LCA) were considered [46]. Taking into consideration that some sericulturists were illiterate, in order to follow the same pattern all questionnaires were filled by the researchers during face-to-face meetings with the sericulturists in each property. Besides this survey, interviews (based on a structured guide) were conducted with seven focus groups. All interviews were recorded and transcribed, and later transferred into the NVivo 12 Plus software tool for data treatment.

The survey on the environmental aspects was answered by 43 sericulturists. The data collection was given via a structured questionnaire. To build the environmental survey, the researchers used as guides the standards on life cycle assessment (LCA) ISO 14040 [26] and ISO 14044 [27]. Once again, taking into consideration that some sericulturists were illiterate, in order to follow the same pattern all questionnaires were filled by the researchers during face-to-face meetings with the sericulturists in each property. The data gathered was used to map the processes and related environmental aspects (inputs and outputs) of the cultivation of mulberry trees and the rearing of silkworms. The processes were modeled using the software tool Microsoft Visio to identify the physical flows.

4 Socioeconomic and Environmental Aspects of the Production of Silk Cocoons in Brazil

4.1 Socioeconomic Aspects

The socioeconomic aspects present in the production of silk cocoons contribute to several potential impacts, which are directly linked to the sericulturists. This section presents the main socioeconomic aspects concerning the production of silk cocoons in Brazil.

The production of silk cocoons incorporates two main activities, the cultivation of mulberry trees and the rearing of silkworms, which besides being arduous tasks require great physical effort and dedication from the silkworm rearers. In addition, sericulture has some characteristics that are specific to the activity, which can be seen in Fig. 1.

A few characteristics of sericulture overclass those of other similar activities. In sericulture, sericulturists have the advantage of counting on a monthly income, with greater profitability in a relatively small area of land, besides having autonomy over their work routine. Moreover, they also have the possibility of working with other parallel activities on the same property.

A few opportunities brought by sericulture also need to be highlighted, such as the expansion of labor through the entry of new workers, and the family succession in the business, in which sericulturists' sons and daughters carry on the activity previously performed by their parents. The sericultural activity also allows the establishment of sericultural associations and presents a vast field for research.

Nonetheless, sericulture also presents some disadvantages such as the off-season, in which producers spend an average of three months without income, due to zero production in winter. In such cases, they need to supplement their income seeking to cover the family's livelihood needs. Sericulturists also face difficulties regarding production costs, since a great part of their revenue goes to covering such costs. In addition, they feel the need for greater governmental assistance. Further challenges in their activities are long working hours, bad weather during leaf harvesting, and the risk of accidents involving fire and snakes, on top of little freedom, as they have almost no spare time available.

The production of silk cocoons is also faced with threats, such as diseases and pests that affect silkworms, climate instability that can affect the mulberry fields, and application of pesticides by large producers of other cultures. On top of those, sericulturists may also suffer from the lack of labor force and economic instability.

The main aspects addressed, as well as the categories and subcategories of socioeconomic impact, based on Unep guidelines [46], can be seen in Fig. 2.

In order to obtain a silk production in which socioeconomic aspects lead to minimum impacts, it is necessary to provide favorable conditions for those involved in the activity.

