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# *Homegrown/Homespun; Scaling Up a Low-Carbon Textile System in Lancashire*

By

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In collaboration with

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# *Abstract*

'Homegrown/Homespun; Scaling Up a Low-Carbon Textile System in Lancashire'

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With growing interest in ethically- and environmentally-sound fashion systems, regional economic resilience, and community climate action, this research aimed to investigate the feasibility to upscale a localised and low-carbon textile system. Using a case study approach of the 'Homegrown/Homespun' textile initiative in Blackburn, East Lancashire, the thesis highlights the opportunities and tensions involved in upscale, focusing on a proposed flax and natural indigo supply chain.

Guided by the triple bottom line (TBL) framework for sustainability (Elkington, 1998), a mixed-methods approach drew conclusions from primary and secondary quantitative and qualitative data. Contributing to a growing interdisciplinary field of research, the thesis is situated between the fields of environmental research, sustainable supply chain management, transitions research, and environmental psychology.

The research findings recommend a gradual re-localisation, recognising the short-term trade-offs between elements of sustainability within a long-term vision towards a UK-based sustainable textiles industry. Collaborative endeavours across the industry are suggested to support economic feasibility, considering the current economic and infrastructural challenges. The carbon life cycle assessment (LCA) proposes flax-based denim to be a low-carbon fibre alternative, potentially with less than half the associated carbon impact of a cotton pair of jeans.

A participatory action approach supported holistic and community-centric research into social sustainability within TBL. Findings from a small sample imply the 'Homegrown/Homespun' project facilitates the behavioural and psychological capability of the volunteering community to engage in environmental action.

This research has supported a greater understanding of upscaling sustainable business models and considering the prospects for re-shoring garment manufacturing to a high-cost economy, building on existing literature. The thesis contributes an in-depth account of upscaling efforts from small-scale initiatives grounded in sustainability principles and innovative thinking.

*Keywords* – sustainable textiles, re-shoring, supply chain management, TBL sustainability, low-carbon, regenerative farming, climate action.

*Word Count* – 34,978

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## *Abbreviations*

**CELC** European Confederation of Flax and Hemp

**EF** Emissions factors

**EPR** Extended Producer Responsibility

**ESG** Environmental and social governance

**ILO** International Labour Organisation

**LCA** Life cycle assessment

**LCI** Life cycle inventory

**NAAC** National Association of Agricultural Contractors

**NGO** Non-governmental organisation

**PET** Polyethylene Terephthalate

**PEB** Pro-environmental behaviour

**SBM** Sustainable business model

**SDGs** Sustainable Development Goals

**SME** Small to medium-sized enterprise

**SPINDIGO** Sustainable Production of Plant-Derived Indigo

**SSCM** Sustainable supply chain management

**TBL** Triple bottom line

**VBN** Value-Belief Norm

**WBCSD** World Business Council on Sustainable Development

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## *Author's Declaration*

I DECLARE THAT THIS SUBMISSION IS MY OWN WORK. I HAVE NOT SUBMITTED IT IN SUBSTANTIALLY THE SAME FORM TOWARDS THE AWARD OF ANOTHER DEGREE OR QUALIFICATION. IT HAS NOT BEEN WRITTEN OR COMPOSED BY ANY OTHER PERSON, AND ALL SOURCES HAVE BEEN APPROPRIATELY REFERENCED OR ACKNOWLEDGED.

# Chapter One: Introduction

## 1.1 Motivations and Research Field

The global fashion industry has been widely critiqued for its substantial contribution to environmental pollution, ethical injustice, and a high volume of waste (Bick et al., 2018; Niinimäki et al., 2020). The scale of these challenges has been significantly exacerbated by the rise of 'fast fashion' in recent decades, producing high volumes of inexpensive garments, and contributing to what is known as 'throwaway culture' (Bick et al; 2018). The materials clothes are made from are resource-intensive, often dependent on fossil fuel extraction. Since the 1990s, academics have investigated this exploitative and linear system, calling for the transition towards a more resource-efficient and environmentally-sound industry.

