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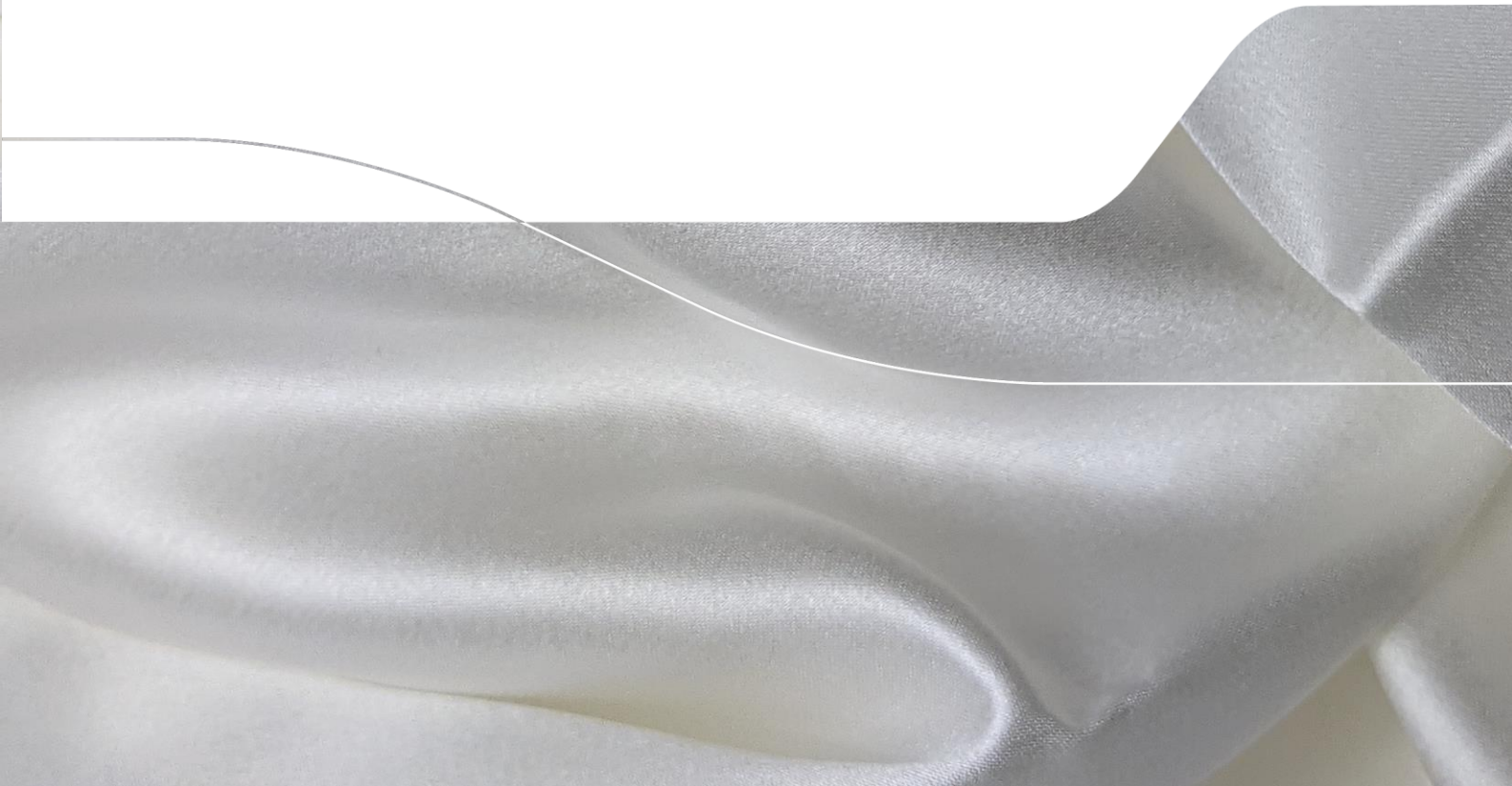
Hermès' silk supply chain:
Impacts on biodiversity



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Executive Summary

Hermès is committed to sustainable development and biodiversity conservation. Silk is a key resource for Hermès and its production reflects the Company's sustainability ethos. Silk is a renewable, biodegradable resource.

The silk sourced for Hermès is produced in Brazil, the world's most biodiverse country. Hermès has committed to including biodiversity in its global development strategy, contributing towards internationally agreed biodiversity objectives. This report looks at the Company's silk supply chain, considering positive and negative environmental impacts with a focus on losses and gains for biodiversity. The three main components of silk production considered are mulberry cultivation, silkworm rearing and silk processing. Positive steps already taken to mitigate negative impacts are noted. Recommendations are made that support the values, processes of innovation and commitment to dialogue with stakeholders that are synonymous with Hermès.

Silk production takes place in the southern part of the Atlantic Forest region of Brazil which extends overall from the Brazilian northeast to northern Argentina and Paraguay. The Atlantic Forest is a global biodiversity hotspot. The rich forest vegetation has been extensively cleared over the past five hundred years but habitats for iconic species of plants and animals remain. There is now a comprehensive legal framework for biodiversity conservation in the region. Native species diversity is dependent on both legally protected areas and the forest fragments that remain within the agricultural landscape. Carefully managed silk production can support the conservation of biodiversity within the region.

Hermès local partner, the only silk export company in Brazil, is a signatory to the UN Global Compact. It applies environmental standards of excellence to its integrated production and supply chain. Contracts with silk producers specify environmental requirements in line with National and State legislation. Additional environmental guidance and advice are provided by the Company on a regular basis.

Positive impacts

Hermès local partner's silk production system embraces circular and resource efficient approaches, minimising where possible the demand for natural resources.

The system is not associated with any recent loss of natural habitat. Mulberry plantations, whilst not as good for biodiversity as natural forests, do provide many ecological services. They sequester carbon, prevent soil erosion and improve water infiltration into the soil, nutrient recycling, soil fertility and soil carbon storage.

Natural forest patches remain in areas of silkworm production, retained in accordance with national law. These patches likely support other species of plants and animals that are of global, national or regional conservation value. Hermès local partner has a reforestation area of producing *Eucalyptus* wood used in heating water for silk processing, thus taking pressure off remaining forests. Some native species are also grown at the site.

Farming techniques are adopted to conserve soils and reduce the need for chemicals on the mulberry farms. Mulberry cultivation uses significantly less agrochemicals than other agricultural crops in the surrounding farmlands of Brazil where for example corn, soybeans and sugarcane are cultivated using pesticides that are highly damaging to silkworm production. Hermès local partner supports research into pesticide use and engages positively in local dialogue to reduce agrochemical use in surrounding farmlands.

Water use in the silk production is carefully managed to reduce pollution and demand. Hermès local partner has an extensive water recycling process.

Negative impacts

Fertilisers and pesticides used in mulberry cultivation, although limited compared to cultivation of other crops, may contribute to local pollution of water sources and soils.

Silkworm production requires a large amount of water. Whilst Hermès local partner has a stringent approach to water recycling, but the impact of the extraction is not fully known.

Chemicals used in silkworm rearing are a source of pollution potentially impacting on local biodiversity.

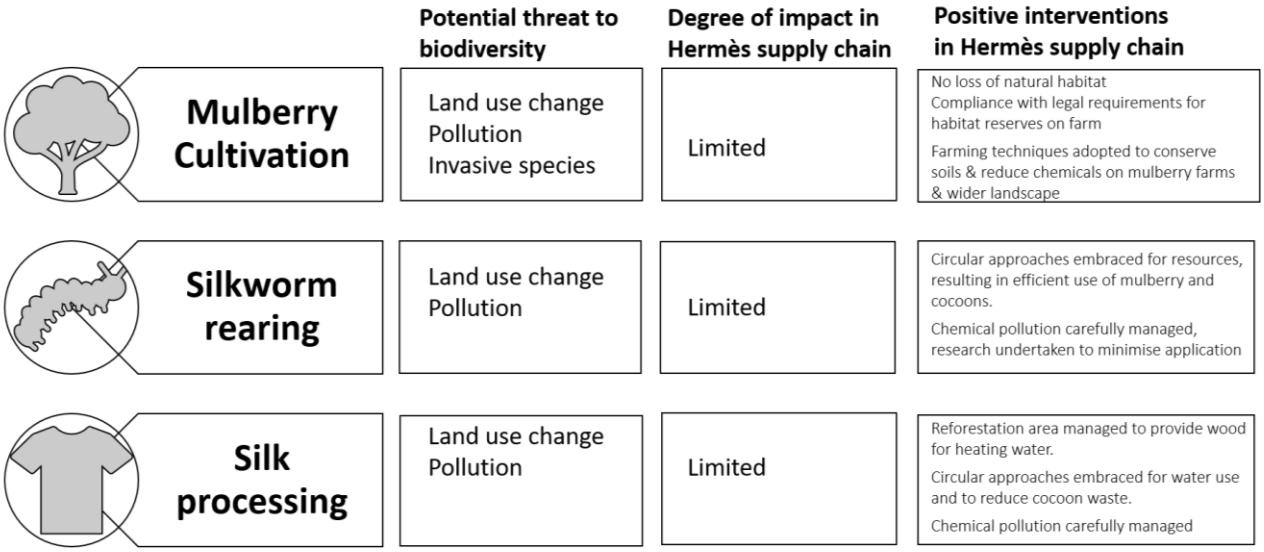

Figure 1: Summary of threats, degree of impact and positive interventions in Hermès silk supply chain.