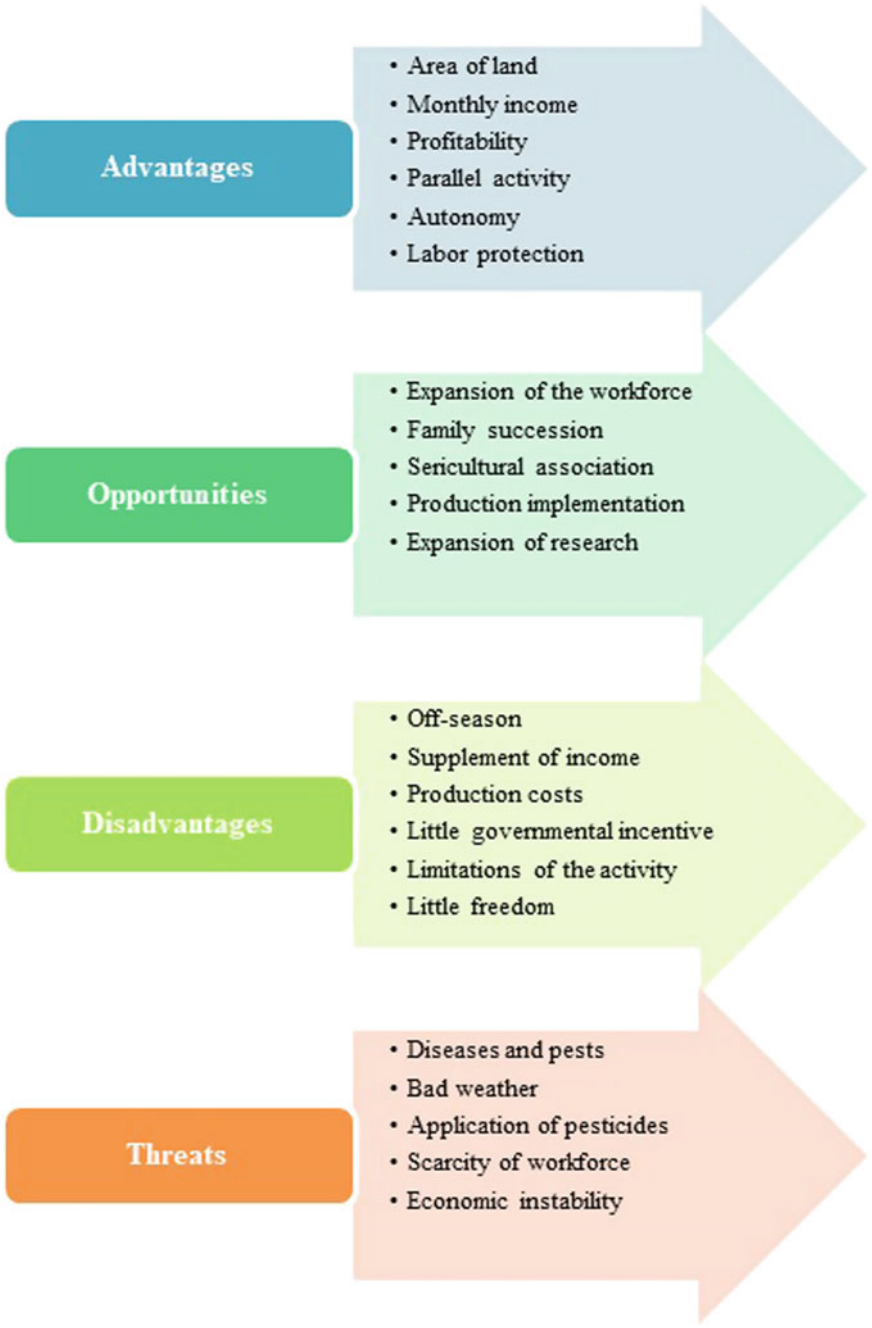

Fig. 1 Characteristics of the sericulture in Brazil

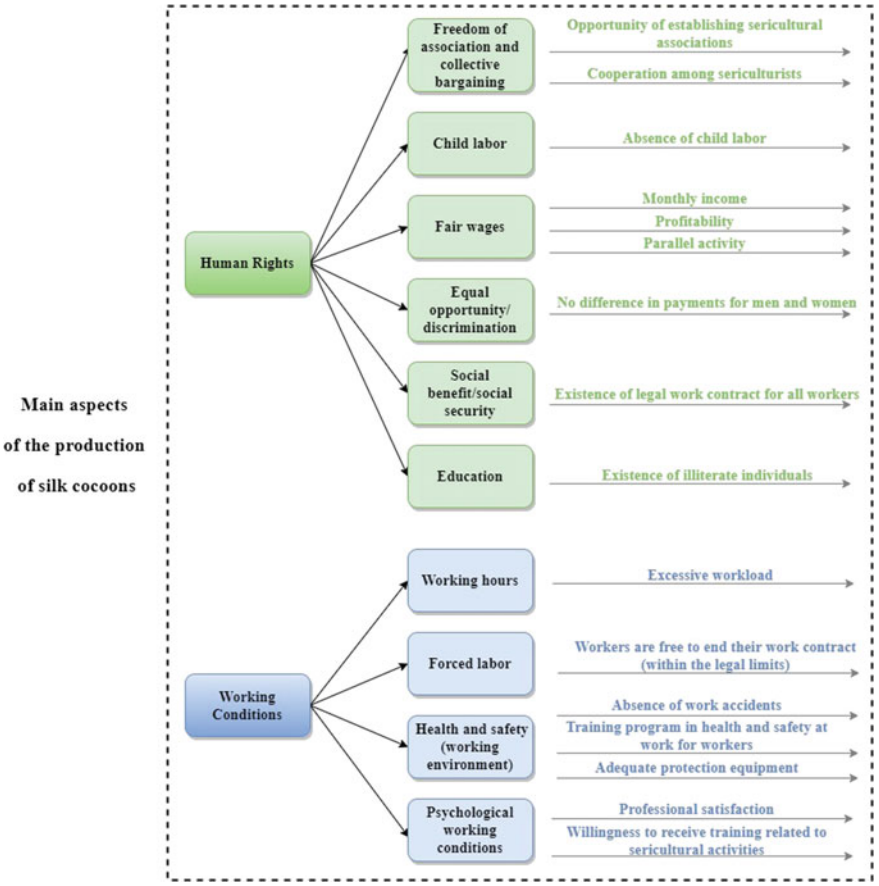

Fig. 2 Socioeconomic aspects of silk cocoon production in rural properties in Brazil

4.1.1 Aspects Related to Human Rights

Freedom of association and collective bargaining

It is worth noting the opportunity that sericulturists have to establish sericultural associations in all municipalities where there is still no association. Through associations, sericulturists can obtain advantages, benefiting the production of cocoons, by obtaining machinery, such as tractors, used to clean rearing beds and to transport mulberry leaves; brush cutters, for the pruning of the mulberry trees, among other equipment that is necessary for the sericultural activities. That way, sericulturists with less economic capital can invest in other production needs.

There is also a need to develop cooperativism among sericulturists, in which it is essential for associations to be established and prosper, as well as the exchange of experiences and the establishment of partnerships. Through associations, several

actions with socioeconomic benefits can be planned and implemented by the sericulturists themselves.

Child labor

In the studied region, the presence of child labor in sericultural activities was not observed. All children at school age were properly enrolled, according to parents' information. It is noted that only when in their adolescent age they start contributing to the family business, in a moderate way, starting with the feeding of silkworms.