Drawing together elements of sustainable supply chain management (SSCM) and transitions research, the literature has begun to explore the feasibility of scaling up sustainable innovations and alternative business models to the current fashion system (Lam et al., 2020; Moretto et al., 2018; Islam et al., 2020). The triple bottom line (TBL) approach, a popular framework developed by Elkington (1998), argues the equal importance of environmental, economic, and social supply chain practices, and the opportunity to produce competitive advantage through effective implementation. It has been used to approach sustainability challenges more broadly across different industries, with evidenced application to textiles and apparel supply chains (Spukotanage et al., 2018). Notably, the social dimension has been under-represented in existing studies and management approaches (Chiesa and Przychodzen, 2020; Köksal and Strähle, 2021).

One approach to facilitating SSCM is re-localisation of production and re-shoring of industry. There is increasing attention on the relationship between re-shoring and sustainability, identifying drivers, opportunities, and challenges through case study analysis and theoretical lenses (Orzes and Sarkis, 2019; Ashby, 2016; Pal et al., 2018; Benstead et al., 2017). Despite this growing research interest, there remains a research gap for examining the upscaling of sustainable enterprises and business models, especially in the context of re-localisation, triple bottom line sustainability, and high-cost locations. Furthermore, coupling product value with local context within business models is another explored avenue for producing sustainable and economically resilient textile systems (Burns and Carver, 2021).

The literature advocates for the need to upscale sustainable innovations (Islam et al., 2020). Yet, there is limited research on the opportunities, barriers and challenges faced by small sustainable businesses, especially in relation to the fashion and textiles industry and within a high-cost environment. This research attempts to address this research gap and provide an in-depth case study analysis of upscaling sustainable textiles in the UK context. Furthermore, sustainable fibres are considered one of the most pivotal innovations toward a sustainable fashion system (Todeschini et al., 2017). Therefore, this research provides key insights into scaling up a re-localised industry using sustainable materials.

## *1.2 Introduction to 'Homegrown/Homespun' as a Case Study*

'Homegrown/Homespun' is a collaborative enterprise between 'Community Clothing', 'North West England Fibershed', and 'Super Slow Way', based in Blackburn, East Lancashire. This is further supported by the JJ Charitable Trust and the National Lottery Climate Action Fund. Since April 2021, they have been piloting the feasibility of growing flax and natural indigo using regenerative principles as part of a volunteer initiative (Super Slow Way, n.d.). Flax, a durable natural fibre used to produce linen, and natural indigo, a blue pigment sourced from various dye plants, reflect hundreds of years of textile and colour history (Kozlowski et al., 2020; John, 2009). Taking inspiration from the global Fibershed movement, which advocates for a textile system that focuses on nurturing the soil, ecosystem, and local communities, the initiative strives for a deeper connection between textile production and fashion consumption (Burgess and White, 2019).

Growing on a small area of council land in Blackburn city centre, their first crop in 2021 was used to produce a piece of hand-spun, hand-woven, and hand dyed denim cloth for the 2021 British Textile Biennial (Aldersey-Williams, 2021; Super Slow Way, n.d.). 2022 has seen the expansion of the flax growing sites to include an old bowling green and school site, expansion of the original site for more flax and separate indigo plot, and also growing indigo plants in a greenhouse managed by the Lancashire Wildlife Trust at Witton Park (Super Slow Way, n.d.). ‘Homegrown/Homespun’ is growing multiple flax varieties from the Linum genus and trialling both the native Woad (*Isatis tinctoria*) and non-native Japanese indigo (*Polygonum tinctoria*).

The aspiration is to produce jeans for Community Clothing made from UK-grown flax and natural indigo in time for the 2023 British Textile Biennial. The novelty and ambition in the fact there are few examples of naturally dyed, linen denim on the commercial market. In the efforts to produce these jeans, the team and the volunteers have dedicated hours to grow and harvest these plants. The initiative is collaborating with textile professionals and other projects around the world. Furthermore, the initiative is tied to a global movement towards a more sustainable fashion future.

This research attempted to provide a service in navigating the complexity of the upscale of the ‘Homegrown/Homespun’ initiative, taking a nuanced approach to supply chain management, TBL sustainability, and exploring the tensions and synergies at play. Case study approaches are valued for exploring theories and contributing new theories through producing ‘information-richness’ from an iterative process and identifying emergent relationships (Perry, 1998; Easterby-Smith et al, 2021). Building on these ideas, the research utilised a participatory action research approach, which involved directly engaging with this community and participating in the volunteer activities, supported a more holistic inclusion of social sustainability (Keahey, 2021).