Key recommendations

Hermès has an excellent opportunity to showcase the links between silk production and biodiversity conservation in Brazil working with their supply company by:

- Developing and communicate a strategy for biodiversity in silk production areas of Brazil
- Identifying an appropriate target for improving biodiversity outcomes
- Supporting monitoring of biodiversity and working with farmers to enhance biodiversity knowledge
- Continuing to protect remnant habitat within mulberry farms and silk production areas
- Examining opportunities to restore native habitat on farms and in the wider landscape
- Continuing to use environmentally friendly fertiliser systems and promoting reduction in use of harmful chemicals used in silkworm production
- Continuing to embrace circularity and resource efficiency.
- Sharing their knowledge with the wider industry to help drive transformative change

It is recommended, in line with Hermès' commitment to the Fashion Pact, that these actions are integrated in to the AR^{3}T framework: Avoid, Reduce, Restore & Regenerate & Transform. These actions could help deliver a 'nature positive' silk supply chain.

Contents

Hermès & Silk

Silk is signature material for Hermès, featuring across their product range, but most famously in their iconic scarves. Silk is a key resource for Hermès and its production reflects the Company's sustainability ethos. Silk is a renewable, biodegradable resource and its production uses less water, chemicals, and energy than the production of most other fibres including cotton and synthetics.

For decades Hermès has sourced silk, via their local partner, from smallholder farmers in the state of Paraná in the Atlantic Forest region of Brazil, a global biodiversity hotspot. Hermès local partner's silk production system aims to work in harmony with nature by using low intensity, regenerative and circular agriculture. According to a recent study from Intersoie (Union of Silk Makers), Brazilian silk has a carbon footprint 30% smaller than Chinese silk[1].

Hermès has collaborated with the University of Cambridge Institute for Sustainability Leadership, a leading institution in the field of biodiversity, to undertake a review to confirm the value of the approach of this partner and identify additional actions that could further increase the benefits of this system.

Objectives

The objective of this study has been to assess Hermès' current approach to silk production to highlight how existing actions are likely to benefit biodiversity and identify additional actions that could further improve impact.

Approach

To undertake a literature review and consultation with experts to determine what supply chain approaches and interventions positively contribute to biodiversity in the production of silk.

Silk production in Brazil

Hermès sources all its silk from Brazil one of the world's main producers. Within Brazil silk production is concentrated in the southern states of Paraná (83%), Sao Paulo (12%) and Mato Grosso do Sul (5%). Silkworm breeding was introduced to Brazil in 1848 initially with production taking place alongside the coffee industry in São Paulo. Silkworm farming began in Paraná in the 1930s, introduced by Japanese settlers, with movement of people to the north of the State. By the 1980s, Paraná replaced São Paulo as the main silk producer and remains the largest Brazilian exporter. Further details are provided in Annex 1.

Sericulture (silk farming) in Brazil takes place on small family farms with an average of 2.4 hectares. It remains an important activity in both the rural and urban economy[2]. Small rural properties are generally surrounded by large plantations of corn, soybeans and sugarcane.

Brazil's silk production is a highly integrated production chain which includes the cultivation of mulberry trees, raising of silkworms, preparation of silk threads, and textile production. Currently, silk production in Brazil is restricted to one processing company, responsible for raw material processing and reeling of silk yarns. Hermès local partner is a private company with 1,000 direct employees. Under agricultural partnership, Hermès local partner contracts around 2,700 families of farmers to feed its silkworms and deliver cocoons. Around 8,100 individuals are working on sericulture activities in partnership with Hermès local partner. This review focuses primarily on the cultivation of mulberry, the raising of silkworms and the silk processing.

Hermès local partner has a close relationship with its farmers and provides extensive support to enable them to meet strict company-set requirements that go beyond legislative requirements.

Company requirements

Hermès local partner is a signatory to the UN Global Compact and obliges each farmer by contract to implement mechanisms to comply with environmental protection rules. It applies environmental standards of excellence to its integrated production and supply chain in accordance with ISO 14001 metrics and methodology. Contract provisions in the partnership agreement with each farm define environmental requirements and draw attention to relevant legislation. Hermès local partner can visit the property and plantation at any time during the season in order to provide technical assistance and verify performance. Hermès local partner works with third party environmental experts and has two internal environmental engineers.

Government requirements

There is a formal manual for silk production in Brazil, and each contractual agreement signed by the farmers describes general rules to be applied.

Company support for farmers

Hermès local partner has 50 employees in the field focused on tracking cocoon production, visiting the farms weekly to provide technical assistance and improving the relationship with each farmer family. On a quarterly basis, Abraseda – the Brazilian Silk Association - provides formal training sessions on operational requirements and best practices.

Hermès local partner provides guidelines and informal orientation on environmental standards together with operational standards. Formal annual lectures performed by Abraseda in national and state silk congresses are also focused on environment, health and safety best practices.

Biodiversity of silk production areas in Brazil

Silk production is concentrated in southern Brazil in the Atlantic Forest biome one of the world's biodiversity hotspots.[a] Over the past 500 years, more than 85% of the Atlantic Forest has been cleared and the forest ecosystems that remain are highly fragmented. Now the Brazilian Forest Code (Federal Law 12.651/2012) protects natural vegetation near rivers and other water bodies as well as on steep slopes and hilltops. Private landowners are required to keep 20% of their land in native forest. The Atlantic Forest Law further protects Atlantic Forest remnants.

The Interior Forest is the largest biogeographic subregion of the Atlantic Forest and has various types of seasonal forest vegetation. Seasonal forests have been largely destroyed over the last 100 years, and only about 2.5% remains. The extreme degree of forest fragmentation and degradation, resulting from the expansion of agriculture remains the key threat to biodiversity in the region.

Despite the loss of natural vegetation, many iconic plants and animals remain in the Atlantic Forest region. More detailed information on biodiversity of silk production areas is given in Annex 2. Silk farms can therefore play an important part in conserving biodiversity in the region.

Environmental impacts of silk production

There are five key drivers of biodiversity loss: climate change, land use change, pollution, exploitation of species and invasive species. Relatively few studies have been carried out on direct or indirect environmental impacts of silk production either in Brazil or elsewhere in the world. Sustainability issues identified at a global level generally relate to environmental impacts of chemical use and high energy input, together with the separate issues of animal rights and labour practices. An IUCN global overview study on biodiversity risks and opportunities in the clothing sector notes that silk production does not seem to drive land conversion - therefore direct habitat impacts are limited. However, it notes that the cleaning process of raw silk involves chemicals and the polluted wastewater can be discharged to local waterways. Furthermore, processing and transportation of silk contributes to pollution[3].

Some studies undertaken over the past 25 years have been noted for Bangladesh[4], China[5], India[6] and Thailand[7]. General environmental considerations relating to silk production and sustainable development in India highlight the lack of effective pest management programs with high yield losses due to weeds, pests, and diseases; low fertility of land, erosion, water logging and salinity[8].

Recent scientific papers on sustainability of silk production suggest that Brazilian sericulture causes limited environmental impacts[2,9,10] All the experts contacted in preparation of our report, including authors of these

[a] https://www.conservation.org/priorities/biodiversity-hotspots.

published papers, have confirmed the largely positive impacts of Brazilian silk production on the environment. However, the potential impacts are summarised in Box 1.

"There is a certain care on the part of the sericulture farmers in relation to biodiversity, because when they find snakes, they call the responsible organ[isation] to make the collection. This demonstrates the concern with the preservation of species. Regarding birds and butterflies, I believe that it does not affect their species, since the cultivation of mulberries intended exclusively for feeding silkworms, cannot have contact with pesticides, otherwise it causes the death of silkworms." Silvia Bortoloto Damasceno Barcelos (in litt. 2020).

Box 1 Potential impacts of Brazilian silk on biodiversity following the IPBES driver framework

1. **Changes in land use** – the historical change in land use with clearance of natural vegetation to cultivate mulberry and construct barns used in silkworm management may have led to local species extinctions, loss of genetic diversity of native species alongside loss of habitat.

However, silk production takes place in landscapes which have been modified and managed for at least 70 years and there is no current evidence of clearance of native vegetation for silk production. Now cultivation of mulberry has a relatively benign impact on the land compared to the cultivation of other local crops including soy and corn. Care is taken to make efficient use of the mulberry leaves in the silkworm rearing system reducing the need for further land conversion.

Wood is used to heat water for the purposes of silk processing, but a non-native plantation is managed for this purpose, reducing pressure on native forests.

Extensive amounts of water are used in silk production. Water consumption may indirectly impact on aquatic habitats and biodiversity, but no information has been found on this.

2. Direct exploitation of organisms – Both mulberry and silkworm are domesticated species and silk production in Brazil does not exploit any native species directly.