Fair wages

Brazilian silk-related businesses accompany the international market, therefore sericulturists might face positive or negative oscillations in prices [36]. The monthly income of sericulturists coming exclusively from the sericultural activity is satisfactory to meet the basic needs of the family (mainly food); however, those who work as sharecroppers, go through financial hardships. Nonetheless, the profitability of the sericulture, considering the size of the property, is better than that of other types of crops.

Parallel activities are another reality for sericultural families. However, parallel activities should exist as a supplement for families to have an extra income, and not as a complement of income for the fixed monthly expenses.

There is a possibility of producing and selling other products through the sericultural association (creation of cooperatives), along with the production of cocoons, considering that they can develop the capacity to transform second-quality cocoons into textile products for the home, such as curtains, sofa shawls, pillows, among other products. This initiative can gain the attention of children, guaranteeing family succession. Sericulturists can also seek partnerships with other companies and/or projects for the second-quality cocoons, as an option for extra income.

Another possibility is the development of an annual productivity reward system for sericulturists. Considering the partnership system, the company needs sericulturists to obtain the raw material for the production of silk yarns, that is the silk cocoons, and the sericulturists need the yarn manufacturing company to buy their production of cocoons. Without the yarn manufacturer, the sericulturists do not have whom to sell their production to nationally. This award system must be well structured so that it can benefit sericulturists in a fair and equal way.

Moreover, the yarn manufacturer could anticipate the sericulturists' monthly production and dilute the annual payment made to each of them into 12 payments (considering the average of the previous harvest), paying the sericulturist in advance during the three months when there is no production, and discounting the amount paid in advance from the payments in the next nine months. This way, sericulturists can have better living conditions in the off-season.

Equal opportunity/discrimination

In the sericultural activity, no difference was identified between women and men in the price paid for the kilogram of cocoon.

Social benefit/social security

All cocoon production is sold to the yarn manufacturer and a sales invoice is issued to the sericulturist. In this case, the sericulturists are also affiliated with rural unions, being duly supported by social insurance in case they need it.

Education

Most sericulturists have basic literacy. However, shockingly, some are found in a state of illiteracy, that is, they never went to school. Considering children and young people, everyone has been or is being schooled.

4.1.2 Aspects Related to Working Conditions

Working hours

Work is necessary to move toward a sustainable economy, but a balance between working time and free time is also needed. The workload of sericulturists is considerably high because it is usually just the couple who owns the farm who works full-time, thus demanding them a lot of time.

One way to provide more free time would be the mechanization of time-consuming activities, such as automation of the silkworm feeding, taking into account that it is one of the activities that most demands time and physical effort.

Forced labor

There is no presence of forced labor in the sericultural activities in the studied region. Sericulturists work in partnership with the silk yarn manufacturer, by contract, and they can leave the activity at any time they wish. However, there is no such intention on the part of sericulturists, because the current arrangement is reported to be the best option for family farming at the moment.

Health and safety (working environment)

There is no data available on the exposure of sericulturists to chemicals such as formaldehyde, known to be carcinogenic by the International Agency for Research on Cancer (IARC), or to biological material, indicating an important gap in protecting the health of these workers [36].

Any serious accidents during the sericultural activities have not been observed or reported. However, there is a need for certain precautions, such as the use of personal protection equipment (PPE), considering that sericulturists handle chemicals such as herbicides, formaldehyde, chlorine, tools such as machetes, hoes, sickles, and may even encounter snakes in the middle of the mulberry fields.

The possibility of implementing a training program in health and safety at work is noted, which can be developed by the yarn manufacturer and offered to sericulturists through partnerships such as with the Paraná Institute of Technical Assistance and Rural Extension (EMATER—*Instituto Paranaense de Assistência Técnica e Extensão Rural*), the Agronomic Institute of Paraná (IAPAR—*Instituto Agronômico*

do Paraná), and municipal governments, which are all already partners, among others.

It is also noticed that the equipment owned by the sericulturists is appropriate for their activities; however, the possibility of improving technicity is noted, expanding the types of equipment, machinery. and automation. One example would be installing air conditioning equipment for the sheds, which can be facilitated by the silk spinning company since there is a financing system for partner sericulturists.

Psychological working conditions

In general, it can be noted that sericulturists are professionally satisfied and are willing to receive training related to sericultural activities, in order to improve their capabilities and also the productivity of the cocoon production.

In this sense, there is a need to develop an intensive production training program, in which sericulturists can sane their doubts, as well as get updates on new production techniques, something that goes beyond the traditional monitoring of the rearers by the spinning company agents.

There is also a need for a program to value the sericulturist, where issues of social nature, collective leisure, lectures, among others, can be addressed in order to provide sericulturists with greater well-being and to emphasize the importance of the sericulturist as the social capital of sericulture.

4.2 Environmental Aspects

The silk cocoon production comprises several environmental aspects, which contribute to varied environmental impacts. This section presents the major environmental aspects embedded in the silk cocoon production in Brazil, taking into perspective model practices.

The major input flows, which contribute to extracting/consuming resources from the environment, and output flows, which contribute to releasing emissions to the environment (to air, soil, or water), are depicted in Fig. 3.

The two main sets of activities that can be observed in the rural properties, for the production of silk cocoons, are the cultivation of the mulberry trees, and the activities related to the rearing of silkworms.