Moving away from “traditional” research approaches and assumed validity through neutrality, this alternative research focus critically engages with breaking down power imbalances and encouraging a unilateral form of knowledge sharing (Köksal and Strähle, 2021; Touboulic and McCarthy, 2020). Furthermore, becoming embedded within the volunteer community encouraged a deeper insight into the initiative and the people driving this vision forward, while also prompting critical reflections on my position within the research context and consequential impact. A reflective journal became a crucial tool for exploring the case study and critically engaging with the role of being a participatory researcher.

## *1.3 Research Objectives*

The following aim and objectives were informed by a live brief provided by the stakeholder team of 'Homegrown/Homespun', and subsequently co-designed as the partnership and academic understanding developed. After initial review of the literature and gaps, in a group meeting, we revisited the focus and research questions to be explored.

The aim of the research was to investigate the feasibility of upscaling a low-carbon, regenerative flax and natural dye industry in the North-West of England, and in doing so uncover the barriers and enablers for sustainable fashion and fibre industry re-localisation. The research methodology incorporated both inductive and deductive approaches for the different empirical areas, drawing on the identified research gaps in the literature and comprehensively exploring the case study to provide depth and breadth for the research aim. A research journal became a critical space to coordinate my thinking and to actively reflect on the research process, as well as to practice 'reflexivity' for this participatory style of research.

The research was guided by the following objectives, further conceptualised in figure 1.1. This figure further illustrates the case study approach and captures the interrelationship between each objective toward the overall research aim.

*Objective 1*: Review current academic understanding of barriers and opportunities to upscaling sustainable industries, with a focus on textiles and re-localised production.

*Objective 2*: Investigate the economic considerations for a UK-based flax and natural indigo supply chain, using 'Homegrown/Homespun' as a case study to explore the potential for upscaling these industries.

*Objective 3*: Quantify the carbon emissions of the proposed flax and natural dye supply chain, using 'Homegrown/Homespun' as a case study and considering the carbon impact of differing supply chain management decisions.

*Objective 4*: Investigate the current social impact of the 'Homegrown/Homespun' case study and explore the potential changes to this impact in the face of upscaling the initiative, and more generally the social sustainability of an upscaled textile industry.

*Objective 5*: Investigate the degree of impact volunteering with the 'Homegrown/Homespun' initiative has on encouraging environmental behaviour change.

*Objective 6*: Identify the broad barriers, synergies, and tensions presented by upscale, using 'Homegrown/Homespun as a case study'.

*Objective 7*: Combining objectives 1 to 6 (O1-6) to produce a set of recommendations for ensuring sustainable upscale of a local textile system.