3. Climate change – considered in a separate report which shows that sericulture in Brazil accounts for around 29% of carbon emissions in a study of French silk manufacturing[1]. Mulberry cultivation removes and stores carbon from the atmosphere. The carbon sequestration of mulberry production in Brazil shows that mulberry fields attenuate CO^2 equivalent at a ratio of near 735 times the weight of produced silk fibre per cultivated area[10].

4. Pollution - In silk production around the world the use of chemicals is a source of air, land and aquatic pollution. In mulberry cultivation, fertilisers and pesticides can have negative impacts on biodiversity. In silkworm rearing a range of chemicals is used to prevent disease and chemicals used in silk processing are a further source of pollutants.

5. **Invasive alien species** - The mulberry *Morus alba*, native to China is cultivated throughout Brazil most extensively in the South for sericulture. It is considered to be a moderate risk as an invasive species establishing in degraded forest environments, with high light intensity and well-drained soils, such as riparian areas (http://bd.institutohorus.org.br).

Impacts of mulberry cultivation worldwide (excluding Brazil)

Mulberry is cultivated for its leaves which are harvested as the only food source for silkworms. The primary potential impacts of mulberry cultivation on biodiversity are through land use change and chemical pollution.

Mulberry (*Morus alba*) is the only plant species used in silk production. It is generally considered to be a beneficial multipurpose plant with high value for sustainable development. As well as its essential use in sericulture, mulberry is an important animal fodder crop especially for cattle, it is used in food, cosmetic and health care industries and is used in bioenergy production. It has ecological values in carbon sequestration, restoration of degraded lands, bioremediation of polluted sites, and conservation of soil and water through its extensive rooting system.[11–13]

Leaves of mulberry plants have noted ability to absorb air pollutants including carbon dioxide, carbon monoxide, hydrogen fluoride, sulphur dioxide and chlorine. In India, mulberry leaf has been used for the synthesis of nanoparticles used to combat silkworm diseases[13]. The roots of mulberry have high ability to uptake the carbon pollutants and heavy metal pollutants from the soil. Mulberry is often associated with mycorrhizae (symbiotic root fungi) that are beneficial to soils and has been reported to produce root exudates which nurture soil micro flora and fauna.

Mulberry is ideally suited to integrated farming systems which are generally considered to be ecologically favourable. In landscape management, practices that support the maintenance of biodiversity-friendly farming systems and diversity of landscape mosaics within and around production systems are encouraged, for example the management of riparian corridors, hedges, field margins, windbreaks, woodland patches, clearings in forests, waterways, ponds or other biodiversity-friendly features of the production environment.

In silk production around the world the use of chemicals is a source of air, land and aquatic pollution. In mulberry cultivation, fertilisers and pesticides can have negative impacts on biodiversity. Mulberry is attractive to many insect predators as noted in Nigeria[14] and in India[15]. de Almeida, J.E. and Fonseca, T.C. (2002) summarise the pests and diseases which impact on mulberry in Brazil[16].

Whilst mulberry cultivation is a relatively low-impact for of agriculture, all types of land-use have an opportunity cost. This is the biodiversity that historically would have occupied the area before conversion to agriculture, or that would occupy the area if it were restored to natural habitat.

Impacts of mulberry cultivation in Brazil (Hermès supply chain)

In Brazil, minimal chemical inputs are used in cultivation. Mulberry cultivation is likely to be significantly more environmentally friendly than production other crops grown in the region. Management of farms where mulberry is grown could be further enhanced to secure biodiversity benefits.

Mulberry cultivation for Brazilian silk production is carried out on family farms on small plots with minimal mechanisation. Hermès local partner provides advice on mulberry varieties, disease control and planting density, the latter determined by the Brazilian Sericulture Manual and Benchmark. In comparison with other silk production countries Brazilian legislation provides relatively strict environment, health and safety rules. There is no evidence to suggest that current silk farming has caused any recent deforestation and

"[*Hermès local partner] farms each maintain a reserve area of 20% to 35% of the total property with native vegetation complying with Federal Law 12.651/2012. All [Hermès local partner] properties issue a public register called CAR (Rural Environmental Register) that is mandatory for countryside properties in Brazil, which aims to consolidate environmental information regarding the state of nature in the locations of farms, processing sites and surrounding areas. Due to local laws, every family rural tenure complies with sustainable practices of soil and water management and water resources, guaranteeing their quality and quantity in accordance with the rules of the Environment Agency. "*

Further, Hermès local partner Producers take measures to protect endangered species and native flora and fauna. And cultivation does not occur in protected areas or their officially designated buffer zones, except where it complies with applicable law. Farmers are encouraged to maintain all remnant forest trees wherever possible and to manage other native trees on the farm.

Mulberry cultivation in Brazil can be considered a form of "low external input agriculture" (LEIA). LEIA reduces use of inputs (seeds, agrochemicals, irrigation water, fuel, etc.) from outside the production system. Yields are maintained through greater emphasis on agronomic practices, integrated pest management, and use of on-farm resources (especially labour) and management. The expected benefits of reduced inputs such as pesticides, is reduced impact on insect and soil diversity and consequently on bird, amphibian, reptile and mammal diversity.

Mulberry, as a perennial tree crop, provides various ecological services. However frequent pruning prevents plants from flowering and fruiting, and so mulberry does not provide a direct source of food for pollinators or frugivorous species such as birds and mammals.

Mulberry is grown as a monoculture in Brazil with soil between rows of plants cleared for weed control. This may lead to some soil loss and water run-off. However mulberry tree residues are used as mulch and other cover crops are used by Hermès local partner to reduce soil erosion. Studies are under way to integrate beans (leguminous plants) into mulberry plantations. Erosion by water and wind is also reduced through practices such as re-vegetation of steep areas and terracing.

In Brazilian silk production the use of superphosphate fertiliser in mulberry cultivation can have negative impacts. Alternatively, the use of organic fertiliser resulting from poultry farming, although preferable, may also have negative impacts on soil and water. The use of manure-based fertilizers in silk production could lead to eutrophication with increased nutrient loads to bodies of water leading to harmful algae blooms, dead zones, and fish kills. However, Hermès local partner undertakes laboratory analysis of soils on its farms and Producers are advised to use organic fertilizers and by-products available at farm level first, (optimizing the use of mulberry leaf waste during cutting and the remains of the rearing beds - mulberry stems and dry leaves and silkworm litter) and only supplement by inorganic fertilizer if nutrients are still lacking.

"[Hermès local partner] supports farmers with negotiation and logistics for organic fertilizers supply and inspection."

The use of pesticides is limited in Brazilian silk production because the quality of the leaves can be altered if the mulberry plants are contaminated with pesticide. There are few pesticides registered for use in the crop, except for herbicides, which can be used in mulberry plantations to combat invasive plants[17].

"[Hermès local partner] jointly work[s] with government agricultural agencies in order to apply and inspect available pest control techniques that discourage the development of pest populations in other cultures without risks to human health and the environment and without threaten sericulture farmers." Hermès local partner works with farmers to reduce contamination by pesticides from surrounding farmland, through spray drift or other pathways, for example by creating non-crop vegetative barriers. However, "*Unfortunately, irregular aerial spraying of pesticides generates drift of pesticides that can intoxicate the silkworm over distances greater than 50 km even though the vegetative barriers are in place."*

Although irrigation of mulberry plantations has not been necessary in the past, reducing the environmental impact, some irrigation of the crop is becoming necessary in Brazil as a result of increasingly dry climatic conditions.

Impacts of silkworm rearing worldwide (excluding Brazil)

Silkworm rearing takes place in carefully controlled artificial environments. The major potential impacts of silkworm rearing on biodiversity are through water use and chemical pollution

Silkworm rearing is undertaken in indoors, traditionally at relatively small scales by individual farmers, but industrial approaches are also emerging[b] . The land footprint of silkworm rearing is primarily due to mulberry cultivation, so the silkworm rearing stage does not contribute significantly to further land use change.

Large amounts of energy can be required to keep silkworms at the correct temperature and humidity, particularly for industrial scale operations in hot climates. Large quantities of water are used in silkworm rearing, in barn and grid disinfection. Chlorine used in barn disinfection and formaldehyde used for grid disinfection are both potential sources of pollution for local waterways. Other chemicals such as Methoprene and hormone disrupters are also used in silkworm rearing to lengthen the time silkworms spin silk.

