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Life Cycle Based Comparison of Textile Ecolabels

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Abstract: Environmental impacts of textile production increased over the last decades. This also led to an increasing demand for sustainable textiles and ecolabels, which intend to provide information on environmental aspects of textiles for the consumer. The goal of the paper is to assess selected labels with regard to their strengths and weaknesses, as well as their coverage of relevant environmental aspects over the life cycle of textiles. We applied a characterization scheme to analyse seven selected labels (Blue Angel Textiles, bluesign®, Cotton made in Africa (CMiA), Cradle to Cradle Certified™, Global Organic Textile Standard (GOTS), Global Recycled Standard (GRS), VAUDE Green Shape), and compared their focus to the environmental hotpots identified in the product environmental footprint case study of t-shirts. Most labels focus on the environmental aspects toxicity, water use, and air emissions predominantly in the upstream life cycle phases of textiles (mainly garment production), whereas some relevant impacts and life cycle phases like water in textile use phase remain neglected. We found significant differences between the ecolabels, and none of them cover all relevant aspects and impacts over the life cycle. Consumers need to be aware of these limitations when making purchase decisions.

Keywords: textile life cycle; environmental aspects; ecolabel; sustainable textiles

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1. Introduction

The urgency of the climate crisis is more present now than ever before, with the "International Panel on Climate Changes" (IPCC) special report on global warming [1], more than 11,000 scientists warning of a climate emergency [2], and millions of people on the streets for the largest climate strike ever seen [3–6]. The scientists describe a close link between the excessive consumption of a wealthy lifestyle and the climate crisis, naming the global north as mainly responsible for the historic and current greenhouse gas (GHG) emissions [2]. One industry with a particularly devastating impact on the environment is the fashion industry. Apart from a vast contribution to the climate change (in 2015, the textile production alone was responsible for around 1.2 billion CO_2 equivalents of GHG emissions [7]), it is responsible for a whole host of environmental impacts occurring in different life cycle stages of textile products. These impacts include overuse of water resources and excessive use of pesticides during cotton cultivation, contamination of water bodies with untreated wastewater discharged from the textile processing, or pollution with microplastics during the use phase [8]. From 2000 to 2015, the production of clothing has doubled [7]. Due to this constant growth of the fashion industry [9], the environmental impacts associated with textile production are also steadily increasing. This effect was multiplied by a shift in the fashion industry in 1990 towards a fast fashion concept, which lead to an uptake in the speed of production and buying cycles.

At the same time, during the past decades, the awareness of the environmental issues associated with the textile production has continuously increased. A recent study demonstrates that 72% of consumers worldwide would prefer to buy from environmentally friendly brands [10]. As a result, during the last 40 years, various organizations and initiatives emerged using sustainability standards, labels, audits, certificates, or management

strategies to enforce sustainable value creation generally referred to as environmental labels and information schemes (ELIS) [11,12]. These include ecolabelling (e.g., Global Organic Textile Standard, GOTS [13]), umbrella ecolabels (e.g., Grüner Knopf [14]), and initiatives for sustainable cotton production (Better Cotton Initiative, BCI [15]) and textiles (Zero Discharge of Hazardous Chemicals, ZDHC [16]). These initiatives aim to make sustainability assessments of textile products easier and provide guidance for consumers. However, as the various labels follow different approaches and have different focus, it remains difficult for consumers to identify relevance and quality of the information the labels offer.

Recently, several studies were conducted with the aim to review and compare textile ecolabels. While some publications provide an evaluation of a single label, e.g., Blue Angel [17] and C2C Certified [18,19], others analyse similarities and differences between the scope and criteria of different labels. For example, Koszewska provides an overview of most popular textile ecolabel and their recognisability among Polish buyers [20]. Existing comparisons between textile ecolabels consider different environmental aspects and life cycle stages of textiles. Partzsch et al. analyse the effect of the certification on cotton cultivation in Sub-Saharan Africa with regard to the use of fertilizers, pesticides, and genetically modified organisms (GMO) for four certification types (Better Cotton Initiative (BCI), Cotton made in Africa (CmiA), Fairtrade Labelling Organization (FLO), and EU Organic Regulation) [21]. Targosz-Wrona provides an overview of the label requirements on chemical residues in fibres and emissions thresholds for the textile manufacturing phase for the labels EU Flower, Ecological product, Eco-sign, Slovak environmental friendly product, and Nordic Swan [22]. Henniger compares the requirements of the 15 most relevant textile labels for the UK market with regard to different environmental aspects (e.g., water use, deforestation, CO_2-emissions) and assessment approaches adopted by the labels (e.g., life cycle assessment, raw material assessment) [23]. An analysis of the labels requirements considering all life cycle stages of textile products is carried out by Clancy et al. for six ecolabels with high relevance for the market in Sweden (EU Ecolabel, Bluesign, Cradle-to-cradle, Made-by, Textile Exchange, Oeko-Tex) [24]. For each life cycle stage from design and raw material production to waste management, the authors evaluate whether the labels provide specific requirements (e.g., a restriction of the use of specific chemicals) or optional/indirect criteria (i.e., the requirement is not binding or the life cycle stage is influenced by the requirements for a different life cycle stage). An analysis of the complete life cycle of textiles, as well as different environmental aspects and hotspots, is conducted in the study of Minkov et al., who compare similarities and gaps between the requirements of the Product Environmental Footprint (PEF) and European Flower (EUF) [25]. Although all aforementioned studies evaluate label requirements, two following questions remain unclear: (1) Whether the focus of the labels with regard to considered environmental aspects and life cycle stages of products is comparable and (2) whether the label requirements address the main environmental hotspots in the life cycle of textiles, and thus contribute to the reduction of the environmental burden of certified products.

To address this gap, the goal of this paper is to evaluate similarities and gaps between textile ecolabels and analyse their focus areas concerning covered environmental aspects and life cycle stages. For this, seven textile ecolabels with different scopes and approaches for the requirement setting are evaluated with regard to their main characteristics (e.g., type of communication, scope, etc.), addressed environmental issues (e.g., climate change, water use, etc.), and covered life cycle stages of textiles. Following labels were selected for the analysis: Blue Angel Textiles [26], bluesign® [27], Cotton made in Africa (CMiA) [28], Cradle to Cradle Certified™ [29], Global Organic Textile Standard (GOTS) [13], Global Recycled Standard (GRS) [30], and VAUDE Green Shape [31]. Further, we analyse whether the environmental requirements of the labels cover the hotspots with regard to environmental aspects and life cycle stages of textiles. This paper addresses only environmental aspects of sustainability, omitting other sustainability dimensions (social and economic criteria) of ecolabels. It is structured as follows: Section 2 provides an overview of the life cycle

stages and environmental hotspots of textiles and introduces the characterization scheme for the ecolabels, in Section 3, a description of the selected ecolabels and methodological procedure is provided, Section 4 presents the results. In Section 5, the results are discussed, and Section 6 concludes with a short outlook.

2. Theoretical Background

2.1. Environmental Impacts throughout the Textile Life Cycle

Based on existing literature (see Table S1), five main life cycle stages of textiles can be identified:

- Raw material production;
- textile manufacturing;
- distribution;
- garment use;
- textile disposal.