4.2.1 Mulberry Production

Within the mulberry production, the main activities that can be pointed out are soil correction, soil preparation, mulberry planting, and soil maintenance.

Sericulturists usually practice a sort of rotation in the cultivation of mulberry trees in order to assure a year-long supply for feeding the silkworms. They usually have a certain area which is divided into three smaller areas and each one of them comprises one separate cycle of mulberry cultivation. That is given due to the need

Fig. 3 Major flows for the production of silk cocoons in rural properties in Brazil

for the leaves to have adequate characteristics to be fed to silkworms, otherwise either the silkworms will reject them or they will not provide adequate quality feed. Moreover, it is recommended that every ten years the mulberry fields get renewed, in order to maintain both soil and crop quality.

Soil Correction

Part of soil correction activities takes place once a year, and part of it, every ten years, when the mulberry fields are renewed.

Lime and phosphorus are used in the soil to provide adequate conditions for the production of quality mulberry leaves for silkworms. Their use serves to supplement the soil and is given according to the technical analysis of the soil, or when renewing the mulberry fields.

For the application of both phosphorus and lime, a tractor is used, consuming diesel, accounting for different amounts of diesel consumption in their applications.

With those inputs, even though lime and phosphorus have positive effects on mulberry cultivation, their negative effects might permeate longer. Phosphorus is a nutrient largely used in agriculture, but it might cause eutrophication. As sericulturists use ground wells, this might lead to water contamination, which can be either consumed at the property or carried to other water bodies. Lime, in turn, can be a way to control soil acidity, but in excess can lead to carbonation and sulfate attack.

As outputs for this process, one can observe greenhouse gas (GHG) emissions, due to the consumption of diesel, contributing to air pollution and to aggravating global warming effects.

Soil preparation

This activity takes place only when the mulberry field gets renewed, thus every ten years, according to the technical recommendation. It consists of preparing the soil to receive the new mulberry crop.

Different equipment is used for this activity, as it is observed that the sericulturists have to till the soil. The main input and output flows in this activity account for diesel and GHG emissions, respectively.

Mulberry planting

For mulberry planting, the sericulturists basically use water and mulberry stems.

Water is obtained from ground wells and the mulberry stems are provided by the silk manufacturer. This activity also takes place only once every ten years, when the mulberry fields need to be renewed, or according to the technical recommendation. As this activity is conducted manually, no direct emissions are accounted for.

Soil Maintenance

Maintaining the soil means keeping it free of pests and also fertile. Therefore, the main inputs accounted for in this activity are herbicides and fertilizers, as well as water to dilute them, and diesel for their application on the fields.

Needless to say, herbicides are the causes of negative effects on both the direct environment and on human health. They can have long-lasting effects, permeating soil and water, contributing to concerning levels of toxicity. Besides, they might also reach non-target organisms and cause environmental imbalances in soil biology, even more because the products of their degradation can continue to be toxic in the long term.

Fertilizers, as for phosphorus, can be the cause of eutrophication. Eutrophication comprises a high load of nutrients (e.g. phosphates and nitrates). This mainly concerns the contamination of water bodies, affecting the fauna and flora of these habitats, and causing an imbalance in natural systems. Moreover, fertilizers also carry chemicals that contribute to GHG emissions.

4.2.2 Infrastructure and Other Environmental Aspects of Mulberry Production

Besides the input and output flows for the cultivation of mulberry trees, many of the activities mentioned previously need heavy machinery and equipment to be performed. These infrastructure aspects have not been taken into account and they lack addressing in environmental assessments of silk production systems. Agricultural machinery, such as tractors (as well as passenger cars and trucks used for transportation), also account for environmental impacts for their manufacturing, by extracting natural resources and accounting for varied emissions to air, soil, and water for their manufacturing and distribution.

All packaging systems of the products used for the mulberry cultivation also contribute to environmental impacts, for the same reasons mentioned above, since they require extracting resources from the natural environment, processing/manufacturing, and distributing.

Furthermore, manpower is also an aspect that can contribute to environmental impacts. It requires efforts that result in the consumption of resources (e.g. water and food) that would otherwise not be consumed or used to produce results for other systems. Nonetheless, manpower is (dare we say) never included in the accounting of environmental impacts due to the difficulty in tracking related inputs and outputs.

4.2.3 Silk Cocoon Production

Within the silk cocoon production, the main activities can be pointed to be shed disinfection, grid scorching, grid disinfection, silkworm purchase, transport of mulberry leaves, silkworm rearing, bed cleaning, packing, transport of silk cocoons, and open burning (paper and plastic packaging waste).

Shed disinfection

The sheds need to be disinfected before receiving a new lot of silkworms. It takes a short time between one batch of silk cocoons being delivered to the silk manufacturer and a new batch of silkworms coming into the sheds. In the meantime, the sheds need to be disinfected in order to prepare them for the new silkworms.

Inputs for the disinfection include chlorine, lime, water, and kraft paper. Chlorine and lime are diluted in water and sprayed over the walls, rearing beds, and floors. Besides, lime is dusted over the rearing beds and floors to prevent humidity, which can be hazardous to silkworms, thus preventing the spread of diseases. Moreover, the bottom of the rearing beds is covered with kraft paper, to help protect and maintain temperature, and to facilitate taking out the rearing bed waste.