[b] http://www.xinhuanet.com/english/2019-01/22/c_137765585.htm

Impacts of silkworm rearing in Brazil (Hermès supply chain)

Silkworm production in Brazil is carefully managed to minimise environmental impacts. Application of chemicals used in barn and grid disinfection are carefully controlled to minimise environmental risk

In Brazil, the silkworm rearing takes place on the smallholder farms. Hermès local partner provides farmers with guidance on water management in the barns where silkworms are reared and on the disinfection of grids on which silkworms spin silk. Bordeaux mixture, widely used in silkworm rearing, is another traditional agricultural fungicide composed of a mixture of copper sulphate and hydrated lime that is effective over a wide range of fungal diseases in crops. Hermès local partner has partly funded research to evaluate the use of Bordeaux mixture to control silkworm diseases caused by fungi and viruses. The research showed that Bordeaux mixture solution at a concentration of just 10% prevents fungal diseases and at the same concentration positively activates increased resistance to the virus BmNPV.[18]

The remains of the silkworm rearing bed are recycled appropriately. The plastic packaging used for chlorine and formaldehyde, and the paper packages used for lime are disposed of appropriately. Water used in raw silk production to remove yarn from the cocoon is recycled appropriately

Kraft paper is commonly used by producers in Brazil to cover the silkworms on the rearing beds, in order to maintain a stable temperature. The process for producing Kraft paper involves removing lignin from cellulose in wood fibres using sodium sulphide and caustic sodium hydroxide There may be more environmentally friendly alternatives such as newsprint, recycled paper nonwoven fabric or even reusable lightweight fabric with good breathability, and potential for reuse are recommended[9]. However, the impact of Kraft paper is not as significant as other environmental impacts.

The Brazilian rearing system also takes a circular approach using waste products efficiently such as the pupae as fish feed. This efficient use of materials helps to reduce the overall environmental impact of the system. This helps to reduce the pressure for further direct or indirect forest conversion by ensuring more efficient use of existing plantations.

Impacts of silk processing worldwide (excluding Brazil)

The potential impacts of silk processing on biodiversity are through water use and chemical pollution

Silk processing generally uses large amounts of energy in transport, to control temperature in silkworm rearing facilities, and to heat water for silk production as well as in dying and processing. The most energy-intensive part of the process tends to be in treating the cocoons. The cocoons are placed into very hot water in order to soften and dissolve the gum that is holding the cocoon together. This is a crucial step in silk production process as it ensures that there is no damage to the continuity of each thread.

Once the cocoons are produced, they are sorted by size, fibre quality, and defects and brushed to find the end of the filament. Several filaments are gathered together to form a yarn and are wound onto a reel in a process called reeling, which takes place in a facility called a filature. As filaments are reeled, they may be twisted (a process called throwing). How many filaments are used and how many times they are twisted varies depending on the intended use and appearance of the yarn. Reeling can be done either by machine or by hand. Toxic chemicals may be used during reeling and materials processing to both clean the silk and remove sericin. Any remaining sericin is removed from the silk, usually by soaking the yarn in hot soapy water, but sometimes bleach and other chemicals are used. Extensive amounts of water are used in the removal of the sericin

Impacts of silk processing in Brazil (Hermès supply chain)

Hermès local partner has extensive systems and standards to recycle water used in silk production. They also deploy innovative circular approaches to reduce waste of cocoons in the production system.

The Brazilian plants that produce the raw silk require large quantities of warm water to wet the cocoon so that can pull the yarn from the cocoon. Water is treated prior to application to ensure it is of good quality to obtain the yarn. Water consumption may indirectly impact on ground water, aquatic habitats and biodiversity but no information has been found on this. In Brazil, the plants that produce the raw silk have a filtration station to recycle the water so that it is suitable for general urban use. Quality of water is under control of the local authorities.

"*Water is used in 100% of the production of the Silk thread, being able to use this natural resource and return it to the environment in the appropriate standards for maintaining Fauna and Flora is a reason for pride and satisfaction for [Hermès local partner].*"

The wood used in the boilers used to heat water for the silk reeling process comes from Hermès local partner's own reforestation unit of 881 ha of *Eucalyptus*. *Eucalyptus* spp. are not native, but several species are widely grown as a tree crop in Brazil since their introduction over a century ago. Eucalyptus is fast-growing and provides wood for furniture, paper and cellulose production, charcoal and power generation. Planting on a large scale has been controversial and highly damaging when replacing natural forest. In Brazil, Eucalyptus plantations have generally been intensively managed in short rotations as extensive monocultures, which prevent the natural regeneration of native woody species. However, it has been shown that less intensively managed and abandoned eucalypt plantations host a high diversity of plants and birds. Experimental work in the Atlantic Forest has shown that mixing plantations of eucalypts and native trees is a promising restoration strategy[19].Hermès local partner could consider the use of fast-growing native species as alternatives gradually replacing Eucalyptus at least in part of the reforestation unit. A list of fast-growing native tree species with potential to restore the Atlantic Forest is, for example, provided by Meli *et al* 2018[20].

Hermès local partner has created an efficient and circular production system to use virtually every piece of the cocoon preventing waste and promoting sustainability. The silk 'blaze' produced just before the cocoon is spun is used in various products such as string, upholstery, pillows and quilting. While. the 'sharp' the last bit of the cocoon spun to make a cotton-like fabric.

Recommendations for enhancing biodiversity in Brazilian silk production

Little attention has been given to the enhancement of biodiversity through silk production. Brazil has a strong legal enabling framework for biodiversity conservation but there is potential for the small rural properties producing silk in Brazil to be managed as "refuges" for biodiversity.

The following recommendations are based on our review of the questionnaire response, survey of scientific literature and understanding of best practice in agricultural production and supply chains. Recommendations are provided elsewhere for further action to enhance sustainability in Brazilian silk production noting that guidelines for mulberry and cocoon production are provided to the producers by the yarn manufacturing company[9]. Furthermore, they note that producers will only take actions towards better environmental performance if such actions comply with the yarn manufacturing company's policy, and if it is economically beneficial. From the information provided by Hermès local partner we consider that silk production is Brazil can be celebrated for its positive environmental benefits with the potential to further increase biodiversity gains through a variety of measures. Sustainable silk initiatives are also being established in countries other than Brazil in response to concerns about the environmental impacts of silk production see Box 2.

Bombyx – a Chinese case study

China is the world's largest silk producer, six times larger than the second biggest producer, India. Silk rearing and reeling industries within China are large-scale and highly mechanised. Formed in 2018, BOMBYX is an innovative silk supplier and textile manufacturer that aims to create environmentally conscious textiles through best practices in the industry. BOMBYX set new standards through transparent business practices and trusted supply chain by integrating social and environmentally responsible approaches to benefit all stakeholders, communities and nature. The central farming and factory site is based in Nanchong's Yilong County, located in the Northeast of China's Sichuan Province.

Mulberry cultivation involves terrace farming, rotational cropping, intercropping, biological pest control and fertiliser production. Solar powered electric lamps are used to attract harmful insects which are trapped in bottles attached to the lamps.

Organic limestone ash is used in powder form in the silkworm nurseries and in paint form on tree trunks for pest control.

Measures are being taken to improve silk production from silk reeling to degumming and uses environmentally certified weaving machines.

Bombyx has achieved CERES Certification (see Annex 3) at their mulberry and silkworm farms. Key metrics include the conservation or improvement of soil fertility and sustainable use of water. The standard for water is applicable to surface water, groundwater, treated aquaculture wastewater, and industrial wastewater.

Create a strategy & commit to a biodiversity target

Consider further integrating biodiversity issues into the business by making a public commitment, developing a biodiversity strategy and targets and, if necessary, further building staff capacity to deliver this target. The silk production system is a good candidate for delivering a 'net-positive' biodiversity target.

Monitor biodiversity

Evaluate the biodiversity of production locations, particularly the mulberry farms, to better understand the species that co-exist with the production system, especially those that may be rare or endangered, for examples, see Box 3. The silkworm farmers could undertake some of the monitoring using easy-to-follow guides showing species of interest. Local biodiversity surveys could act as baselines for any biodiversity target helping to track the additional benefits to that can be achieved by continued careful land management for silk production. The impacts of water extraction for the silk processing on biodiversity could also be studied further.

Box 3 Species of interest in Brazilian silk production areas

Particular attention should be given to noteworthy species of conservation interest where present in silk production areas. For example, *Leopardus guttulus* is the smallest wild cat species in Brazil and is considered a flagship species that can be used to draw attention to biodiversity conservation and an umbrella species whose conservation can provide protection to a large number of species that naturally occur in the same area.

Bird species of conservation interest, noting some silk producing municipalities where they occur, include Crowned Eagle, *Buteogallus coronatus* (Endangered) - Glória de Dourados-MS; White-bearded Antshrike, *Biatas nigropectus* (Vulnerable) - Itapeva-SP; Temminck's Seedeater, *Sporophila falcirostris* (Vulnerable) - Itapeva-SP. Globally Near Threatened bird species include Greater Rhea, *Rhea americana* - Umuarama-PR, Glória de Dourados-MS; Blue-fronted Amazon, *Amazona aestiva* - Maringá-PR, Umuarama-PR and Glória de Dourados-MS; Bare-throated Bellbird, *Procnias nudicollis* - Itapeva-SP, Itaquiraí-MS and Novo Horizonte do Sul-MS

Blue-fronted Amazon, Bare-throated Bellbird (and possibly Temminck's seedeater) are threatened by capture for the pet bird trade in addition to habitat loss. Local conservation work for the Blue-fronted Amazon, taking place in Novo Horizonte do Sul for example is focused on monitoring nests, assessing the scale of bird trafficking and working with local communities to address this problem. Although not directly relevant to silk production this may be an action worthy of support.