The raw material production phase considers either the growing of natural fibres such as cotton, wool, silk, and flax, or the manufacturing of fibres made from a variety of raw material sources, including plant, animal, and synthetic polymers [32]. The main concerns in this stage originate from either the agricultural production and the attributed intense use of water and pesticides or the production of synthetic and cellulosic fibres and the resulting emissions to air and water [32]. One of the most famous examples of the severe environmental consequences that can occur through cotton cultivation is the tragedy of the Aral Sea. The increased water diversion for irrigation of cotton fields lead to an insufficient water supply from its two river sources, causing the Aral Sea to dramatically decrease in size and water volume since the early 1960s [33].

The yarn and textile manufacturing itself has several steps including sizing, knitting, pre-treatment, dyeing, and finishing. The making up process encompasses, pattern drafting, producing samples, cutting, sewing, and applying embellishments [34,35]. The environmental issues in this phase vary from the inhalation of cotton dust during the yarn manufacturing, to the contamination of wastewater with mineral knitting oils, remaining pesticides, and leftovers from bleaching, as well as dyes that usually contain heavy metals and auxiliary chemicals used for finishing. For the distribution phase, the garments are usually packed in polyester bags and distributed to warehouses or retailers [35].

The garment use phase is characterized by acquisition, use, and maintenance activities [34]. It is mainly concerned with washing and drying the garments. Thus, the environmental impacts are associated mainly with electricity, detergent, and water use [36]. The nature and quality of a fibre can further influence the maintenance of a textile [37]. The quality of cotton fibres, where high quality fibres are not as easy to get dirty, as well as the difference between mechanical and chemical treatment, can significantly impact the behaviour of the fabric in use [37].

During the textile disposal phase, sending the apparel to landfills dominates re-use, recycling, and other end-of-life management activities [34].

2.2. Textile Ecolabels

During the past decades, increasing attention of the consumers to the environmental and social impacts of products resulted in an increasing adoption of sustainability practices in business, e.g., eco-innovation and lean management. The latter allow companies to reduce the environmental burden associated with their production activities, and at the same time to foster the development of new products, technologies, or business structures, which increases their overall market viability [38]. As demonstrated in recent studies, the implementation of Corporate Social Responsibility (CSR) strategies gained importance for the competitiveness in the textile sector [39–42]. One of the strategic CSR areas is the so-called "marketplace CSR", which includes company's communication with its suppliers, consumers, and other stakeholders along the value chain. Particularly with regard to

the consumer relations, textile producers increasingly adopt ecolabels to demonstrate (improved) environmental and/or social performance of their goods [41].

Ecolabels are voluntary environmental product information schemes (EPIS), which are used in order to systematically approach the environmental information of a product.

The mandatory approach to EPIS includes declarations of contents such as food ingredients, usage, and disposal information, mainly applying to chemical substances and products. The voluntary approach to EPIS (i.e., ecolabels) leaves it to the market actors to decide whether to sign or label their product. In the following, the focus is set on the voluntary ecolabels and declarations. The overall goal of the voluntary environmental labels and declarations is encouragement of the demand for and supply of the products that cause less pressure on the environment. This is achieved through communication of verifiable and accurate information on the product's environmental performance [43]. Stø et al. [44] demonstrated that product information is usually asymmetrically allocated between buyers and sellers. This knowledge gap can only be filled through external support as supposedly offered by ecolabels and EPIS [44].

The ecolabel or environmental declaration should consider the life cycle of a product or service from production to final disposal. However, the undertaking of a life cycle assessment is not always necessarily required [43]. Three types of environmental labelling are further specified by the ISO standards: Environmental labels (Type I), self-declared environmental claims (Type II), and environmental declarations (Type III) [45–47].

The first voluntary public ecolabels were developed following the introduction of the German Blue Angel label in the 1970s [11,48], which provided information about products with the best environmental characteristics in the entire life cycle of a product [11]. They were followed in the next years by a proliferation of eco-labelling and single-issue certification, as well as the development of individual company private standards [11,48]. Since the 2000s, a large number of ecolabels and other ELIS coexist [11,48].

2.3. Characterization Scheme for Environmental Labels and Declarations

As described in the previous section, three types of environmental labels and declarations are distinguished according to ISO. Nevertheless, as demonstrated in recent studies, several ecolabels cannot be assigned to any of these types due to different awarding criteria and formats, which makes it difficult to classify and compare ecolabels [49]. A recently introduced characterization scheme overcomes this obstacle by introducing 22 attributes with regard to following aspects of the labels: communication, scope, standard characteristics, governance, and conclusive characteristics [18,49]. In the following, these attributes and some examples of corresponding label features are shortly introduced. A detailed description of all characterization attributes and features can be found in the study of Minkov et al. [18,49].

The aspect communication characteristics includes the following five attributes: ISO typology (e.g., Type I, undefined), awarding format (seal, rating), multiplicity of covered aspects (single or multi-aspect), aspects diversity (environmental, social), and end-user focus (e.g., business-to-business (B2B)). The aspect scope includes the attributes sector scope (i.e., sector-specific or multi-sector), operational scope (e.g., product, organization), geographical scope (national, international), awarding criteria scope (product-specific or generic), application of materiality principle, and life cycle perspective. The aspect standard characteristics considers compulsoriness (voluntary or mandatory), financing, purpose (i.e., idealistic or neutral), and longevity (single issued or renewable). The aspect governance characteristics includes the attributes governance (governmental, private), verification (e.g., first or second party), awarding criteria revision, and stakeholder involvement (low, high). The aspect conclusive characteristics consists of three attributes: Transparency, comparability, and environmental excellence.

3. Materials and Methods

3.1. Selected Ecolabels

As stated in the introduction of the paper, this study aims at analysing textile ecolabels with different scopes and approaches for setting the requirements on the environmental issues. In the following, the reasons for the inclusion of each label in this study are explained, and the labels are shortly introduced. Table 1 summarizes the general information of the ecolabels.

The seven ecolabels were selected considering their relevance as an ecolabel as well as their relevance for their individual focus area (i.e., cotton production, circularity, recycling). The Blue Angel Textile label was chosen due to the label's relevance as the oldest existing ecolabel. The bluesign ecolabel has a strong focus on chemical use and is considered to be one of the strictest ecolabels in this area. The Cotton made in Africa ecolabel has a regional validity for sub-Saharan Africa and is one of the most relevant organic labels with a focus on cotton with many corporate labels referring to it. The Cradle to Cradle Certified™ ecolabel set a clear focus on circularity and is relevant, as the ecolabel requirements are specifically based in the Cradle to Cradle concept. The Global Organic Cotton Standard ecolabel proves its relevance as one of the most commonly used and best known ecolabels. The Global Recycling Standard is relevant within the special focus area of recycling. The VAUDE Green Shape ecolabel was chosen for this analysis as a company initiated ecolabel that was possible to analyse due to its comparably well provided information on the ecolabels criteria.

3.1.1. Blue Angel Textiles

The Blue Angel Textiles label was established in a cooperation of the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety and the German Environmental Agency. The objective of the label is to offer guidance for sustainable products through four approaches: "Promoting higher environmental standards in the production process; improving occupational safety and social conditions during production; avoiding chemical hazards to health in the end product; verifying the product's fitness for use" [50].