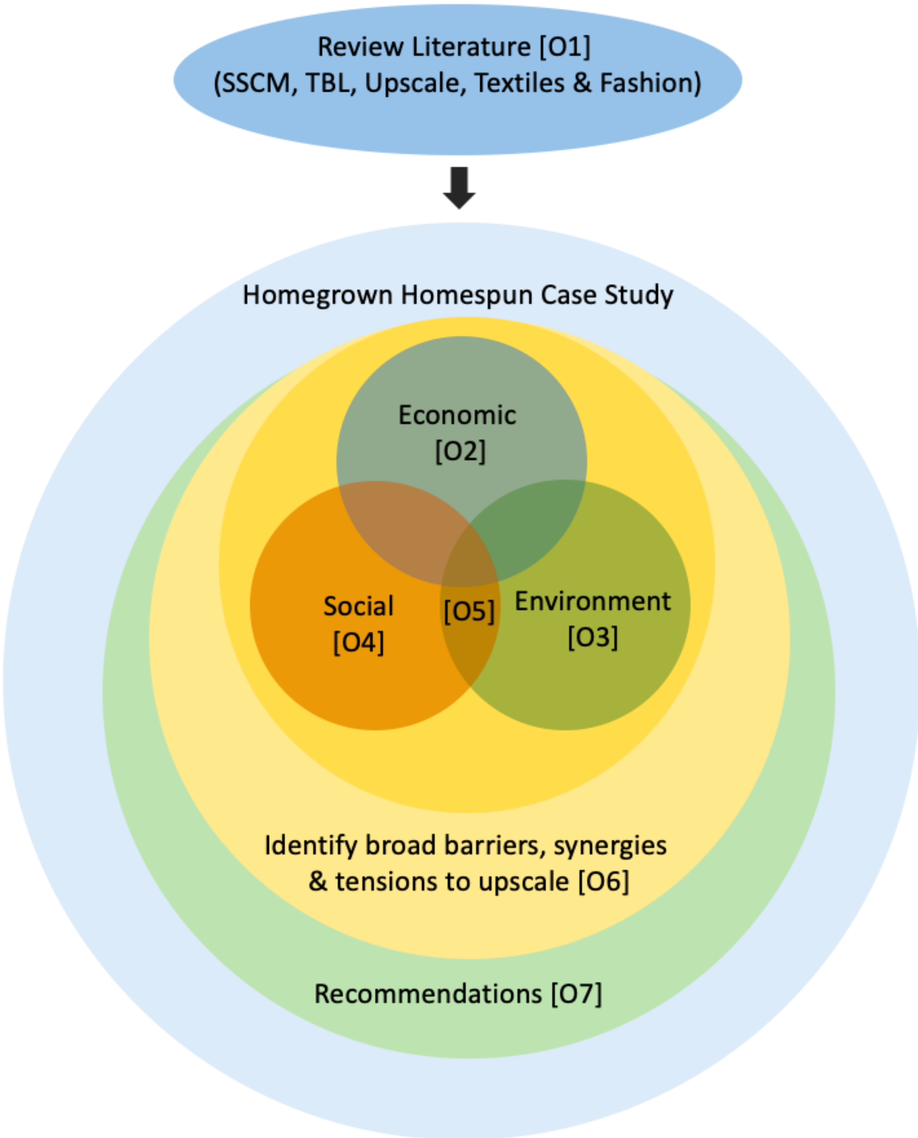



*Figure 1.1: Diagram of the research objectives contextualised within the case study approach and research structure.*

The thesis is structured to first review relevant sustainability, upscaling, and management literature in chapter two. Chapter three explores the economic dimension, chapter four the environmental aspect, and chapters five and six the social dimension. Chapter seven draws the elements from chapters two through to six into a discussion about triple bottom line sustainability, and the recommendations for upscale. Finally, chapter eight brings all the information from the previous chapters to a conclusion.

# *Chapter Two: Literature Review*

## *2.1 Overview & Guiding Questions*

The following literature review identifies the existing academic and grey literature on the current state of fashion, firstly exploring the lifecycle impacts of apparel supply chains, from production through to post-consumer. It then explores the shift underway towards a more sustainable fashion system and determines the opportunities and barriers to scaling up sustainable alternative supply chains and innovations, taking a focus on the clothing industry. In doing so, I hope to provide context for the 'Homegrown/Homespun' case study and recognise where my research could contribute to the sustainable upscale of an innovative alternative textile system, and broader learnings to sustainable transitions and apparel production in a high-cost environment.

Questions the literature review attempts to address are as follows:

Q1. What can be drawn from the literature about unsustainable fashion systems, and how has this prompted a shift towards sustainable production?

Q2. How is sustainable supply chain management (SSCM) applied to the clothing industry in current literature?

Q3. What barriers, synergies and facilitators can be identified in the literature to scaling up local textile production?

## *2.2 Unsustainable Fashion*

Fashion in the 21st century is contributing to global environmental and social crises. Over the past few centuries, textile and clothing production has transitioned from one of local craftsmanship with use of predominantly local materials, to a highly globalised complex system. This transition has brought with it a raft of environmental and social sustainability dilemmas (Bick et al., 2018; Ledezma, 2017; Ninnimäki et al., 2020). Environmental pollution, occupational hazards, ethical injustices, vast quantities of waste due to over-production, overconsumption, poor management at end of product life, and greenhouse gas emissions are some of the prominent challenges produced by the current fashion system (Ninnimäki et al., 2020). To illustrate the scale of impact, textile production produces 1.2 billion tonnes of carbon dioxide equivalent ($CO_2e$) per year, outweighing emissions from international flights and maritime shipping (Ellen MacArthur Foundation, 2017).

Challenges for fashion and textile industry sustainability continues to grow, particularly in light of the rise of 'fast fashion' in recent decades. The business model of fast fashion is reliant on the rapid production of inexpensive garments and accessories, requiring supply chains that are highly responsive and support frequent changes to product design (Bick et al., 2018; Caro and Martínez-de-Albéniz, 2014). The linearity of fashion supply chains in increasingly highlighted as a problem in the literature as large volumes of clothing are produced and are most often destined for landfill or incineration in a few months or years after purchase (Ellen MacArthur Foundation, 2017). It is estimated around 5.8 million tonnes of textiles are discarded every year by EU consumers (European Commission, 2022). This is a massively exploitative and unjust system. Therefore, finding means to transition this industry towards sustainability is an urgent and important challenge. Furthermore, as public attention focuses on the climate crisis, labour injustice, and sustainability more broadly, the industry is being forced to seek more sustainable practices to meet the demands of regulating institutions and consumers (Ninnimäki et al., 2020).