Maintain & enhance on-farm habitats

Mulberry plantations provide environmental services including carbon sequestration, water retention and maintenance of soil health. Mulberry is grown as a monoculture in Brazil but Hermès local partner is experimenting with co-cultivation of beans which are nitrogen-fixing and thus enhance soil fertility. Frequent pruning of mulberry, which is grown only for the leaves, prevents plants from flowering and fruiting, and so mulberry does not provide a direct source of food for pollinators or frugivorous species such as birds and mammals. Hermès local partner could experiment with different pruning regimes to see if benefits for wildlife can be enhanced. However, the maintenance of natural vegetation does however provide compensatory resources for native animal species as well as other environmental services.

Remnant natural vegetation is increasingly important for biodiversity conservation in agricultural landscapes both in Brazil and globally. Remnants of natural vegetation retained within the Brazilian mulberry farms provide havens for biodiversity. To the extent possible forest fragments should remain undisturbed allowing ground flora to survive as well as the shrubs and trees. Hermès local partner can also apply these principles to its native forest farm (200 hectares) and a protected mulberry plantation area (500 hectares).

Restoration

Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. Forest fragments act as reservoirs of plant material for expanding forest cover and boosting populations of species that may be in decline. The structure and composition of forest fragments provide a reference point for restoration of degraded areas with more extensive local protected forests being useful for comparison. Based on knowledge of the species composition, appropriate seeds and other propagation materials can be collected for nursery cultivation or direct planting.

Wider landscape

Hermès local partner farmers are located over a relatively wide area in the region. Systematic conservation planning could be undertaken to maximise the benefits from restoration activities, for example, to help establish wildlife corridors linking up larger fragments of Atlantic Forest. Increased amounts of natural vegetation will help to buffer mulberry farms from pesticide drift from the surrounding landscape.

Continue to reduce the use of pesticides & fertilisers

On farm the use of biofertilisers composed of living microorganisms could be used to further assist the development, supply, and availability of primary nutrients to the mulberry[9]. Further use could also potentially be made of mulberry leaf waste produced during cutting, noting that on average, about 30% of plant material is wasted during the harvest, and further use of the remains of the silkworm rearing beds (mulberry stems and dry leaves, and silkworm litter)[9]. Composting of this material could provide an alternative to poultry manure. Composting decreases the need for chemical fertilisers while conserving natural resources and brings economic and social benefits. It improves the chemical, physical and biological properties of the soil, promoting root development, with higher yield and quality in cultivation. The use of living fertilisers or "green manure" is also recommended to replace organic manure. Planted between the mulberry rows, grass mixes and leguminous plants such as clover and alfalfa, add nutrients to the soil and suppresses the growth of weeds. Such practices build on the experimental planting of beans as undertaken by Hermès local partner.

In the wider landscape

In Brazil, pesticides used in surrounding areas of crop production have negative impacts on silkworm production by contaminating the mulberry leaves which are the sole source of food for the silkworms. Research has shown that contamination of mulberry leaves by the fungicide pyraclostrobin, commonly used in sugarcane cultivation, promotes increased mortality rates in silkworms proportional to the amount of fungicide that reaches the leaves. This fungicide can be moderately persistent to persistent in the soil, including in areas of sugar cane

cultivation and can be harmful to aquatic ecosystems[17]. Drift from aerial spraying is a problem and it maybe some time before the farmer realises that this has occurred. Silkworm producers have called on the justice department to limit the application of pesticides in areas with cocoon production (Nicodemo *in litt*.).

Continue to embrace circularity & efficiency in resource use

Hermès local partner already demonstrates impressive innovation in its approach to reducing waste in its silk production system. For example, waste products from silkworm rearing are used as mulch for the mulberry trees, the silkworm cocoons are used for multiple products, and finally measures are used to reduce and recycle water.

The concepts of reuse and recycling for all materials used in silkworm rearing should be maintained. There may be additional efficiency gains that can be made, for example, in silkworm rearing, alternatives to Kraft paper that have a lower environmental footprint could be used such as newsprint, nonwoven fabric or even reusable lightweight fabric with good breathability, and potential for reuse[9].

As irrigation of mulberry trees becomes necessary due to climate change, renewable, efficient sources of water should be sort. For example, by harvesting rainwater, minimising run-off and improving water retention qualities of the soil.

Share your knowledge with the wider industry

The Brazilian silk production system provides an excellent example of how risk to nature can be minimised. Lessons could potentially be transferred to silk production in other countries, helping the industry as a whole improve its environmental impact.

Hermès silk production within the Science Based Targets for nature framework

Science-based targets for nature (SBTN) are measurable, actionable, and time-bound objectives, based on the best available science, that allow actors to align with Earth's limits and societal sustainability goals[21]. Full guidance on SBTN are expected in 2022, but in the interim the SBT network has provided interim guidance for companies. Within this guidance is the AR^{3}T action framework, which allows companies to develop grounded plans to deliver on biodiversity targets. As a signatory of the Fashion Pact, Hermès is committed to adopting SBTN. We have therefore scoped an AR^{3}T framework based on Hermès silk supply chain

Potential goal: For Hermès silk supply chain to contribute to the restoration of nature in the Atlantic Forest region, through nature-positive mulberry cultivation and silk production.

Avoid	Continue to avoid sourcing from farms and systems where environmental impacts such as deforestation and chemical pollution are occurring. Continue to avoid any harm to remaining forest fragments which are of increasing global importance for biodiversity conservation. Any remnant forests and other areas of natural vegetation, ponds and riparian areas within the silk farms and surrounding areas should continue to be conserved. Continue to avoid discharging any chemicals into the environment.
Reduce	Continue to embrace circular approaches to water and other resource use. As irrigation becomes necessary, techniques that improve moisture retention of the soil and use harvested rainwater should be adopted in preference to extracting water from rivers and reservoirs. Care should be taken to minimize any waste in the harvesting of the mulberry leaves. Continue to reduce the use of fertilisers in mulberry production with environmentally friendly alternatives promoted where possible. Reduce the use of other chemicals in silk production as much as possible.
Restore & Regenerate	Restoration of forests is an important objective in the Atlantic Forest global biodiversity hotspot. Within silk production farmland, assistance with mapping appropriate areas for restoration, and providing tree seedlings, could make a significant difference. Tree planting with appropriate species at a minimum up to the legal requirements (areas of permanent protection along waterways and on slopes, and legal reserves) such be supported. Other appropriate species should be considered in planting schemes such as native bamboos (*Guadua* and *Merostachys* spp.) on which the globally threatened bird species White-bearded antshrike and Temminck's seedeater are dependent. Restoration of degraded areas and formation of ecological corridors in silk production areas could be a major contributor to national and global targets. At a local level such activities help buffer against negative impacts from more intensive farming on surrounding lands. The Brazilian Forest Law of 2012 allows farmers to restore Permanent Preservation Areas (riparian zones, springs, hillsides and ridge tops) and conservation set-asides (known as Legal Reserves), which are required on all rural lands, through agroforestry practices.

	Eucalyptus plantations could be managed better for biodiversity by including native tree species. Soil biodiversity should continue to be monitored and restored to the extent practicable and enhanced considering FAO 2017 guidelines (see Annex 3).
Transform	Continue to promote conservation of biodiversity in surrounding farmed areas particularly through actions to reduce pesticide use and promote reforestation by engaging with the wider farming community and policy makers. Share with the wider industry the lessons learned from circular approaches to silk production. Work with others in the fashion industry to define environmentally acceptable standards for silk production. Sharing a roadmap for achieving a nature-positive silk supply chain. Invest in research to find even more efficient ways of producing silk by reducing key dependencies on water and chemicals.

Conclusions

Nature is declining at unprecedented rates with 1 million species threatened with extinction. Protecting and restoring nature is fundamental not only to global economic prosperity, but to the health and wellbeing of society. In 2021 there is expected to be renewed ambition to strengthen global targets and mechanisms that will reverse the loss of nature by 2030.

The silk production system is of relatively low environmental impact, especially when compared to neighbouring agricultural activities such as soy and sugarcane.

The growth of silkworms depends on a diet exclusively based on the leaves of the mulberry tree. Mulberry plantations sequester carbon, prevent erosion and help regenerate the soil. Far fewer agrochemicals are used in mulberry cultivation especially compared to the surrounding farmland where soybeans and sugarcane are grown.

Waste from mulberry cultivation and silkworm rearing is largely recycled within the production system. Virtually every piece of the cocoon as well as other co-products of the silk industry are used, for everything from fish food to fabric. Such circularity reduces the demand for raw materials, which means that more space can be left for nature.

We consider that silk production in Brazil can be celebrated for its positive environmental benefits. However, there is still potential to create greater benefits for the biodiversity that persists in the fragmented Atlantic Forest region.

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Annex 1 – Description of Brazilian silk production

In the State of Mato Grosso do Sul, silk production is in Itaquiraí, Glória de Dourados and Novo Horizonte do Sul. In the municipality of Glória de Dourados, sericulture for many years was one of the main activities performed by rural producers in combination with other agricultural activities. Production has declined due to economic and climatic factors with farmers switching to less physically intensive forms of farming (Rochefeler *et al* undated).