3.1.2. Bluesign®

Under the name bluesign® system, bluesign technologies AG created a network of chemical suppliers, manufacturers, and brands which are guided by the bluesign® criteria. The bluesign® system covers all bluesign® criteria, and the bluesign® system partners based on the management of inputs and responsible actions across the whole supply chain following five principles: Resource productivity, consumer safety, water emissions, air emissions, and occupational health and safety [27]. When being awarded the bluesign® label, all involved parties need to follow certain milestones, for example, a bluesign® system partner agreement, the certification of chemical products and articles, as well as labelling [51]. The end-product is labelled a bluesign® product if at least 90% of the used fabric and at least 30% of the used accessories are bluesign® approved [52]. Part of the bluesign® system is the bluesign® system substances list. It includes around 900 substances that are either not permitted (around 600) or subject to certain limitations. Within the bluesign® system, chemicals are rated as blue, grey, or black. Blue rated chemicals fulfil all criteria for the final product, the worker, and the environmental release. Grey rated chemicals can only be used under certain conditions for bluesign® approved materials, while black rated chemicals fail the criteria and their use is not accepted.

Table 1. General information on selected labels.

Name	Focus	Short Description	Managing Organisation	Founded in	Reason for Selection
Blue Angel Textiles	Textile products	Being the oldest environmental label the Blue Angel aspires to provide reliable guidance for consumers. The Blue Angel Textiles represents a subcategory of the Blue Angel Label which certifies a wide range of products.	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; German Environmental Agency; Environmental Label Jury; RAL gGmbH	1978	Oldest existing ecolabel
bluesign®	Textile manufacturing chain/ecological footprint	With special focus on the used chemicals, bluesign® offers a standard for suppliers, manufacturers, and top-brands to reduce their textile footprint.	Bluesign Technologies AG	2000	Considered to be one of the strictest ecolabels regarding chemical use
Cotton made in Africa (CmiA)	Cotton	The label promotes sustainable cotton growing and farming approaches to enable African cotton farmers to improve their living conditions on their own, referring to ecological, social, and economic aspects.	Aid by Trade Foundation (ABTF) Non-profit	2005	One of the most relevant organic label with a focus on cotton; regional focus for sub-Saharan Africa
Cradle to Cradle Certified™	Circularity	Based on the Cradle to Cradle framework, the certificate consists of basic, silver, gold, and platinum levels for safer, more sustainable products made for the circular economy. The label certifies different product categories one of which is textiles.	Cradle to Cradle Products Innovation Institute Non-profit	2005 by McDonough Braungart Design Chemistry (MBDC) and donated to the Cradle to Cradle Products Innovation Institute in 2010.	One of the most relevant labels with a focus on circularity
Global Organic Textile Standard (GOTS)	Organic natural Fibre Products	The self-declared leading textile standard considers social and environmental criteria in the processing of organic fibres throughout the entire textile supply chain.	Global Standard gGmbH	2005 agreement on the first version and implementation scheme.	One of the most commonly used and best known textile ecolabels
Global Recycled Standard (GRS)	Recycling	Observing the full supply chain, the standard focuses on traceability, environmental principles, social requirements, and labelling. It tracks and verifies recycled input material from input to the final product.	Textile Exchange Non-profit	2008	One of the most relevant labels with a focus on recycling
VAUDE Green Shape	Functional, environmentally friendly textile products	The corporate label certifies its own textile products made from sustainable materials covering the whole life cycle of the product.	VAUDE Sport GmbH & Co. KG	2009	A company initiated label that provides information about the certification requirements

3.1.3. Cotton made in Africa (CmiA)

The Cotton made in Africa label was designed by the Aid by Trade Foundation with the goal to improve living conditions for local farmers and promote environmentally friendly cotton production [28]. The criteria set for the CmiA is two-tier. The first set includes criteria that determine if farmers and companies can participate in the program. The second-level criteria are sustainability criteria. The participants in the CmiA programme are not immediately required to meet all sustainability criteria, but can develop and improve following a development plan. The criteria follow a traffic light assessment that rates the status of the criteria as green, yellow, or red [53]. For the entry phase, a minimum of 50% of the sustainability criteria must be rated as yellow or green. All red and yellow classified sustainability criteria must have recommendations for possible improvement. In the next verification after two years, in an ideal case all formerly red criteria are improved to yellow and the yellows to green. For subsequent verifications, ideally all criteria should now be rated green and the overall green status should be maintained [28].

3.1.4. Cradle to Cradle Certified™

The Cradle to Cradle approach integrates multiple attributes, such as safe materials, continuous reclamation and reuse of materials, clean water, renewable energy, and social fairness [29]. A decisive aspect in the Cradle to Cradle approach is the definition of the three principles: Eliminating the concept of waste, use renewable energy, and celebrate diversity [54]. The goal is to achieve a perpetual cycling of ingredients which either biodegrade naturally and restore the soil or are being fully recycled into high quality materials for subsequent product generations. Cradle to Cradle therefore defines two effective material cycles: The biological cycle, able to safely re-enter the biological system, and the technical nutrient cycle, where products or materials can be recovered at the end-of-use phase [54]. This approach has been criticized by many scholars due to its theoretical nature and lacking feasibility [19]. The Cradle to Cradle^{TM} label applies to materials, sub-assemblies, and finished products. To create a standard that promotes improvement, the label uses a 5-Level System of Basic, Bronze, Silver, Gold, and Platinum. In order to qualify for one of the levels, the requirements from all lower levels must be met as well. The final certification level is determined by the minimum level of achievement in the five different levels [54].

3.1.5. Global Organic Textile Standard (GOTS)

The GOTS standards was initiated in 2002 at the Intercot Conference and was started as a certification system in 2006. Its aim is to ensure an organic status of textiles from harvesting through socially and environmentally responsible manufacturing up to labelling. In recognition of the fact that textile production today is nearly impossible without chemicals, the label defines criteria for low impact and low residual natural and synthetic chemical inputs [55]. The standard offers two label grades either "organic"/"organic—in conversion" or "made with (x%) organic materials"/"made with (x%) organic materials—in conversion" [55]. The criteria focus on compulsory criteria with only expressly stated exceptions.

3.1.6. Global Recycled Standard (GRS)

The Global Recycling Standard, initiated by Control Union, was passed on to Textile Exchange in 2011, who also own and administer other standards such as the Content Claim Standard (CCS) and the Recycled Claim Standard (RCS). The overall goal of the GRS is to increase the use of recycled materials in products while reducing or eliminating the harm caused by their production. It aims to concentrate on recycled content, the chain of custody, social and environmental practices, as well as chemical restrictions [56]. The GRS can be used for any product that contains at least 20% recycled materials [56].

3.1.7. VAUDE Green Shape

The Green Shape Label is the corporate label from the outdoor outfitter VAUDE. It was invented by the company due to the absence of a comprehensive textile label [57]. With the Green Shape Label, VAUDE claims to have "developed its own rating system for environmentally friendly outdoor products" [57]. According to VAUDE's online presentation of the label, it "covers the entire product lifecycle with its strict standards—from design and production to maintenance, repair, and disposal" [57].

3.2. Analysis of the Labels

First, a characterization of the selected labels is carried out based on the characterization scheme proposed by Minkov et al. (see Section 2.3) [18,49]. Next, we analyse the label requirements following a three-step procedure. In the first step, considered environmental aspects (e.g., water use) and life cycle phases (e.g., raw material production) were identified based on the documentation of the labels. Then, the label requirements were assigned to the life cycle stages and environmental aspects of textile products. If a requirement could not be assigned to one specific environmental aspect (e.g., the prerequisite to use organic materials influences several environmental aspects including toxicity, water use, and land use), it was identified as a "general" requirement (see Table 2).