In the following sub-sections, I will provide an overview of textile production, labour, and consumption to give greater clarity into the dimensions of current unsustainable fashion. Addressing question one of this literature review, exploring the current unsustainability of the fashion industry provides the contextual background which has prompted research and development of sustainable supply chains. It further explores the general motivation of the 'Homegrown/Homespun' initiative to challenge dominant unethical and unsustainable production.

### *2.2.1 Fibre Production*

Textiles can be formed from a wide array of natural and synthetic fibres, each with their own set of sustainability pros and cons.

Cotton is one of the most important natural fibres, dominating natural fibre textile production, with a history that goes back to the early industrial development of the textile industry (Beckert, 2017).

The cotton industry was at the centre of the Industrial Revolution, becoming the most important manufacturing industry in Britain at the time. Neo-Marxist interpretations suggest the dominance of cotton in today's textile industry is deeply tied to a violent colonial history and the power imbalances that contributed to the emergence of global capitalism, such as through armed intervention which forced cotton producers to sell at lower rates (Beckert, 2017; Choundhury, 2019). Despite fierce activism, modern production of cotton remains a highly unethical practice, frequently breaching human rights and labour laws, as has been evidenced by forced labour in some of the highest cotton producing regions, such as by Uyghur, Zazakh and other minority groups in Xingjiang, China (Murphy et al., 2021).

Environmentally, cotton is a highly intensive crop for water, pesticide, and land use during conventional cultivation (Rosa and Grammatikos, 2019). Cotton is the fourth largest consumer of agricultural chemicals, with pesticides having serious consequences on human health, soil fertility, and water quality, having been extensively explored in the literature (Rani et al., 2021). Both the social and environmental implications of cotton production call into question the choice of cotton and prompts the diversification and exploration of other natural fibres.

There has been a shift in the global apparel market to favouring synthetic fibres over natural ones since their development upon advances in polymer synthesis in the early 20$^{th}$ century (Morgan, 2006). Notably, polyester, manufactured from oil-based polyethylene terephthalate (PET), alongside other synthetic fibres are highly polluting during all stages of production (Palacios-Mateo et al., 2021). Favoured for their cheap production and attractive qualities, such as elasticity and easy care, synthetic fibres compromise environmental health. Issues with microfibres, consequences from oil extraction, e.g. spillages to the surrounding environment, and taking millions of years to decompose, are a few examples of this (Palacois-Mateo et al., 2021). Synthetic fibres release microfibres during production, use phase, and at end-of-life disposal, which are associated with ecological toxicity and have been found abundantly in world's oceans, freshwater systems, and sediments (Henry et al., 2019). It is estimated that between 200,000 and 500,000 tonnes of microplastics from textiles enter the marine environment each year (European Environment Agency, 2021).

Alongside the textile industry switching to synthetic fibres, synthetic dyes have come into widespread use for creating long-lasting colourful hues. The ecological toxicity of synthetic dyes, and the chemicals to 'fix' them to the fabric, result in hazardous water effluents which are often released untreated into watercourses (Khattab et al., 2020; Bick et al., 2018). The estimated one hundred tonnes of dye effluent per year from the textile industry, the highest amount of dye wastewater from a single industry, undoubtedly, have catastrophic consequences for aquatic species and human health (Solís et al., 2012 in Katheresan et al., 2018). Associated with high water and energy consumption, the intensive and polluting nature of synthetically dyeing textiles is of growing concern among social-environmental organisations and academics, especially with increased volumes of clothing production, adversely impacting local ecological diversity and local communities.