As outputs, chlorine, kraft paper waste (from the lime package), and kraft paper waste from the bottom of the rearing bed (which gets mixed with silkworm litter and mulberry stems left behind by silkworms) can be observed. The chlorine is likely to evaporate with time, at varied rates depending on (e.g.) climate conditions, thus becoming a hazard to human health. Lime wastes are accumulated and eliminated

(together with the kraft paper) along with silkworm litter and mulberry stems when the rearing beds are cleaned.

Grid scorching

When silkworms are ready to form cocoons, they are accommodated in grids. When the cocoons leave the grids, these are scorched, to eliminate the remains of previous cocoons, in order to prevent the proliferation of fungi that might cause diseases.

With adequate equipment, the grids are scorched using liquefied petroleum gas (LPG). Although little, compared to other potential sources, LPG is responsible for GHG emissions.

Grid disinfection

After being scorched, the grids are disinfected. Inputs for this disinfection are formaldehyde and water. Formaldehyde is diluted in water and sprayed over the grids.

As outputs, this results in air emissions of formaldehyde, which can also be hazardous to human health.

Silkworm purchase

The purchase of silkworms includes transportation of what the sericulturists call boxes, which are small packages with approximately 40,000 larvae each, a piece of kraft paper (where the larvae come wrapped in), and a negligible amount of mulberry leaves which are eaten by silkworms.

Therefore, inputs in this activity include the kraft paper, the larvae, and the diesel consumed for transportation. Outputs mainly include the kraft paper waste (which is burnt), generating GHG emissions, along with the emissions from the use of diesel.

Transport of mulberry leaves

This activity is labor-intensive, comprising the collection of mulberry leaves from the mulberry fields and their transport to the sheds where the silkworms will be fed. This transportation is done using a tractor. Thus, besides manpower, the main input for this activity is the diesel used in the tractor. Outputs, hence, comprise mainly GHG emissions. It is worth mentioning that in this activity most of the sericulturists harvest the mulberry leaves manually, with the help of a sickle.

Silkworm rearing

This activity comprises the main efforts employed during the rearing of silkworms. The most volume-intensive input in this activity is the mulberry leaves, which are the only food for the silkworms. Mulberry branches are taken from the trees and placed on the rearing beds. Silkworms feed on the mulberry leaves and leave the stems behind as silkworms climb them staying always on the surface.

Other inputs comprise lime, water, kraft paper, and electricity. Lime is dusted over the beds to absorb moisture from the decomposition of the mulberry leaves and silkworm litter. Kraft paper is laid on top of the rearing beds to both help control temperature and avoid the action of predators (e.g. birds). Water is used to water

the floor, in order to avoid dust from floating and laying over the rearing beds and also to maintain the mulberry leaves always fresh in the storage room. Electricity is consumed for lighting and to power a few pieces of equipment (e.g. for disinfecting the sheds and for cleaning the silk cocoons before packing).

Outputs from this activity include a mixture of lime, silkworm litter, and the mulberry stems left behind by the silkworms. This mixture, named here as rearing bed waste, is used as a biofertilizer and laid on the mulberry fields. As the lime might be beneficial to control soil acidity, as commented previously, this excess of lime can cause eutrophication in the long term. One positive aspect is that due to the organic load present in the silkworm litter and the remains of mulberry branches, it decreases the need for mineral fertilizer.

A further output is the kraft paper waste (the paper used to cover the rearing beds), which is burned and thus responsible for GHG emissions.

Bed cleaning

This activity comprises the transportation of the rearing bed waste from the sheds to the mulberry fields. This is done with the help of a tractor. Thus, diesel is direct input. The output, hence, comprises mainly GHG emissions.

Packing

Once the cocoons are ready, they go through a classification process and are packed. The packaging comprises putting them into raffia sacks for transporting to the silk manufacturer. Thus, the main input in this activity is raffia sacks. The output comprises raffia sack wastes.

Transport of silk cocoons

After packing, the silk cocoons are taken to the yarn manufacturer using a pickup truck. Thus, the main input in this activity is diesel. The output, hence, comprises mainly GHG emissions.

Open burning

Most of the packages of the products used in the sericultural activities, along with the kraft paper, are subject to open burning. Inputs for such open burning include the wastes of raffia sacks (the ones that can no longer be reused), lime and chlorine packages, and any kraft paper waste. Outputs include GHG emissions derived from the open burning.

4.2.4 Infrastructure and Other Environmental Aspects of Silk Cocoon Production

Just as for the mulberry production, it requires manpower, and thus all related aspects are also tied to the activities.

Aspects of infrastructure are also to be accounted for, including the heavy machinery necessary for the transportation of mulberry leaves, as well as for transporting the larvae to the property and the silk cocoons to the yarn manufacturer. Equipment needed for disinfection of the sheds and grids, as well as for scorching grids also, contributes to consuming resources and generating emissions (considering extraction of raw materials, manufacturing, and distribution).

Packages also need consideration. Packages for chlorine and formaldehyde (used in the shed and grid disinfection) and the raffia sacks (used for packaging) are products that went through previous processing, and their environmental loads should be accounted for.

Moreover, further aspects that need to be considered regard the use of electricity, which depend on the mix that is delivered by the carrier.

5 Concluding Remarks

In Brazil, sericulture has developed in a way that has put Brazilian silk among the largest silk producers in the world, in addition to its increased demand for the quality it presents. However, it is necessary to consider the socioeconomic and environmental impacts of Brazilian silk production. It is important that efforts be made to improve the silk cocoon production processes, in order to achieve sustainable sericulture.