Table 2. Exemplary table for the analysis of ecolabels.

Life Cycle Step/Env. Aspect	Toxicity	Water Use	Air Emissions	Land Use	Recycling
Raw material production	General requirements.				
	Specific requirements.	Specific requirements.	Specific requirements.	Specific requirements.	Specific requirements.
Textile Manufacturing					
Distribution					
Garment Use					
Textile Disposal					

Finally, we compare the requirements of the labels to the environmental hotspots that occur in the life cycle of textiles following the procedure proposed by Minkov et al. [25]. This is done based on the hotspots analysis published as part of the Product Environmental Footprint Category Rules (PEFCR) for t-shirts [58]. The latter were developed within the Product Environmental Footprint (PEF), which aims at providing a harmonized methodology and rules for the environmental assessment of products under the life cycle perspective [59,60]. The PEF study provides an overview of the environmental hotspots on a level of impact categories (e.g., climate change), life cycle stages (e.g., production of material), and processes (e.g., cotton fibres) with the cradle-to-grave system boundary. The results of the PEF study [58] were considered for the impact categories that relate to the environmental impacts with a high relevance in the life cycle of textiles (see Section 2.1): Climate change (impact on air emissions), water scarcity (impact on water consumption), acidification (terrestrial and freshwater), and freshwater eutrophication (impact on water pollution) (see Table 3).

The applied methodological procedure is illustrated in Figure 1.

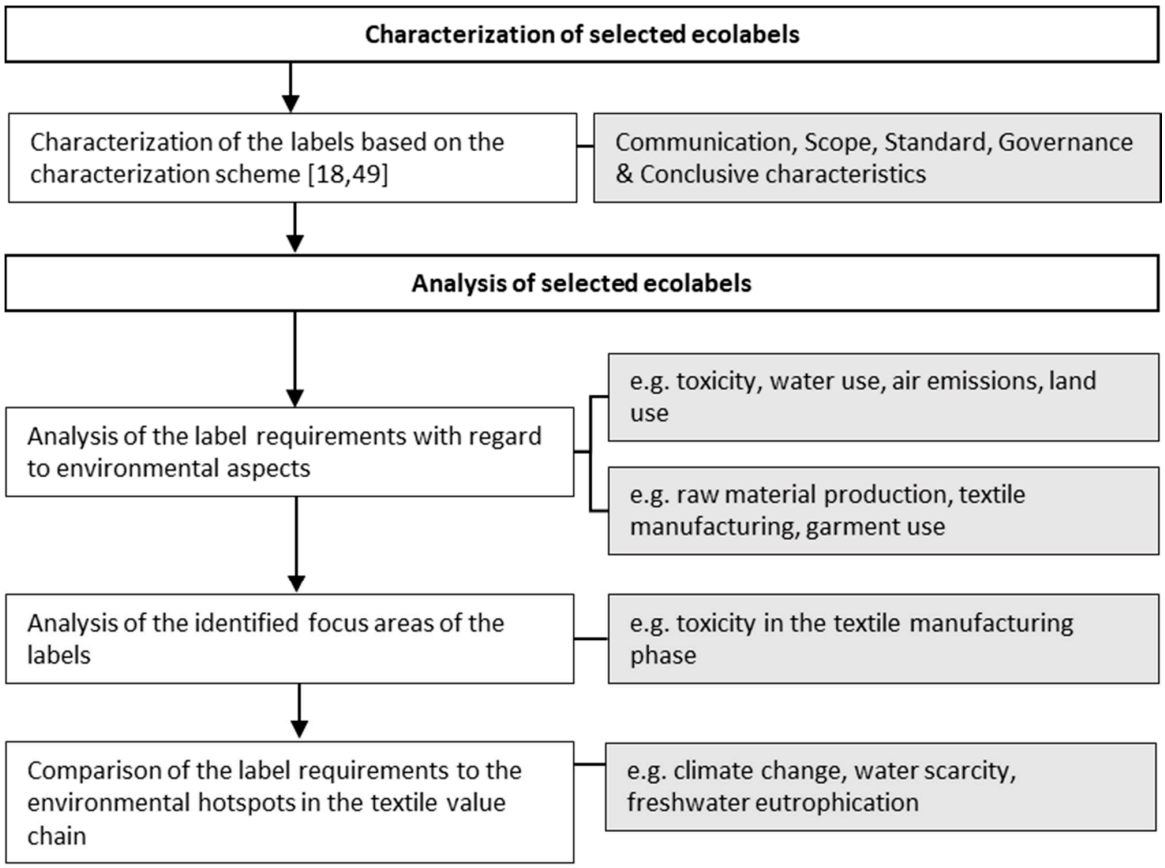

Figure 1. Methodological procedure. White boxes indicate working steps carried out within the methodological procedure; grey boxes demonstrate examples of the outcomes of each step.

Table 3. Overview of environmental hotspots of a T-shirt for selected impact categories over the life cycle (modified from [58]).

		% Contribution			
Life Cycle Stage	**Processes**	**Climate Change**	**Water Scarcity**	**Acidification (Terrestrial and Freshwater)**	**Freshwater Eutrophication**
Production of material	Cotton fibres	23.7	58.3	24.6	75.7
Production of T-shirt	Spinning, production of cotton yarn (combed)	5.0	-	6.8	-
	Spinning, production of cotton yarn (carded)	3.3	-	4.7	-
	Circular knitting	3.6	-	5.1	-
	Fabric dyeing	10.7	-	11.3	-
	Yarn dyeing	3.9	-	3.9	5.0
	T-shirt assembly	9.1	-	14.2	-
	Total production	35.6	-	46.0	5.0
Transportation by customer	Passenger car, average	13.6	-	7.2	-
Use stage/Washing	Electricity grid mix 1 kV–60 kV	7.9	30.0	4.0	-

4. Results

4.1. Characterization of Selected Ecolabels

The results of the applied characterization scheme are shown in Table 4. All analysed labels show several similarities regarding the communication characteristics, more specific all have a multi-aspect approach, address both environmental and social and/or health aspects, and have a B2C focus. Five labels represent a seal, while CmiA and Cradle to Cradle^{TM} label follow a rating awarding format. A significant difference between the labels can be detected for the attribute ISO typology. Only the Blue Angel Textiles and GOTS label are a fully conformant Type I eco-label program. The rest of the labels does not fully conform with the Type I requirements, and the typology of the CmiA label can be characterized as "undefined". With regard to the sectoral scope, three labels can be characterized as multi-sectoral (Blue Angel Textiles as part of the Blue Angel label, Cradle to Cradle^{TM}, and GRS), while all other labels serve for the textile products only (or cotton in case of the CmiA label). Except for the CmiA, which is applicable only for the cotton production in Africa, all labels have an international geographical scope and claim to apply the life cycle perspective by providing requirements for different life cycle stages of textiles, e.g., raw material production, textile manufacturing, and use. This attribute is analysed in detail in the next chapters.

The labels show similarities also with regard to the attribute standard characteristics, for example, all labels are voluntary and ideals-centric, i.e., serve as a benchmark of achieving certain ideals or excellence. In contrast to the VAUDE Green Shape, which is a single-issued label (i.e., is never re-verified), all other labels are renewable (are revised and reissued after expiration) or improvement-based (CmiA and Cradle to Cradle^{TM}), which means that they require a demonstration of improved performance for a re-certification [18].