Paraná's sericulture is represented by about 1867 small producers in 161 municipalities, occupying an area of 3.78 thousand hectares that resulted in a production of 2.5 tons of green cocoons, and generated about US$ 16 million in revenues from the export of silk yarn and silk fibres in the first half of 2019 (Bortoloto Damasceno Barcelos *et al* 2020). Ciria, 2019, notes that silk production in Parana occurs in 18 of the regional agricultural centres delimited by SEAB/DERAL. The Ivaiporã and Maringá centres have the largest mulberry cultivation areas and production of green cocoons. The regional core of Ivaiporã has 14% of the sericulture area of the state, accounting for 13% of production with 16% of sericulture farmers. Maringá has about 20% of the general area of the state, 23% of the total production. Productivity in the regional core of Umuarama was 14% higher than the average general state occupying 5% of the state's sericulture area. There is no sericultural activity in the Coastal Pre-territory and in the Vale da Ribeira and Center South Territories.

Silkworm rearing

Bombyx mori, the domestic silk moth, is the species used in 95% of global silk production and is the basis for the carefully controlled Brazilian industry. Silkworm rearing takes place in closed systems with temperature and light managed for maximum production. In silkworm rearing, silk moths lay around 300-400 eggs. The eggs are incubated in a controlled environment until they hatch to form larvae. The silkworm larvae feed continually on a huge amount of locally produced mulberry taking around 6 weeks to grow to their full potential at which time they are ready to spin their cocoon. The larvae go through various instar stages (depending on race). Generally, in Brazil, silkworms are provided to the producers when they are in the 3rd instar of larval development (Santos *et al* 2011).

Silkworms shed their skin at each instar stage. In the course of moulting the content of the exuvial gland and Malpighian vessel flows out between the new and old skins to help cast the exuvia or outer skin. In the final larval stage, the body is divisible into 3 parts, a small head with special spinneret through which silk is exuded; thorax with 3 segments, each with a pair of clawed legs which are used for holding the leaves while feeding; and abdomen with 11 segments. The full-grown final instar (ripe worm or larva) stops feeding and is translucent as the gut discards all its green content. The body of ripe worm shrinks in length and a visible constriction appears at 4^{th} and 5^{th} segments. As the worm stops feeding it usually moves towards the edge of rearing tray and prepares to pupate, spinning the protective cocoon.

The ripe worm secretes a tiny droplet of silk – the anchorage spot, which hardens and sticks onto the supporting structure. The larva then anchors itself to that spot and spins a loose hammock forming the framework of the cocoon. This loose, tangled mass of filament is called blaze or floss which is not reelable.

After getting a good foothold in the hammock, the larva spins the silk cocoon by rotating its body in a figure-8 movement around 300,000 times – a process which takes around 3 to 8 days. Each silkworm produces one single strand of silk, which measures about 100 metres in length and is made of two main elements: fibroin, which makes up between 75 and 90% of the filament, and sericin, the gum secreted by the caterpillar to glue the silk thread into a cocoon, which comprises about 10-25%.

Once the cocoon formation is over, the larvae moult inside and transform into pupae. Before transforming into proper pupae, the mature larvae pass through a pre-pupal stage during which dissolution of many larval organs such as the silk gland, moulting gland, abdominal appendages takes place. Within the cocoons, silkworms metamorphosize into moths which secrete a fluid that dissolves one end of the cocoon so they can emerge. Most silkworms used in silk production are killed inside the cocoon before metamorphosis is complete, usually by using steam. Some silkworms are allowed to metamorphosize, so they can be used for breeding and laying more silkworm eggs.

In silkworm rearing both light and temperature are carefully controlled. Silkworms are photosensitive and generally tend to crawl towards dim light. Light conditions are carefully controlled to prevent irregularity in growth and moulting of the silkworm larvae.

Silkworms are susceptible to pathogenic microorganisms which cause a variety of diseases. Infection by viruses cause grasserie disease, bacteria cause flacherie disease, fungi cause green muscardine & white muscardine diseases and protozoa cause pebrine disease. Santos *et al* 2011, discuss the main silkworm diseases in Brazilian production. Breeding for resistance is one way of decreasing the effects of infection. The nucleopolyhedrovirus (BmNPV) is a major cause of silkworm loss causing a serious problem for Paraná sericulture (Pereira et al 2013). The susceptibility or resistance to BmNPV in silkworm germplasm has been studied at the Universidade Estadual de Maringá (UEM) which maintains the public *B. mori* germplasm bank in Brazil (Pereira et al 2013).

An additional hazard for any insect culture is the widespread use of a biological agent, the bacterium *Bacillus thuringiensis* (Bt) to control plant pests. Commercial preparations of different varieties of *Bacillus thuringiensis* (Bt) have been used as biopesticides around the world for decades. This bacteria is also responsible for a special type of flacherie disease known as "Sotto" which kills silkworms.

Prevention and control of silkworm diseases in the rearing sheds is one of the most important aspects in the success of commercial sericulture by using good hygiene and disinfection. Disease control is generally difficult because of the high concentration of silkworms; their short life cycle, which limits the time to combat the disease; direct contact with employees; relatively high temperature and humidity; little control over contamination of the mulberry branches that are brought from the field; the large production of organic waste and the rustic nature of the sheds, which make it difficult to complete disinfection; and the clustering large numbers of sheds in a single region. The limited availability of disinfectants and other products that are not toxic to caterpillars is another factor to consider. Chemical disinfectants that are used in sericulture may cause poisoning of silkworms and also be harmful to farmers. Use of the same product, over a long period, can lead to resistance to one or more active ingredients so it is beneficial to periodically rotate control products.

Annex 2 – Biodiversity of Brazilian silk production areas

Biological diversity means the variability among living organisms including genetic diversity within species, between species and of ecosystems. The information in this section results from a rapid literature search and correspondence with experts. It is far from complete. Published information on biodiversity in the areas of silk production is mainly produced by researchers at the Universities of Londrina, Maringa and São Paulo where there is considerable local expertise. Where the IUCN conservation categories are given these are:

LC	Least Concern
NT	Near Threatened
VU	Vulnerable
EN	Endangered
CR	Critically Endangered

Vegetation and plant species

Silk production takes place predominantly in the region of Seasonal Semideciduous Forest (FES) - the second main forest formation in Paraná and the most threatened. FES originally covered 37% of the state, but currently only 3% of the total remains. Such forests occur at altitudes between 200 and 800 m, in the West, Northwest and North of the State, largely coinciding with the region of occurrence of the commonly known "terra roxa" (Estevan *et al* 2016). Tree species composition varies for example due to proximity to water courses. Cattle grazing is one of the main threats to the remnant forest patches.

The municipality of Londrina, in the hydrographic basin of the Tibagi River, has FES as the dominant vegetation type. One of the largest forest remnants in the region, consisting of 1,126 ha of fragmented natural forest, is the Experimental Agrozootechnical Station Hildegard Georgina von Pritzelwitz, a Private Reserve of Natural Heritage (Ordinance No. 195/98 / IAP / GP). The vegetation of this Reserve has been analysed (Estevan *et al* 2016) and can be used as a reference site for original vegetation in the region. Trees of conservation significance are those listed as rare for the State of Paraná by the Environment Secretariat (1995): *Achatocarpus pubescens*, *Astronium graveolens*, *Aspidosperma polyneuron*, *Lonchocarpus muelbergianus*, *Machaerium paraguariense* and *Myrocarpus frondosus*. These species are included in this category due to the reduction of their habitat, but are not yet in danger of extinction. Additionally, uncommon tree species found in the Reserve include *Cordia ecalyculata*, *Crysophyllum marginatum*, *Bastardiopsis densiflora*, *Strychnos brasiliensis*, *Ruprechtia paranensis, Mollinedia clavigera*, *Myrsine laetevirens*, *Plinia trunciflora*, *Guapira hirsuta*, *Guapira opiamia.*

Estevan *et al* 2016, compare the vegetation of the Private Reserve with 19 forest fragments in the region. São Jerônimo da Serra, has a large number of exclusive species almost 25% (38 spp.) This area includes typical species of savannah of Paraná, such as *Anadenanthera peregrina*, *Caryocar brasiliense*, *Couepia grandiflora*, *Handroanthus ochraceus*, *Qualea cordata*, *Ouratea spectabilis*, *Stryphnodendron adstringens*.

Also in the municipality of Londrina is the Mata dos Godoy State Park (MGSP) a remnant of SEF with an area of 690 ha. A catalogue of 508 plant species has been produced for this important conservation site, including 40 ferns and lycophytes, with the State level conservation status noted for 21 species (Sandoli Rossetto and Santos Vieira 2013).