The socioeconomic impacts that directly and indirectly affect sericulturists are present, both in the activities of mulberry cultivation and in the rearing of silkworms. Sericulture requires a lot of dedication and physical effort from those involved, in addition to bringing potential health risks by the use of chemicals. For sericulturists, government incentive is important and is part of rural sustainability, since via this incentive they can develop further and with greater flexibility, being able to channel investment into production.

The sustainability of sericulture may be entering a state of instability due to the aging of sericulturists, the lack of new labor, and unsatisfactory family succession. There is an urgent need to plan actions toward changing this future scenario in Brazilian sericulture. Sericulturists fear that sericulture will not continue as a promising activity, and will not be sustained over the coming decades if there are no strategies to improve their socioeconomic status. Another relevant point is that sericulturists do not realize the risks they face, nor how much their activities impact their lives positively and/or negatively. This makes clear the need for further research that contributes to improving socioeconomic performance in sericulture.

Furthermore, all inputs and outputs for every process in the sericultural activities have their respective impacts either on the environment or on human health. Both the production of mulberry and silk cocoons account for environmental aspects (exchanges with the natural environment) and elementary processes which will somehow lead to environmental aspects in other stages of production, be it in the extraction of resources to produce raw materials (e.g. chlorine, formaldehyde, lime,

and packages) or the manufacturing phase of these products. The set of all these aspects lead to the overall environmental impacts of the production of silk cocoons.

There are particularities for producing cocoons in different locations, under different (technological and climate) conditions. In this chapter, we set out to reveal the average conditions of the production of silk cocoons in the most representative region in Brazil, thus accounting for the general production of silk cocoons in the country.

Determining the complete environmental impacts of the production of silk cocoons calls for the use of quantitative tools, such as the life cycle assessment, which has been said to be the most complete and complex, but also time-consuming, tool for environmental profiling.

Regarding the expected impacts, a concerning issue is the lack of awareness of the sericulturists about the hazardous effects many of the chemicals and other products they use have both on their health and on the environment.

This chapter presented the impacts of the production of silk cocoons on the socioeconomic and environmental conditions, from which measures can be drawn toward improving those conditions to both provide a better quality of life for silk cocoon producers and improve the environmental conditions of the activity, in order to ensure continuity of the sericulture in the Brazilian territory.

Overall, the results show that sericulture has proven to be ahead of many other rural activities with regard to socioeconomic aspects, for being an alternative to diversifying small rural properties, generating monthly income to families in rural areas. Moreover, a fair background was given to enable the deployment of efforts to make sericultural activities less environmentally impacting. Nonetheless, further investigation and practical guidance are needed in order for the sericulture to reach more sustainable conduct.

Acknowledgements This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES)—Finance Code 001, and the National Council for Scientific and Technological Development (CNPq) (Sponsored by CNPq 310686/2017-2), Fundação Araucária (Support for Scientific and Technological Development of Paraná) by means of CP20/2013, Doctoral Program in Textile Engineering in partnership with a Foreign Institution (Uminho/UEM/UTFPR), and the ERDF through the Operational Program for Competitiveness Factors—COMPETE and national funds by FCT—Foundation for Science and Technology.

The authors would like to show their gratitude for the support provided by the Universidade Tecnológica Federal do Paraná (UTFPR) (Brazil), University of Minho (Portugal), and the State University of Maringá (Brazil).