The Blue Angel Textiles is the only one quasi-governmental label (i.e., initiated by a government, but managed by a private company), while other labels are private. Other governance characteristics are addressed similarly by all labels except VAUDE Green Shape, e.g., the labels are verified by third party, have regularly revised awarding criteria and medium to high stakeholders involvement. The VAUDE Green Shape, in contrast, is second party certified (verification through VAUDE Sports) and does not provide information on the attributes awarding criteria revision and stakeholders involvement.

All analysed labels have a high level of transparency (only for the VAUDE Green Shape, the program rules cannot be accessed) and intend environmental excellence (i.e., the certification promotes environmental excellence of the product). Five labels have a medium score for the characterization attribute comparability, since these labels do not allow a comparison between products awarded by the same scheme, but intend superiority to non-awarded products. The comparability of the CmiA and Cradle to Cradle^{TM} labels is evaluated as low, since the comparison of products is difficult due to different levels of conformity introduced by these labels.

Table 4. Characterization of the labels according to the characterization scheme by Minkov et al. (2018, 2019).

Attribute	Blue Angel Textiles	Bluesign®	Cotton Made in Africa (CmiA)	Cradle to Cradle Certified™	Global Organic Textile Standard (GOTS)	Global Recycled Standard (GRS)	VAUDE Green Shape
Communication Characteristics							
ISO typology	Fully conformant Type I eco-label program according to ISO 14024	Does not fully conform with Type I requirements of ISO	Undefined	Does not fully conform with Type I or Type III label requirements of ISO	Fully conformant Type I eco-label program according to ISO 14024	Does not fully conform with Type I requirements of ISO	Does not fully conform with Type I requirements of ISO
Awarding format	Seal	Seal	Rating (sealed; ranked on a traffic light system)	Rating (sealed; ranked on a predefined scale after complying with minimum performance criteria)	Seal	Seal	Seal
Multiplicity of covered aspects	Multi-aspect	Multi-aspect	Multi-aspect	Multi-aspect	Multi-aspect	Multi-aspect	Multi-aspect
Aspects diversity	Mostly environmental and occupational health and safety	Mostly environmental and occupational health and safety	Both environmental and social/health	Both environmental and social/health	Both environmental and social/health	Both environmental and social/health	Both environmental and social/health
End-user focus	B2C	B2C	B2C	B2B and B2C	B2C	B2B und B2C	B2C
Scope							
Sector scope	Multi-sectorial	Sector specific	Sector specific	Multi-sectorial	Sector-Specific	Multi-Sectoral	Sector-Specific
Operation scope	Product	Product	Product	Product (certain criteria in three of five quality categories relate to the organization)	Product	Product	Product
Geographic scope	International	International	Regional (Africa)	International	International	International	International
Awarding criteria scope	Product specific (specific requirements for different fibres)	Generic	Generic	Generic (equal criteria for all products)	Generic	Generic	Product specific (different requirements for apparel and other textile products)
Materiality principle	No (all products are assessed against the same set of criteria, independent from their individual materiality)	No (all products are assessed against the same set of criteria, independent from their individual materiality)	No (all products are assessed against the same set of criteria, independent from their individual materiality)	No (all products are assessed against the same set of criteria, independent from their individual materiality)	No (all products are assessed against the same set of criteria, independent from their individual materiality)	No (all products are assessed against the same set of criteria, independent from their individual materiality)	No (all products are assessed against the same set of criteria, independent from their individual materiality)

Table 4. *Cont.*

Attribute	Blue Angel Textiles	Bluesign®	Cotton Made in Africa (CmiA)	Cradle to Cradle Certified™	Global Organic Textile Standard (GOTS)	Global Recycled Standard (GRS)	VAUDE Green Shape
Life cycle (LC) perspective	LC based	Partly LC based	Non-LC based	Partly LC based	LC based	Partly LC based	LC-based
Standard Characteristics							
Compulsoriness	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary
Financing	Governmental subsidies	Information not provided	Fees and/or member dues; donations	Fees and/or member dues; donations	Self-financed using yearly licence fees and certification costs	Fees and/or member dues; other (Consulting, etc.)	Information not provided
Purpose	Ideals-centric	Ideals-centric	Ideals-centric	Ideals-centric (a benchmark of achieving conformance with the C2C principles)	Ideals-centric	Ideals-centric	Ideals-centric
Longevity	Renewable Label validity: Three to five years	Renewable Label	Improvement-based; valid for two years	Improvement-based (in case of re-certification, intentions for improvement must be reported)	Renewable	Renewable	Single-issued
Governance Characteristics							
Governance	Quasi-governmental	Private	Private	Private	Private	Private	Private
Verification	Third party (mandatory by independent, external body)	Third party	Third party	Third party (mandatory by independent, internal certification body; however, independence of the conformance assessment body not assured)	Third party	Third Party	Second party (verification through VAUDE Sports)
Awarding criteria revision	Yes, regularly; criteria revised after three to five years	Yes, regularly; criteria revised at least every four years	Yes regularly (interval of revision cycle not clear)	Yes, regularly (revision of the Product Standard to be done every three years)	Yes regularly; criteria revised after three years	Yes regularly (interval of revision cycle not clear)	Information not provided
Stakeholders involvement	High (open consultations during the development of new or updating existing awarding criteria)	High (public consultation during the revision of bluesign® criteria)	High (open consultation during revision of the standards)	Medium (during the product standard revision process, two public comment periods are at disposal for comments by stakeholders; not yet carried out in practice)	High (selected stakeholders invited to participate in the revision process)	High (submission of feedback always possible)	Information not provided

Table 4. *Cont.*

Attribute	Blue Angel Textiles	Bluesign®	Cotton Made in Africa (CmiA)	Cradle to Cradle Certified™	Global Organic Textile Standard (GOTS)	Global Recycled Standard (GRS)	VAUDE Green Shape
				Conclusive Characteristics			
Transparency	Program rules—yes Awarding criteria—yes Awardees—yes	Program rules—yes Awarding criteria—yes Awardees—yes	Program rules—yes Awarding criteria—yes Awardees—yes	Program rules—yes Certification criteria—yes Awardees—yes	Program rules—yes Certification criteria—yes Awardees— Yes	Program rules—yes Certification criteria—yes Awardees— yes	Program rules—no Certification criteria—yes Awardees— Yes
Comparability	Medium (comparison and comparative assertions are not possible between products awarded the same label; awarded products can claim superiority to non-awarded products)	Medium (binary awarding system prohibits comparability between products awarded the ecolabel; awarded products can claim superiority to non-awarded products)	Low (comparison between products is difficult due to the different levels of conformity based on the traffic light system colours)	Low (comparison between products is difficult due to the five quality categories; comparative assertions are not possible; comparability is not strived for by the program)	Medium (binary awarding system prohibits comparability between products awarded the ecolabel; awarded products can claim superiority to non-awarded products)	Medium (binary awarding system prohibits comparability between products awarded the ecolabel; awarded products can claim superiority to non-awarded products)	Medium (binary awarding system prohibits comparability between products awarded the ecolabel; awarded products can claim superiority to non-awarded products)
Environmental excellence	Intended	Intended	Intended	Intended (however, frontrunner principle not applied)	Intended	Intended	Intended

4.2. Considered Environmental Aspects and Life Cycle Phases

In the following, the results with regard to the considered environmental aspects and life cycle phases are presented (see Table 5 and Tables S2–S8).