According to Marques and dos Anjos (2014), who used MGSP to study the impact of forest fragmentation on bird species, the northern region of the MGSP, a plateau at about 600 m altitude, has a dense, closed canopy between 12 m to 20 m where the most abundant tree species are *Cabraela canjerana*, *Euterpe edulis*, *Ocotea indecora* and *Nectandra megapotamica*. The midstory and understory receive little light, and the understory is relatively open, with short trees and bushes such as *Eugenia verrucosa*, *Sorocea bonplandii* and species of *Miconiatritis*, *Maranta* and *Piper*. The southern portion of the Park consists of a sloped area (600 – 470 m) ending in a floodplain of the Apertados river, the southern boundary of the Park. The canopy is less compact, with the largest trees sparsely distributed, including *Chrysophyllum gonocarpum*, *Campomanesia xanthocarpa* and *Parapiptadenia rigida*. The midstory, however, has a higher density of smaller tree species, with *Nectandra megapotamica*, *Alseis floribunda*, *Matayba elaeagnoides*, *Lonchocarpus muehlbergianus*, *Sebastiana commersoniana*, *Eugenia verrucosa* and *Trichilia cassaretti*. Forest clearings resulting from tree fall are dominated by the widespread *Celtis iguanaea* and bamboo *Chusquea* sp. The edge of the park is characterized by a riparian forest floodplain which has trees such as *Bastardiopsis densiflora* and *Ocotea puberula*.

The local species *Euterpe edulis* (Juçara) is a palm tree widely distributed in the Atlantic Forest, which produces edible fruits. Growing to 20 m in height, this palm produces bee-pollinated flowers in spring followed by purple fruits which are an important food source for birds such as parrots and toucans, and a variety of mammals including squirrels, agoutis and wild pigs. Palmiteiro can be abundant in well-preserved areas of natural habitat but it has been systematically exploited for the extraction of palm hearts or palmito throughout its range. It is one of the most important non-timber forest products (NTFP) exploited in the Atlantic Forest, providing an important source of additional income for farmers. Extraction of the palm heart is undertaken by people also known as palmiteiros, who sometimes work seasonally on banana plantations. The wood of *E. edulis* is used as a by-product in lightweight construction for example to make fence posts. In some areas all adult individuals of the palm have been exploited, leading to local extinction. Overall *Euterpe edulis* is considered to be Vulnerable in Brazil by CNC Flora, the Brazilian Plant Red Listing Authority.

The conservation status of trees referred to in the text is given in the table below.

Scientific name	IUCN Global Status	Status in Brazil
Achatocarpus pubescens		Rare in Paraná
Anadenanthera peregrina *(Peregrina linearifolia)*		Vulnerable*
Astronium graveolens		Rare in Paraná, LC nationally
Alseis floribunda	LC	

Aspidosperma polyneuron	EN (needs updating)	Rare in Paraná, NT nationally & on the list of IBAMA (Normative Instruction no. 06, of 23/09/2008)
Bastardiopsis densiflora		
Cabraela canjerana		
Campomanesia xanthocarpa		LC
Caryocar brasiliense	LC	VU in Parana, LC nationally
Celtis iguanaea	LC	LC
Cordia ecalyculata		
Couepia grandiflora		
Chrysophyllum gonocarpum	LC	
Crysophyllum marginatum	LC	
Eugenia verrucosa		
Euterpe edulis		Vulnerable
Guapira hirsuta		LC
Guapira opiamia		
Handroanthus ochraceus		
Lonchocarpus muelbergianus		Rare in Paraná
M*achaerium paraguariense*		Rare in Paraná, LC nationally
Matayba elaeagnoides	LC	
Mollinedia clavigera	LC	
Myrocarpus frondosus		LC
Myrsine laetevirens		
Nectandra megapotamica	LC	
Ocotea indecora	LC	
Ocotea puberula	LC (needs updating)	NT, (impacted in Maringa region as a consequence of deforestation for agriculture)
Ouratea spectabilis		Rare in Paraná, LC nationally
Parapiptadenia rigida	LC	
Plinia trunciflora		

Qualea cordata	LC	
Ruprechtia paranensis		
Sebastiana commersoniana		
Sorocea bonplandii		
Strychnos brasiliensis	LC	
Stryphnodendron adstringens		Rare in Paraná, LC nationally
Trichilia cassaretti	VU (needs updating)	LC

Sources: Species listed as rare for the State of Paraná by the Environment Secretariat (1995):
CNC Flora, the Brazilian Plant Red Listing Authority,

Mammals

There are few records of studies on mammal inventories in the forested fragments in the north-western region of Paraná (de Oliveira Martins *et al* 2016). The table below gives some examples of species recorded in areas of silk production with their conservation status. It does not include smaller species, for example of rodents.

Scientific name	Common name	IUCN Global Status	Status in Brazil
Panthera onca	Jaguar	NT	increasing fragmentation in southeastern Brazil
Puma yagouaroundi	Jaguarundi	LC	VU
Leopardus guttulus	Southern tiger cat	VU	VU
Cerdocyon thous	Crab-eating fox	LC	
Procyon cancrivorus	Crab-eating raccoon	LC	
Tapirus terrestris	Lowland tapir	VU	Persists in landscapes of commercially produced crops with only small degraded forest fragments in the interior of Sao Paulo and Parana.
Mazama gouazoubira	Grey brocket deer	LC	
Leontopithecus chrysopygus	Black Lion tamarin	EN	Endemic to Sao Paulo. In the southeast of the state it occurs mainly in non-protected patches of gallery forest in at least one municipality – Itapeva – where silk production occurs. The species is able to live in modified/disturbed environments such

			as secondary forests, relying only on sufficient year round available resources, such as tree holes to be used as sleeping sites, and fruit trees or foraging sites.
Sapajus nigritus	Black-horned capuchin	NT	Occurs in secondary forests and forest fragments in agricultural land.
Alouatta guariba	Brown howler monkey	VU	
Nasua nasua	South American Coati	LC	
Pecari tajacu	Collared peccary	LC	
Tayassu pecari	White-lipped peccary	VU	Locally extinct???
Dasyprocta azarae	Azara's agouti	DD	occurs in the municipality of Maringa and in Cianorte.
Dasypus novemcinctus	Nine-banded armadillo	LC	
Euphractus sexcinctus	Yellow armadillo	LC	Adapts well to habitat modifications for agriculture.
Hydrochoerus hydrochaeris	Capybara	LC	Riverine habitats
Myocastor coypus	Coypu	LC	Riverine habitats
Cuniculus paca	Agouti	LC	Endangered in Parana
Sciurus aestuans	Guianan or Brazilian squirrel	LC	
Sylvilagus sp.			VU in Parana
Eira barbara	Tayra	LC	Can thrive in agricultural areas and near human settlements.
Didelphis aurita	Brazilian common opposum	LC	
Didelphis albiventris	White-eared opossum	LC	
Tamandua tetradactyla	Southern tamandua	LC	
Coendou spinosus	Dwarf hairy porcupine	LC	
Phyllostomus hastatus	Greater spear-nosed bat	LC	
Carollia perspicillata	Seba's short-tailed bat	LC	
Sturnira lilium	Little yellow-shouldered bat	LC	
Artibeus lituratus	Great fruit-eating bat	LC	
Platyrrhinus lineatus	White-lined broad-nosed bat	LC	

Pygoderma bilabiatum	Ipanema bat	LC	
Noctilio leporinus	Greater bulldog bat	LC	
Molossops neglectus	Rufous dog-faced bat	DD	
Molossus molossus	Velvety free-tailed bat	LC	
Eptesicus furinalis	Argentine brown bat	LC	
Lasiurus blossevillii	Southern red bat	LC	
Myotis riparius	Riparian myotis	LC	

Sources: IUCN Red List (sourced 31.12.20) Di Bitetti *et al* 2003; de Oliveira Martins *et al* 2016; Gazarini *et al* 2013; Voltarelli *et al* 2009

A full checklist of mammals of São Paulo State is provided by de Vivo *et al* 2011 noting that in total 231 mammal species have been recorded but many regions of the State continue poorly surveyed.

A list of threatened mammals of Mato Grosso do Sul is provided by Torrecilha *et al* 2018.

Birds

Birds are highly significant indicators of biodiversity. The Atlantic Forest has a rich diversity of species many of which are recorded as threatened.

The first list of fauna threatened with extinction in Paraná was published in 1995 and revised in 2004. Parque das Aves funded and organized the revision of the List of Threatened Bird Species of Paraná through a partnership with the State Department of Environment (SEMA) and the Environmental Institute of Paraná (IAP) with publication in 2018. Decree 11,797 published on November 22, 2018 provides a list of bird species threatened with extinction in Paraná and takes other measures in compliance with Decree No. 3,148 of 2004.

The list includes 118 species threatened with extinction in Paraná. Of these, 11 are Extinct in the Wild, 19 are Critically Endangered, 37 are Endangered, 51 species are Vulnerable, and 35 species are categorized as Near Threatened. https://www.parquedasaves.com.br/en/our-work/avaliacao-e-prioridades/listavermelha/

114 bird species have been recorded in the Mata dos Godoy State Park (MGSP). The relationship between the sensitivity to forest fragmentation of bird species and their spatial distribution within the forest habitat has been studied in this protected area (Marques and dos Anjos, 2014).