### *2.2.2 Labour*

Textile and fashion-related industries have shifted the environmental and occupational burdens from high-income countries in the Global North, to the often, under-resourced communities in the Global South, where production is now concentrated (Bick et al., 2018). Garments for apparel and clothing accessories are ranked as the third product most at risk of modern slavery, with cotton as number one, requiring an immediate shift in supply chains and legislation to protect those at risk (Global Slavery Index, 2018). Since the focal event of the Rana Plaza disaster in 2013, which claimed over one thousand lives of garment workers in Bangladesh, the failure of safety regulations has been at the forefront of labour policy (Frenkel and Schuessler, 2021). Yet, eight years on, global governance is concluded to remain weak and insufficient to support garment workers across the world. Although international progress is evident with the International Labour Organisation's (ILO) code of practice and safety and health within apparel and footwear supply chains, said to benefit 60 million workers (ILO, 2022).

As a result of the COVID-19 pandemic and the responses of major fashion brands, worker layoffs, worsened pay, and increased vulnerability to forced labour have amplified long-standing supply chain inequities (LeBaron et al., 2021; ILO, 2020). Even within the UK, there are estimated to be over 10,000 potential victims of modern slavery, despite substantial action to reduce its prevalence, e.g., through implementing the Modern Slavery Act (GOV, 2020). Allegations that subcontracted companies to fashion retailer, Boohoo, were paying Leicester's garment workers as little as £2.50 per hour, were brought to light in 2020, highlighting the issues of modern slavery within the UK, as well as elsewhere in the world (Labour Behind the Label, 2020). Obscurity of transnational, subcontracted supply chains facilitates uncertainty and allows international brands to remain ignorant of their supply chains.

### *2.2.3 Consumption*

Fashion production is both shaped and acted upon by textiles consumption, primarily by communities in the Global North. The fast fashion paradigm provides consumers of the Global North with a constant supply of cheap products, rapidly changing trends, and large retailer stores, both physical and online, encouraging disposability (Ledezma, 2017). As consumers, we are purchasing too high a volume of clothing, and throwing away equally high volumes after little use, in what has become known as 'throwaway culture' (Bhardwaj and Fairhurst, 2010; Ellen MacArthur Foundation, 2017). High rates of consumption fuel production of cheap, low-quality garments. The pollution footprint, and ethical injustices, occurring to produce these high volumes of clothing are a direct consequence of overconsumption (Bick et al., 2018).

Since the early 21st century, despite increased interest in sustainable fashion consumption, there is a continued gap between attitude and behaviour. This discrepancy, the "attitude-behaviour-gap", is a complex challenge deeply tied to the physical, economic, and social circumstances of the consumer, such as knowledge, values, and social dynamics (Wintschnig, 2021). With an emerging market for sustainable garments, the "attitude-behaviour-gap" presents a challenge when considering potential demand, underpinning the viability and longevity of sustainable businesses.

Value-belief-norm (VBN) theory – which conceptualises the casual variables leading to behaviour – has been widely applied to consumer behaviour, in what is coined as "pro-environmental behaviour" (PEB) (Stern, 2000). Drawing on the field of environmental psychology, academics have explored how to encourage more sustainable consumption. Environmental education and awareness plays a considerable role, but in light of the "attitude-behaviour-gap", efforts go beyond this to encourage a dramatic shift in consuming behaviour that is more responsible (Braun and Dierkes, 2019). Exploring these behavioural aspects highlights the necessary multi-level approach to tackling unsustainable fashion practices, including a shift in both supply chain practices and patterns of consumption.

This section has outlined some of the largest sustainability concerns for the fashion system in its current state, and questions the materials used, substandard labour regulations, and increasing volumes of production and waste. In regard to the United Nation's Sustainable Development Goals (SDGs), our current fashion system does not support attainment. Notably, goal 12 – responsible consumption and production – and goal 13 – climate action – call for the shift away from these environmentally and socially destructive practices of the fashion system (United Nations, n.d. [a]).

In section 2.2, the literature review detailed the environmental and social consequences of current textiles production, including the materials, labour conditions, and current linearity. Section 2.3 outlines the approaches of sustainable supply chain management and triple bottom line sustainability to approach these sustainability challenges.

## *2.3 Sustainable Supply Chains in Fashion*

### *2.3.1 A Growing Trend in Business*

Uncovering the unsustainable practices of most present-day textile supply chains has prompted some businesses to re-evaluate the structure of their supply chains and defining value. Both within and beyond the textile industry, there is greater emphasis and awareness on corporate social responsibility, ethical practices, circular economy, and carbon emissions. Sustainable supply chain management (SSCM) is a growing academic field, with many papers focusing on the potential to implement sustainable organisation and operational practices (Touboulic and Walker, 2015; Moretto et al., 2018; Karaosman et al., 2020). The following section addresses question two of the literature review, exploring applications of SSCM within the fashion industry.