The Blue Angel Textiles label provides requirements for all life cycle stages from raw material production to distribution, while the use phase and disposal are not considered. The raw material production stage is considered most extensively compared to other labels, since all impact categories are addressed and also general requirements are provided. The textile manufacturing stage is also considered by means of both general and specific requirements. While a comprehensive requirements set is provided for the toxicity, water use, and air emissions, two other aspects (land use and recycling) are not addressed in this stage. For the distribution, few requirements with regard to toxicity, recycling, and land use are provided.

The bluesign® label addresses two life cycle stages of textiles: Raw material production and textile manufacturing. For the raw material production, a set of general requirements is provided, e.g., that all raw materials used must be bluesign® approved. For the textile manufacturing stage, both general requirements (e.g., availability of a management system with a plan-do-check-act cycle covering quality, environment/resource savings, and occupational health and safety) and specific requirements for all environmental aspects are provided. Quantitative thresholds are given for the impacts on toxicity, water use, and air emissions, while for land use and recycling, qualitative targets are provided (e.g., "packaging shall be reduced . . . ").

The CmiA label is designed for only the cotton production stage, therefore it provides requirements only for the raw material production, while other life cycle stages of textiles are not considered. The label provides both general and specific requirements, while the level of conformity can be achieved on three levels: Red (non-conformity), yellow (partly conformity), and green (full conformity). Furthermore, excluding criteria are provided, e.g., use of pesticides banned under the Stockholm Convention on Persistent Organic Pollutants (POPs), cotton production under irrigation and cutting of primary forest. The requirements set by the label are mainly quantitative, e.g., sufficient evidence of the risks and dangers related to the storage of pesticides and application of methods for water conservation.

The Cradle to Cradle Certified™ label has a strong focus on the textile manufacturing step. In this step toxicity, water use, air emissions, as well as recycling are addressed, while only the impacts on land use are not considered. The label requirements follow a 5-Level System, which sets basic, bronze, silver, gold, and platinum criteria. The differentiation between basic and platinum criteria is vast and distinct: While for water use in the textile manufacturing, the basic criteria requires no significant violation of discharge permit within the last two years, the platinum criteria requires that only water that meets drinking water quality may leave the manufacturing facility. While raw material production, distribution, and the garment use phases are not addressed at all, in the textile disposal phase, requirements address the environmental aspect recycling.

The GOTS label addresses the raw material production phase with general criteria, i.e., requirement on the share of the fibres produced as "organic". The textile production phase addresses toxicity, water use, and air emission. For the environmental aspects land use and recycling, no requirements were identified in this life cycle step. In contrast to the Cradle to Cradle Certified™ label, GOTS does not set different certification levels. The requirements are presented as general requirements as well as in relation to the individual production steps such as dying, printing, and finishing or sizing and wet processing stages. In the distribution phase, environmental aspects toxicity, air emissions, and land use are covered, while the garment use phase and the textile disposal phase are not considered.

Table 5. Overview of considered life cycle steps and environmental aspects. The colours indicate hotspots in the life cycle stages and environmental impacts according to the PEFCR: Orange—over 20% of the total impact, yellow—over 10% of the total impact. It should be noted that the PEFCR hotspot data was not available for the impacts toxicity, land use, and recycling.

Life Cycle Step/env. Aspect		Toxicity	Water Use	Air Emissions	Land Use	Recycling
Raw material production	General requirements			Blue Angel Textiles bluesign® Cotton made in Africa (CmiA) Global Organic Textiles Standard (GOTS) VAUDE Green Shape		
	Specific requirements	Blue Angel Textiles Cotton made in Africa (CmiA) Global Recycling Standard (GRS)	Blue Angel Textiles Cotton made in Africa (CmiA)	Blue Angel Textiles	Blue Angel Textiles Cotton made in Africa (CmiA)	Blue Angel Textiles Global Recycling Standard (GRS)
Textile Manufacturing	General requirements			Blue Angel Textiles bluesign® Global Recycling Standard (GRS) VAUDE Green Shape		
	Specific requirements	Blue Angel Textiles bluesign® Cradle to Cradle Certified™ Global Organic Textiles Standard (GOTS) Global Recycling Standard (GRS) VAUDE Green Shape	Blue Angel Textiles bluesign® Cradle to Cradle Certified™ Global Organic Textiles Standard (GOTS) Global Recycling Standard (GRS)	Blue Angel Textiles bluesign® Cradle to Cradle Certified™ Global Organic Textiles Standard (GOTS) Global Recycling Standard (GRS)	bluesign®	bluesign® Cradle to Cradle Certified™ Global Recycling Standard (GRS)
Distribution	Specific requirements	Blue Angel Textiles Global Organic Textiles Standard (GOTS)	Not addressed	Global Organic Textiles Standard (GOTS)	Blue Angel Textiles Global Organic Textiles Standard (GOTS)	Blue Angel Textiles
Garment Use	Specific requirements	VAUDE Green Shape	Not addressed	VAUDE Green Shape	Not addressed	Not addressed
Textile Disposal	Specific requirements	Not addressed	Not addressed	Not addressed	Not addressed	Cradle to Cradle Certified™

The GRS label addresses the raw material production and textile manufacturing phases. In the raw material production phase, only the environmental aspects of toxicity and recycling are considered. For the textile manufacturing phase, both general requirements (e.g., Certified Organizations are required to have an environmental management system) and specific requirements (e.g., water use: A drainage plan with understanding of wastewater flow direction and discharge point is required) are provided. The latter consider all environmental impacts except land use and are mainly quantitative, e.g., the rules on the use and storage for chemicals and monitoring of emissions.

In contrast to other labels analysed in this research work, the VAUDE Green Shape label considers besides the raw material production and textile manufacturing the use phase of the garment. For the raw material production, only one criteria is provided, which prohibits any usage of GMO. The general requirements for textile manufacturing include prohibition and rules for the usage of some chemicals (e.g., motif prints need to be either water based or based on sublimation) and the requirement that a minimum of 90% of used garment must be certified/declared. A broad range of certification options is provided, which include supplier certification (e.g., ISO 14001, EMAS), fabric certification (e.g., bluesign® approved, GOTS), or "eco-fabric" (e.g., organic cotton, TENCEL, chlorine free wool). Furthermore, specific requirements for toxicity are provided, according to which compliance with the manufacturing restricted substance list (MRSL) must be assured. In the textile use phase, environmental impacts on toxicity (high impact care) and air emissions (the product requires tumble drying, i.e., high energy use and impact on climate change) are addressed.

Overall, it can be summarized that the Blue Angel Textiles label covers most life cycle phases in the considered environmental impact categories. Followed by a wide margin, the GRS and GOTS label also take into account several life cycle phases.

4.3. Overview of Identified Focus Areas of Selected Labels

In the following section, the identified requirements for the environmental impacts and life cycle phases are presented (see Table 5).

Looking at the life cycle steps, most requirements are formulated for the life cycle stages raw material production and textile manufacturing. For each life cycle step, both general criteria and criteria specific to environmental aspects exist. In the raw material production step, most labels set only general criteria, i.e., requirements on general cultivation practices, for example, controlled organic cultivation (Blue Angel Textiles, GOTS) or chemicals, particularly pesticides management (GOTS, bluesign®). The Blue Angel Textile label addresses all specific environmental aspects, e.g., by providing thresholds for the content of specific pollutants present in the fibres. CmiA addresses specific environmental aspects including toxicity, water use, and land use. The GRS label addresses toxicity (restriction of certain chemicals) and recycling (i.e., recycling content).