Examples of globally threatened bird species recorded in silk production municipalities (Phalan *in litt*. 2021) include:

Crowned Eagle, *Buteogallus coronatus* (Endangered) - Glória de Dourados-MS
White-bearded Antshrike, *Biatas nigropectus* (Vulnerable) - Itapeva-SP
Temminck's Seedeater, Sporophila falcirostris (Vulnerable) - Itapeva-SP

There are also some Near Threatened species recorded in these municipalities:
Greater Rhea, *Rhea americana* - Umuarama-PR, Glória de Dourados-MS
Blue-fronted Amazon, *Amazona aestiva* - Maringá-PR, Umuarama-PR and Glória de Dourados-MS
Bare-throated Bellbird, *Procnias nudicollis* - Itapeva-SP, Itaquiraí-MS and Novo Horizonte do Sul-MS

Blue-fronted Amazon, Bare-throated Bellbird (and possibly Temminck's Seedeater) are threatened by capture for the pet bird trade in addition to habitat loss. There is a local conservation project focused on the Blue-fronted Amazon, for example, in Novo Horizonte do Sul. The project is focused on monitoring nests, assessing the scale of bird trafficking (which is a big problem there - this is the most-trafficked parrot in Brazil) and working with local communities to address this problem.

A checklist of the birds of São Paulo State is provided by Silveira, L.F. & Uezu, A. 2011.

A list of threatened birds of Mato Grosso do Sul is provided by Torrecilha *et al* 2018.

Amphibians

Globally at least one-third of known amphibian species are threatened with extinction, a rate higher than that for birds or mammals. Major threats to amphibians include habitat loss or degradation and the rapidly dispersing infectious disease chytridiomycosis. Amphibians contribute to a range of ecosystem services, for example, by reducing mosquito recruitment from ephemeral wetlands and potentially controlling other pest species.

The State of São Paulo is one of the most studied regions of Brazil in terms of amphibian species richness and distribution but there is still not a comprehensive species list for the State. A list including 231 species of amphibians (225 anurans and six caecilians), of which 27 are endemic is presented by Araújo *et al* 2009.

Amphibian species from Mato Grosso do Sul are listed by Souza *et al* 2017. A total of 97 species are listed (including 25 Anuran genera and one caecilian), representing more than 10% of the known Brazilian amphibians. Semideciduous forests are the second richest vegetation type for amphibians after Cerrado.

There are few studies of amphibians in Northern Paraná and it is thought that many species are yet to be discovered or may have their geographic distributions expanded. De Pavia Affonso *et al* 2014 provide a list of anurans from the rural zone of the municipality of Maringá. They note that lists exist for a few other locations at in the northern region of Paraná state, for example, at Londrina, a municipality around 100 Km far from Maringá, 24 anuran species were reported by Machado *et al* (1999) and Bernarde and dos Anjos (1999), with an overlap of 13 species. The difference between Londrina and Maringá species, probably result from the difference between conservation of the sampled areas and the size of the samples, which was bigger in Londrina. Most of the species found in this study are common to open areas and more adaptable to anthropogenic changes.

The species, *Crossodactylus schmidti* is classified as Near Threatened by IUCN due to its small geographic range and the decline of its habitat. It occurs near permanent streams (in which it breeds) in forest, and probably does

not tolerate habitat disturbance. Only one population of *C. schmidti* was found in the Maringá study and more attention is needed for the ecology of this species (de Pavia Affonso *et al* 2014).

Reptiles

A list of 32 snakes of Londrina municipality is provided by Dainesi *et al* 2019, representing 28% of the species of Parana. Most of the species listed are associated with forest vegetation. The authors note that further studies are needed on the snakes of the northern region of Paraná not least because the sampling of snake species has been used as an important tool for conservation decisions.

Fish

Fish diversity of lower Paranapanema and Ivaí rivers, upper Paraná River basin is described by Cianek *et al* 2012 with a checklist of species.

Annex 3 Legislation and environmental standards

Silk production in Brazil complies with the following legislation:

Topic	Legislation
Biodiversity	Federal Law 6.938/81; Federal Law 11.516/07; Federal Law 12.651/2012
Maintenance of soil productivity	Parana State Law 12.236/15; SP Law 16.402/2016
Fertiliser use	Federal Law 6.894/80
Fungicide use	Decree 24.114/34
Pesticide use	Federal Law 7.802/1989
Water use	Federal Law 9.433/1997
Waste management	Federal Law 12.305/10

Hermès local partner also complies with **International Organization for Standardization (ISO 14001).** ISO 14001 is the international standard for environmental management systems (EMS) and the most widely used EMS in the world, ISO 14001 requires maintain documented evidence that a Company's (EMS) meets the required standard. There are clear documentation requirements but the Company operations and how evidence is recorded is not dictated by the standard. The goal for documentation is to ensure that robust environmental processes are in place. Some of the documents also serve to demonstrate that the entire organisation is aware of and working towards stated environmental objectives, which enables progress towards environmental goals that are both tangible and feasible.

Other certifications schemes and standards mentioned in the report are:

CERES (Certification of Environmental Standards GmbH) is a company accredited/registered to certify according to a range of standards including:

Global Organic Textile Standard (GOTS) Version 6. (Effective Date: 01 March 2021)

Environmental management: In addition to GOTS criteria, all companies shall assure compliance with the applicable national and local legal environmental requirements applicable to their processing/manufacturing stages (including those referring to emissions to air, wastewater discharge as well as disposal of waste and sludge). They shall have a written environmental policy and procedures in place to allow monitoring and improving relevant environmental performances in their facilities. The environmental policy shall be shared with all employees. Depending on the processing/manufacturing stages, the available data and procedures need to include: a) person responsible b) data on energy and water resources and their consumption per kg of textile output c) target goals and procedures to reduce energy and water consumption per kg of textile output d) monitoring of waste and discharges e) procedures to minimise waste and discharges f) procedures to follow in case of waste and pollution incidents g) documentation of staff training in the conservation of water and energy, proper handling and minimal use of chemicals and their correct disposal h) programme for improvement Adequate inventory of GOTS approved chemical inputs should be maintained for processing GOTS Goods. Wet processing units shall keep full records of the use of chemicals, energy, water consumption and

wastewater treatment, including the disposal of sludge. In particular, they shall continuously measure and monitor wastewater temperature, wastewater pH and sediment quantities. On-site waste burning or uncontrolled waste landfilling shall not be undertaken. Certified Entities are required to collect information on sources of greenhouse gas emissions (GHG) within their own operations and identify means for reduction for each source. 2.4.11 Wastewater treatment Wastewater from all wet processing units shall be treated in an internal or external functional wastewater treatment plant before discharged to environment. The applicable national and local legal requirements for wastewater treatment - including limit values with regard to pH, temperature, TOC, BOD, COD, colour removal, residues of (chemical) pollutants and discharge routes - shall be fulfilled. Minimum criteria is local / national law if GOTS requirements are lower. Wastewater discharges to the environment shall not exceed 20 g COD/kg of processed textile (output).

Where legal limits for pH and temperature are not defined for wastewater discharges to surface waters, discharge shall have a pH between 6 and 9 (unless the pH of the receiving water is outside this range) and a temperature of less than 35 °C (unless the temperature of the receiving water is above this value). Wastewater analyses shall be performed and documented periodically at normal operating capacity.

Guidelines on soil biodiversity

- Soils provide one of the largest reservoirs of biodiversity on Earth, and soil organisms play key roles in the delivery of many ecosystem services. The Voluntary Guidelines for Sustainable Soil Management (FAO, 2017) include measures to preserve and enhance soil biodiversity. Although little is currently known about the precise relationships between the diversity of soil biological communities and the maintenance of core soil functions, new biochemical techniques and tools for DNA analysis suggest significant progress in this area is possible. The FAO recommendations on how to preserve and enhance soil biodiversity through good farming practices are summarised below:Monitoring programs for soil biodiversity, including biological indicators (e.g. community ecotoxicology) and in-situ early warning signals, should be undertaken
- Soil organic matter levels should be maintained or enhanced through the provision of sufficient vegetative cover (e.g. cover crops, multiple crops), optimal nutrient additions, addition of diverse organic amendments, minimizing soil disturbance, avoiding salinization, and maintaining or restoring vegetation such as hedgerows and shelterbelts;
- Authorization and use of pesticides in agricultural systems should be based on the recommendations included in the International Code of Conduct on Pesticide Management and relevant national regulations. Integrated or organic pest management should be encouraged;
- The use of nitrogen fixing leguminous species, microbial inoculants, mycorrhizas (spores, hyphae, and root fragments), earthworms and other beneficial micro-, meso- and macro- soil organisms (e.g. beetle banks) should be encouraged where appropriate, with attention to limiting the risk of invasive processes by promoting the use of local biodiversity and avoiding the risk of disturbance in soil services;
- Restoring plant biodiversity in ecosystems, thereby favouring soil biodiversity;
- In-field crop rotation, inter-cropping, and preservation of field margins, hedges and biodiversity refuges should be encouraged; and

Any land use change in areas with high biodiversity should be subject to land use planning and in line with the UNCBD, UNCCD and other relevant international instruments and with national law."