Theoretical perspectives and conceptual frameworks have been used to shape applications of SSCM thinking, exploring competitive advantage from resource collaboration (resource-based view), the complexity of intertwining actors within supply chains (stakeholder theory), and inter-firm pressure to adopt sustainable practices (institutional theory) Touboulic and Walker, 2015). The triple bottom line (TBL) approach is a popular and pragmatic framework used for assessing the sustainability of supply chains. Developed by Elkington (1998), triple bottom line conceptualises the equal importance of environmental, economic, and social sustainable practices within a corporation providing a competitive advantage.

Only with successful implementation of sustainable practices that intersect all three elements of TBL, will an organisation have overall sustainable performance (Sapukotanage et al., 2018). TBL sustainability approaches and implementation has critically been explored in the literature (Tseng et al., 2020; Correia, 2019), with application to sustainable business model (SBM) innovation and organisational changes (Montoya-Torres, 2015; Nosratabadi et al., 2019; Sinkovics et al., 2021), and SBM scalability (Jablonski, 2016). It has since been the inspiration for adapted methods used by academics and businesses to approach sustainability challenges. Moretto et al. (2018) embedded the 'triple-bottom line' approach to develop a five-step roadmap to facilitating SSCM for the fashion industry, providing structure that allows for full implementation of sustainable practices by businesses and managers. TBL has been applied to luxury fashion supply chains (Karaosman et al., 2020) and garment manufacture (Sapukotanage et al., 2018). TBL also facilitates wider thinking beyond the immediate supply chain, prompting organisations to identify their influence within wider socio-ecological, economic, and political systems.

Utilising the mindset of promoting SSCM and TBL, the following sub-sections outline the potential alternatives, with their opportunities and challenges, to critically reflect on what is needed for a more sustainable fashion industry.

### *2.3.2 Reimagining Textile Production*

#### *2.3.2.1 Alternative Fibres*

Alternatives to synthetic fibres and intensive natural fibre crops, such as cotton, offer sustainable and economic appeal. Bast fibres, natural fibres extracted from the stem of the plant, such as hemp, flax, and stinging nettle, are increasingly considered economically viable with technological advances that allow processing (Rosa and Grammatikos, 2019). The fibre examples outlined each have a rich cultural history, with recent interest reflecting on ancient textile practices that were lost to the rise of cotton, and later, synthetic fibres. There has been minimal progress on reviving cultivation of these fibres on mass scale, despite sustainability interest and research to suggest economic feasibility (Riddlestone et al., 1994; Gomez-Campos, 2021; Rosa and Grammatikos, 2019).

Both within fibre alternatives and more generally across the agriculture landscape, organic cultivation has gained interest academically and in practice, most often in the context of cotton production, as it alleviates the environmental and health consequences tied to pesticide-intensive farming (Delate et al., 2020). Organic farming does not use genetically modified seeds, synthetic fertilisers, and most synthetic pesticides (Delate et al., 2020). Regenerative agriculture, a loosely defined approach that prioritises soil health and biodiversity building on indigenous knowledge systems, has similarities to organic agriculture, and has been highlighted as a systems-based approach to sustainable agriculture (Schreefel et al., 2020; Giller et al., 2021). Challenges are present for organic fibre production, including weeds, insects, disease, and reduced yield, shaping the economic viability of organic production (Delate et al., 2020; Rosa and Grammatikos, 2019). There remains a research gap for the regenerative approach of growing textile fibres, although this builds heavily on organic farming approaches.

Overall, sustainable, or alternative fibres are considered one of the most prominent innovations for moving towards a sustainable fashion industry (Todeschini et al., 2017).

#### *2.3.2.2 Recycling Fibres*

The concept of recycling fibres for extended usage, moving towards the idea of greater circularity in business, aims to reduce the large waste stream from the textiles industry and reducing the overall environmental footprint (Sandin and Peters, 2018). Current literature focuses on the potential to recycle cotton and polyester, as these dominate current fibre production and therefore account for the largest volumes of waste.