The textile manufacturing is extensively addressed by all evaluated labels. Most labels provide general criteria, which include requirements on environmental management systems (GRS, bluesign®) or overall compliance of all manufacturing processes with the local legislation at the production site (GRS, Blue Angel Textiles). Specific criteria, for example, thresholds for application of chemicals and wastewater quality parameters are also provided by most labels.

Significantly less focus is set on the distribution, garment use, and textile disposal phases. Only four of the seven ecolabels address these steps, and no ecolabel set any general criteria. In the textile disposal phase, none of the environmental aspects are addressed apart from recycling by the Cradle to Cradle Certified™ label.

Regarding the addressed environmental aspects, toxicity has a clear dominance, and is covered by all seven ecolabels. The aspects of water use and air emissions are addressed by six ecolabels, while the aspects of land use and recycling are addressed by only four ecolabels. The differences in focus on the environmental aspects are not as extreme as the differences in the life cycle steps.

4.4. Comparison of the Label Requirements and Environmental Hotspots Identified by PEF

The identified label requirements are compared with the environmental hotspots identified by PEF. The comparison was performed based on the PEF study for the impacts water use and air emissions (see Section 3). For other impacts addressed by the labels and analysed in this work (toxicity, land use, and recycling), no hotspot data was available. The hotspot in the impact water use was identified based on the impact categories water scarcity (i.e., water consumption) as well as acidification and freshwater eutrophication (i.e., water pollution). Only two labels—Blue Angel Textiles and CmiA—provide specific requirements for water use in the raw material production stage, whereas only CmiA considers water consumption, e.g., by prohibiting cotton production under irrigation and setting goals for the application of water conservation techniques. A clear environmental hotspot with regard to water pollution occurs in the textile manufacturing phase. Here, all analysed labels (except CmiA that considers only raw material production phase) provide requirements with regard to the quality of discharged water, e.g., by setting thresholds for specific pollutants or requiring compliance with local legislation. In contrast to material production and textile manufacturing phase, water use aspects in the garment use phase are not addressed by any of the analysed labels, although this stage contributes to one-third of the total water scarcity impact in the life cycle of textiles (see Table 3). The hotspot for the impact on air emissions was identified based on the impact category climate change considered in the PEFCR. Still, it should be noted that air emissions addressed by the labels include not only the pollutants that contribute to global warming, but a broader set of substances. The first hotspot arises in the life cycle stage raw material production, which contributes to over 20% of the total impact (see Table 3). Out of seven analysed labels, only the Blue Angel Textiles sets specific requirements on air emissions for the raw material production. The latter include thresholds for sulphur compound emissions, volatile organic compounds (VOCs), and nitrogen oxides. Air emissions in the textile manufacturing phase contribute to over one-third of the total impact. This hotspot is addressed by all analysed labels (except CmiA) using specific requirements. In contrast, air emissions in the use stage, which according to PEFCR has around 8% of the total impact, are addressed by only one label: GOTS.

It can be summarized that only one of the hotspots identified by PEF is not covered by the selected labels: Water use in the life cycle stage garment use. Four out of the five hotspots are addressed by the Blue Angel textile label, followed by GOTS with three addressed hotspots.

5. Discussion

5.1. Focus Points and Gaps in the Textile Ecolabeling

According to the applied characterization scheme, all labels show strong similarities with regards to the analysed attributes, e.g., most labels have an international focus (except CmiA), operate mainly on the product level, and focus in particular on the end consumer (i.e., B2C). All labels have a multi-aspect approach and intend environmental excellence of the certified products. However, the scope with regard to the considered environmental aspects and life cycle stages significantly differs between the analysed labels. While the labels have a comparably similar focus with regard to toxicity and water use in the raw material production and textile manufacturing phase, other impacts (e.g., land use) and life cycle stages (e.g., distribution and use phase) are considered sporadically by different labels. Furthermore, the way the requirements set significantly differ from label to label, i.e., a label provides only general requirements, only specific requirements, or both. This can lead to large differences in the broadness and strictness of the provided requirements. For example, general requirements for cotton cultivation stage include sourcing of organic cotton. Although organic production usually leads to a reduction of fertilizers and pesticides use, it does not set any restrictions on water use (e.g., as it is done by the specific requirement set by the CmiA label). Nevertheless, cotton cultivation is usually associated with high water consumption, which remains not addressed if only a

general requirement is applied for this life cycle stage. In the textile manufacturing phase, general requirements include, for example, implementation of environmental management on a company level, which may reduce environmental impacts that are not directly related to the product, but the organization as a whole (e.g., waste management). In this case, the label with both types of requirements (general and specific) has an advantage over the labels that adopt only a general or specific requirement.

It can be summarized that although the analysed labels have strong similarities (according to the characterization scheme), they are not comparable due to large differences between considered life cycle stages and environmental impacts, as well as the way the requirements are set (i.e., general or specific). These findings are similar to the results of Clancy et al. who demonstrated different scopes of six textile ecolabels with regard to considered life cycle stages [24]. The authors demonstrate that a strong focus is set on the resource acquisition/farming, production of yarn/fabric, and garment manufacturing phases, which is in line with current study. The focus on the use phase was identified for three labels, which is not confirmed for the labels analysed in the current study. Possible reasons for this are discussed later in this section.

With regard to the environmental impacts, it can be seen that the hotspots (water use and air emissions) in the raw material production and textile manufacturing phase are covered by most labels. In contrast, the hotspot related to the water use in the textile usage phase remains a gap despite its high relevance. For the use phase, only toxicity and air emissions are explicitly addressed by one label, while water is not addressed at all. Of course, it is questionable whether and how producers and consumers can influence this life cycle phase, especially explicitly. Even though some studies demonstrate that fibre and garment type can influence consumer behaviour, they also show that laundry practices are highly dependent on cultural and country specific effects (habit of hand washing, quality of washing machines, use of tumble dryers) [61,62]. They are further linked to garment use, social auditing, cultural norms, garment aesthetics, life stage, and household arrangements [63]. The extent to which producers and consumers can influence laundry practices is therefore complex, and further research is needed to identify which requirements can sufficiently influence the impacts associated with the use phase of textiles. Therefore, although the labels Blue Angel Textile and GOTS provide some criteria for the use phase (e.g., the tolerance of change in dimensions during washing and drying or (colour) fastness to washing, perspiration, rubbing, light, and salvia) they were not considered for the evaluation of the use phase in this study. The analysed labels therefore leave out some crucial environmental aspects and life cycle steps, especially in the downstream life cycle stages. For this reason, the claim that the textiles sealed with one of the analysed labels are produced in an environmentally friendly manner can only be partly confirmed.

The ecolabels' function, as defined in chapter 1.2, is to fill a gap in the consumer's knowledge about environmental product information that the consumer cannot obtain on their own [44]. The ISO norm 14,020 further claims that an ecolabel shall consider the life cycle of a product or service from production to final deposit [43]. The fact that the distribution, garment use, and garment disposal steps are neglected by the analysed ecolabels shows that this is not necessarily the case. It is therefore questionable if these ecolabels successfully fill the environmental information gap as they ought to.