References

1. Abit - Brazilian Association of the Textile and Clothing Industry [*Associação Brasileira da Indústria Têxtil e de Confecção*] (2019) Sectoral profile [*Perfil do setor*]. https://www.abit.org.br/cont/perfil-do-setor. Accessed 05 Feb 2020
2. Abit - Brazilian Association of the Textile and Clothing Industry [*Associação Brasileira da Indústria Têxtil e de Confecção*] (2020) Foreign trade [*Comércio exterior*]. https://www.abit.org.br/cont/dados-comercio-exterior. Accessed 05 Feb 2020
3. Abraseda – Brazilian Silk Association [*Associação Brasileira da Seda*] (2018) Núcleos. https://abraseda.wixsite.com/abraseda/nucleos. Accessed 19 Mar 2020
4. AEN – Agência de Notícias do Paraná (2015) Paraná pode aumentar produção de bicho-da-seda em até 50%. Accessed 23 Feb 2020
5. Astudillo MF, Thalwitz G, Vollrath F (2014) Life cycle assessment of Indian silk. J Clean Prod 81:158–167. https://doi.org/10.1016/j.jclepro.2014.06.007
6. Astudillo MF, Thalwitz G, Vollrath F (2015) Life cycle assessment of silk production–a case study from India. Handbook of Life Cycle Assessment (LCA) of textiles and clothing. Woodhead Publishing, Cambridge, UK, pp 255–274
7. Babu KM (2015) Natural textile fibres: Animal and silk fibres. In: Textiles and fashion. Woodhead Publishing, Cambridge, UK. https://doi.org/10.1016/b978-1-84569-931-4.00003-9
8. Babu KM (2019) Silk reeling and silk fabric manufacture. In Silk, 2nd edn. Woodhead Publishing, Cambridge, UK. https://doi.org/10.1016/b978-0-08-102540-6.00002-4
9. Babu KM (2019) Introduction to silk and sericulture. In: Silk, 2nd edn. Woodhead publishing, Cambridge, UK. https://doi.org/10.1016/b978-0-08-102540-6.00001-2
10. Barcelos SMBD, Luz LM, Vasques RS, Piekarski CM, Francisco AC (2013) Introductory background for life cycle assessment (lca) of pure silk fabric. http://dx.doi.org/10.14807/ijmp.v4i1.67. Accessed 06 Apr 2020
11. Barcelos SMBD, Guedes MG, Salvador R and Francisco AC (2019) Introductory analysis for conducting life cycle assessment of silk cocoon in Brazil. In: 6th international scientific conference SWS on social sciences & art – ISCSS, 26 August – 01 September 2019, pp 179–186. https://www.sgemsocial.org/index.php/conference-topics/jresearch?view=publication&task=show&id=4103. Accessed 06 Feb 2020
12. Barcelos SMBD, Salvador R, Guedes MG, Francisco AC (2020) Opportunities for improving the environmental profile of silk cocoon production under Brazilian conditions. Sustainability 12:3214. https://doi.org/10.3390/su12083214
13. Baltar CS, Baltar R (2016) Caminhos da seda no Paraná: a convergência de diferentes processos migratórios na expansão da sericicultura de São Paulo até o Vale da Seda (PR). In: VII Congreso de la Asociación Latinoamericana de Población e XX Encontro Nacional de Estudos Populacionais, ABEP, Foz de Iguaçu-PR, 17 a 22 de outubro. http://www.abep.org.br/publicacoes/index.php/anais/article/view/2809/2695. Accessed 16 Feb 2020
14. Busch APBA (2010) Análise da conjuntura agropecuária. Safra 2010/2011. SEAB – Secretaria de Estado da Agricultura e do Abastecimento, DERAL – Departamento de Economia Rural. http://www.agricultura.pr.gov.br/Pagina/Boletins-Conjunturais. Accessed 13 Feb 2020
15. Bratac (2020) Nossa história. http://www.bratac.com.br/bratac/pt/index.php. Accessed 16 Feb 2020
16. Cirio GM (2014) Sericicultura no Estado do Paraná. Safra 2013/2014 - Relatório Takii. SEAB – Secretaria de Estado da Agricultura e do Abastecimento, DERAL – Departamento de Economia Rural. http://www.agricultura.pr.gov.br/Pagina/Boletins-Conjunturais. Accessed 15 Feb 2020
17. Cirio GM (2016) Sericicultura no Estado do Paraná. Safra 2015/2016 - Relatório Takii. SEAB – Secretaria de Estado da Agricultura e do Abastecimento, DERAL – Departamento de Economia Rural. http://www.agricultura.pr.gov.br/Pagina/Boletins-Conjunturais. Accessed 15 Feb 2020
18. Cirio GM (2017) Sericicultura no Estado do Paraná. Safra 2016/2017 - Relatório Takii. SEAB – Secretaria de Estado da Agricultura e do Abastecimento, DERAL – Departamento de Economia Rural. http://www.agricultura.pr.gov.br/Pagina/Boletins-Conjunturais. Accessed 15 Feb 2020