One solution to increase comprehensibility given the large number of different focus areas of the ecolabels is an umbrella ecolabel. The idea of such an umbrella ecolabel is to form one ecolabel that represents compliance with many different ecolabels, each with different focus areas, so that the umbrella label addresses the sum of important aspects. Consumers can then rely on this umbrella label, instead of familiarizing with various individual ecolabels. One such umbrella label is The Grüner Knopf, which has been developed by the German Federal Ministry for Economic Cooperation and Development and was introduced in September 2019 in Germany [64]. The Grüner Knopf is based on recognized ecolabels in the areas of social and environmental sustainability. For environmental sustain-

ability, so far, nine ecolabels are named that qualify as a basis for the Grüner Knopf. Out of those nine ecolabels, four were analysed in this article: GOTS, Blue Angel, bluesign®, and Cradle to Cradle Certified™ (silver). The requirements for environmental sustainability are set by the Grüner Knopf in the areas of waste water, air emissions, chemical residues, chemicals harmful to health, chemicals harmful to the environment, EU Chemicals Regulation REACH, biodegradability, use of natural fibres, and use of synthetic fibres [64]. These requirements focus only on textile production, leaving out all other life cycle steps. The Grüner Knopf ecolabel therefore, so far, does not add to the existing ecolabels when it comes to environmental sustainability, or the needed informational value.

5.2. Limitations of Results

Seven labels with different scopes were selected for the evaluation. Although the selected labels are broadly applied in textile sector, they cannot be seen as a representation of all existing textile ecolabels.

According to the analysed life cycle steps and environmental aspects, five focus areas (toxicity, water use, air emissions, land use, recycling) were identified. However, the analysis solely considers whether these focus areas are addressed by the labels, but does not evaluate how strict the criteria are. For example, the differences between the thresholds for the emissions in water during the textile production set by different levels are not evaluated. Therefore, a quantitative comparison of the criteria adopted by different labels or definite statements on the quality of those criteria or the ecolabels themselves is impossible. The results merely present if environmental aspects are explicitly addressed in a certain life cycle step, but do not inform about the quality or quantity of the criteria. The seven ecolabels themselves are not directly comparable nor are the differently established criteria. An effort to make the criteria comparable would need to include a way to break down the different approaches and label structures. For this, an approach would be needed to make a single set of requirements comparable to a five level system as well as a traffic light system of requirements adopted by some of the evaluated labels.

The analysis of the hotspots in the textile life cycle includes only the aspects water use (consumption and pollution) and air emissions (based on the PEFCR impact category climate change). Other hotspots could not be evaluated due to missing data. Nevertheless, existing literature highlights further hotspots. As demonstrated in several studies, toxicity effects are particularly relevant in the raw material production (e.g., due to application of pesticides in the cotton cultivation [65,66] or input of chemicals during the production of man-made fibres [67] and textile manufacturing (e.g., mainly due to the input of dyes and auxiliary materials during the textile finishing) phases. While all labels (except CmiA) have a strong focus on the textile manufacturing step, for which several restrictions and thresholds with regard to the usage of toxic substances are provided, toxicity impacts in the raw material production stage are addressed only by three labels. Still, toxicity in the raw material production phase is indirectly addressed by other labels by means of the general criteria like organic cultivation and/or compliance with the legislation on the regulation of chemicals. Another relevant hotspot is land use in the raw material production, which is however addressed only by two labels: Blue Angel Textiles (requirement to source cellulose from wood cultivated according to sustainable forestry management principles) and CmiA (e.g., cutting primary forest is an exclusion criteria, further requirements are available). Production of natural fibres usually leads to the cultivation of a monoculture on large areas. This can lead to such environmental impacts as loss of biodiversity [68] or an increase of wild fires, e.g., in the case of eucalyptus forests, which are often used as a raw material for the production of cellulose fibres [69]. All these aspects are underrepresented in the requirements of the labels.

The analysis further disregards unmentioned environmental aspects. For example, microplastics pollution, which are a relevant environmental aspect, as the use of fibres based on petrochemicals is constantly increasing [8]. This affects environmental aspects such as air emissions during raw material production and emissions to water during the

garment use phase. With each washing cycle, microplastics enter the ecosystem. As this specific environmental aspect was not included in any of the criteria, it was not included in the analysis even though it is a relevant aspect.

A further limitation to the results is that due to the scope of this research, it was not possible to consider the social criteria of textile production. Hence, even though some of the labels address social criteria, these were not evaluated. Including the element of social criteria makes the discussion, especially around the understandability of ecolabels for consumers and use of an umbrella ecolabel, even more complicated.

6. Conclusions

The goal of this paper was to characterize selected labels to identify their strength and weaknesses as well as to determine whether they address all relevant environmental aspects over their life cycle. The analysis showed that none of the selected labels considers all relevant life cycle phases or all relevant environmental impacts. While a clear focus is set on the upstream life cycle phases and for the environmental aspects toxicity, water use, and air emissions, significant gaps in the downstream phases could be identified. Overall, the Blue Angel Textile and the GOTS label performed best. This questions whether the ecolabels are able to fill consumers' information gaps for environmental information as well as lead to more environmental friendly consumption and products.

Based on the presented results of the analysis, several recommendations for policy and practitioners can be derived. The use phase of textiles needs to be considered, because impacts arise due to water and electricity use for washing as well as maintenance of textiles. However, impacts due to water use and electricity, which highly depend on consumer behaviour, are challenging to include in a label. Rather, a reduction of impacts should be reached by awareness rising of consumers. The detergent sector attributes impacts of water use and electricity for washing to the detergents life cycle and is carrying out awareness rising campaigns to change consumers washing behaviours for several years now. By teaming up on these awareness raising campaigns, the use phase of textiles might be reduced in the future. This aspect maintenance should be included in labels as it can be more easily measured and does not fully rely on consumer behaviour, e.g., certain companies are now offering lifelong maintenance and repairs. Further, the mandatory use of labels should be discussed. There are several reasons why ecolabels are mostly a voluntary policy instrument (e.g., costs for company and consumer). However, due to the sever impacts of the textile sector, a mandatory application of labels should be considered, similar as it is done for energy intensive products (e.g., European energy consumption labelling scheme). Different approaches are possible, e.g., deriving a mandatory European label for textile or defining clear benchmarks with regard to environmental impacts that need to be fulfilled by all companies on the European market. One option to do that could be the use of umbrella labels as they enhance not only comprehensibility, but also bring the best of different labels with regard to considered aspect and well-formulated criteria together. For the voluntary market, strengthening exiting well-performing eco labels like the German Blue Angel by carrying out information campaigns to inform more consumers about these labels, and therefore increasing the pressure for more companies to label their products. Further, all labels should be working on including unaddressed relevant environmental impacts.

Supplementary Materials: The following are available online at https://www.mdpi.com/2071-1050/13/4/1751/s1, Table S1: Textile LCA studies in the literature, Table S2: Blue Angel Textiles, Table S3: bluesign®, Table S4: Cotton made in Africa, Table S5: Cradle to Cradle Certified™, Table S6: GOTS Global Organic Content Standard, Table S7: Global Recycled Standard (GRS), Table S8: VAUDE Green Shape.

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reviewed the paper draft. All authors were involved in reviewing and editing the final paper draft. All authors have read and agreed to the published version of the manuscript.

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