19. Cirio GM (2018) Evolution and Current Condition of Sericulture in Paraná [*Evolução e Condição Atual da Sericicultura no Paraná*]. In: Inovações na sericicultura do Paraná: tecnologias, manejo rentabilidade. Dimas Soares Júnior, Edson Luiz Diogo de Almeida, Oswaldo da Silva Pádua: orgs. – Londrina: ABRASEDA: IAPAR, 103 p. il. http://www.emater.pr.gov.br/arquivos/File/Biblioteca_Virtual/RedesReferencia/Livro_Sericicultura2018_2aED.pdf. Accessed 12 Jan 2020
20. Cirio GM (2018) Sericicultura no Estado do Paraná. Safra 2017/2018 - Relatório Takii. SEAB – Secretaria de Estado da Agricultura e do Abastecimento, DERAL – Departamento de Economia Rural. http://www.agricultura.pr.gov.br/sites/default/arquivos_restritos/files/documento/2019-09/sericicultura_2019_v1.pdf. Accessed 15 Feb 2020
21. European Commission (2013) EVALSED: the resource for the evaluation of Socio-Economic Development. https://ec.europa.eu/regional_policy/sources/docgener/evaluation/guide/guide_evalsed.pdf. Accessed 18 Mar 2017
22. Giacomin AM, Garcia JB Jr, Zonatti WF, Silva-Santos MC, Laktim MC, Baruque-Ramos J (2017) Brazilian silk production: economic and sustainability aspects. Proc Eng 200:89–95. https://doi.org/10.1016/j.proeng.2017.07.014
23. Iapar – Paraná Agronomist Institute [*Instituto Agrônomo do Paraná*] (2019) Paraná enters the international silk network [*Paraná ingressa na rede internacional da seda*]. http://www.iapar.br/2019/11/2607/Parana-ingressa-na-rede-internacional-da-seda.html. Accessed 05 Feb 2020
24. ISC - International Sericultural Commission (2019) Global Silk Industry. https://www.inserco.org/en/statistics. Accessed 06 Feb 2020
25. ISC - International Sericultural Commission (2019) Silk - an introduction. http://inserco.org/en/silk_an_introduction. Accessed 06 Feb 2020
26. ISO (International Organization for Standardization) (2006) Environmental management - life cycle assessment - principles and framework, 2nd edn. ISO 14040:2006. ISO, Geneva, Switzerland
27. ISO (International Organization for Standardization) (2006) Environmental management - life cycle assessment - requirements and guidelines, 1st edn. ISO 14044:2006. ISO, Geneva, Switzerland
28. Jain J, Ratan A (2017) Developing a Conceptual Model to Sustain Handloom Silk Industry at Sualkuchi, Assam, India. Eur J Sustain Dev 6(3):413–422
29. Kasi E (2013) Role of women in sericulture and community development: a study from a South Indian Village. SAGE Open, pp 1–11. https://doi.org/10.1177/2158244013502984
30. Lima AS (2018) Analysis of the contractual relations between producers and the silk industry in the municipality of Diamante do Sul, Paraná State [*Análise das relações contratuais entre sericicultores e indústria de seda no município de Diamante do Sul, Estado do Paraná*]. https://lume.ufrgs.br/handle/10183/197790. Accessed 04 Feb 2020
31. Mahan B (2012) Silk industry among the Tai-Ahom of Assam, India as an attraction of tourist. Int J Sci Res Publ 2(12):1–4
32. Makarov I, Sokolova A (2016) Coordination of the Eurasian economic Union and the silk road economic belt: opportunities for Russia. Int Organ Res Journal 11(2):29–42
33. Pennacchio HL (2016) Casulo de seda. Indicadores da agropecuária – Conab, Brasília, Ano XXV, n. 10, outubro, pp 01–114. Disponível em. https://www.conab.gov.br/info-agro/precos/revista-indicadores-da-agropecuaria?start=30. Accessed 14 Feb 2020
34. Pádua OS (2005) A origem da sericicultura. https://www.yumpu.com/pt/document/read/14574154/a-origem-da-sericicultura. Accessed 14 Feb 2020
35. Paul D, Dey S (2014) Essential amino acids, lipid profile and fat-soluble vitamins of the edible silkworm Bombyx mori (Lepidoptera: Bombycidae). Int J Trop Insect Sci 34(4):239–247
36. Pinto NF (2015) O processo saúde-doença dos/as trabalhadores/as da sericicultura no Paraná. Cascavel, PR: Unioeste, 128p. http://tede.unioeste.br:8080/tede/handle/tede/654. Accessed 06 Feb 2020
37. Pinto NF, Murofuse NT (2017) Processos protetores e destrutivos da saúde dos(as) trabalhadores(as) da sericicultura. Saúde debate 41(spe2). Rio de Janeiro. http://dx.doi.org/10.1590/0103-11042017s210. Accessed 04 Feb 2020

38. Porto AJ (2014) Sericicultura no estado de São Paulo. B. Ind Anim Nova Odessa 71(3):291–302. http://www.iz.sp.gov.br/pdfsbia/1412257067.pdf. Accessed 15 Feb 2020
39. Pratama AG, Supratman S, Makkarennu M (2019) Examining forest economies: a case study of silk value chain analysis in Wajo District. Forest Soc 3(1):22–33
40. Sakthivel N, Kumaresan PT, Balakrishna R, Mohan BV (2012) Economic viability of sericulture in southern Tamil Nadu - a case study. Agric Sci Digest 32(2):98–104
41. Siddappaji D, Latha CM, Ashoka SR, Raja MGB (2014) Socio-economic development through sericulture in Karnataka. J Humanities Soc Sci 19(10):24–26. https://doi.org/10.9790/0837-191052426. Ver. V
42. Silin Y, Kapustina L, Trevisan I, Drevalev A (2018) The silk road economic belt: balance of interests. Econ Polit Stud 6(3):293–318
43. Sunitha Rani D, Jayaraju M, Kannan M, Ashok Kumar K (2015) Socioeconomic influence on farmers in seri-business from Tamil Nadu. Int J Eng Bus Enterp Appl 11(2):136–140
44. Tikader A, Vijayan K, and Saratchandra B (2013) Muga silkworm, Antheraea assamensis (Lepidoptera: Saturniidae)-an overview of distribution, biology and breeding. Eur J Entomol 110(2)
45. UNEP – United Nations Environment Programme (2009) Guidelines for social life cycle assessment of products. https://www.lifecycleinitiative.org/wp-content/uploads/2012/12/2009%20-%20Guidelines%20for%20sLCA%20-%20EN.pdf. Accessed 15 Mar 2017
46. UNEP – United Nations Environment Programme (2013) The methodological sheets for subcategories in social life cycle assessment (S-lca). https://www.lifecycleinitiative.org/wp-content/uploads/2013/11/S-LCA_methodological_sheets_11.11.13.pdf. Accessed 15 Mar 2017
47. Vanclay F, Esteves AM, Aucamp I, Franks DM (2015) Evaluación de Impacto Social: Lineamientos para la evaluación y gestión de impactos sociales de proyectos. https://www.iaia.org/pdf/Evaluacion-Impacto-Social-Lineamientos.pdf. Accessed 12 Feb 2017
48. Wani KA, Jaiswal YK (2011) Health hazards of rearing silkworms and environmental impact assessment of rearing households of Kashmir, India. Indian J Public Health Res & Dev 2(2):84–88
49. Wichitsathian S, Nakruang D (2019) Knowledge integration capability and entrepreneurial orientation: case of Pakthongchai Silk Groups Residing. Entrep Sustain Issues 7(2):977–989