Commercial implementation of textile recycling technologies has been limited due to high economic costs, and quality and performance requirements (Le, 2018). Most current recycling of textiles is classed as downcycling or open-loop, producing lower quality or value production, i.e. waste textiles turned into insulation. Contrastingly, there is a low closed- recycling rate, that allows textile waste to be routed back into production of an equivalently valued production. Recycling of petroleum-based fibres, such as polyester, will continue to contribute to microplastics pollution. Technological limitations, and their associated costs, remain the largest barrier to both open-loop and closed-loop recycling (Sandin and Peters, 2018; Le, 2018). Furthermore, the economic viability and future of recycling fibres remain reliant on current excessive volumes of production. Realistically, it is limited as a temporary solution, a valuable tool in the transition to a low-waste economy, as the fashion industry requires an industry-wide shift to lower rates of production and increase in textile quality.

#### *2.3.2.3 Sustainable Dyes*

In the last few decades, there has been widespread numerical and qualitative research to investigate sustainable alternatives to highly polluting synthetic dyes. The colours of natural dyes are sourced from plants (flowers, fruit, seeds, skins, roots), animals (insects), and minerals (metal salts, metal oxides) (Elsahida et al., 2019). Stricter environmental and ecological legislation have been introduced across much of the Global North, and some countries in the Global South, notably India, prompting the re-popularity of naturally occurring bio-colourants through green chemistry approaches (Yusuf et al., 2017). Stringent treatment of dye effluent from factories has also come into effect. Current demand for natural dyes remains minimal, with challenges surrounding the characteristics of colours, natural bonding of dye to fabric/yarn, and the economic viability of production persisting despite high levels of research (Elsahida et al., 2019; Khattab et al., 2020; Yusuf et al., 2017).

There is potential for natural dye sources to be linked to waste streams of other industries, such as the agricultural waste/by-product and food and beverage industries. The appeal of natural dyes goes beyond colours, to include antimicrobial properties, UV protection, antibacterial, anti-inflammatory and anti-insect (Senthikumar et al. cited in E Elsahida et al., 2019). Faced with the lower financial cost and greater efficiency of synthetic dyes, there remains a great challenge for widespread re-introduction of natural dyes, with support required from policymakers, farmers, agricultural unions, governments and businesses (Khattab et al., 2020).

#### *2.3.2.4 Ethical Labour*

Implementing and maintaining labour and ethical standards within the entirety of the textile supply chain have been made increasingly challenging, yet vital, with transnationally operating supply chains (Köksal and Strähle, 2021). Work of the International Labour Organisation, United Nations, Organisation for Economic Co-operation and Development, and European Union have strongly shaped guidelines and procedures to work alongside existing legislation, government policies and private regulation (Frenkel and Schuessler, 2021). Furthermore, social movements among agricultural, manufacturing and textiles workers, and collective voice through unionisation, have contributed to facilitate compliance with, and enforcement of, labour standards (Frenkel and Schuessler, 2021). Calls for 'radical transparency' that interrogates fashion supply chain opacity, and broadly advocates for a fashion system that values the people that make our clothes (Richards, 2021). Köksal and Strähle (2021) developed a framework that may contribute to successful social standard implementation in multi-tier fashion supply chains. They further explore social standard failures, and the opportunistic mindset of suppliers for seeking lowest-cost production.

Although increasing in focus over the last decade, the social element of SSCM has been massively neglected in related academic research (Köksal and Strähle, 2021; Touboulic and Walker, 2015; Chiesa and Pryzhodzen, 2020). A research gap has emerged for social sustainability in supply chains that involves considering the role of small-and-medium sized enterprises (SMEs), as academia has focused on large, influential companies, and for analysing different interpretations of sustainability across languages and cultures (Chiesa and Przychodzen, 2020). Increased communication between academics, policymakers, governments, NGOs, and labour unions, will shape impactful legislation, increase compliance and facilitation of SSCM.

Exploring these dimensions of sustainable production has brought attention to the growing interest and potential for successful implementation of these innovations. It highlights the research gaps and begins to contextualise the barriers the textile industry is facing for a sustainability transition.

### *2.3.3 Reshoring and Localisation*

One approach to facilitating SSCM is through reshoring and localisation of production. The following two sub-sections explore these, their contextualisation, and current opportunities and challenges.

#### *2.3.3.1 Reshoring*

Little is understood of the relationship between reshoring and sustainability, but is increasingly approached in emerging SSCM literature, identifying drivers, opportunities, and challenges, often using case studies and theoretical lenses (Orzes and Sarkis, 2019; Ashby. 2016; Pal et al., 2018; Benstead et al., 2017; Dikler, 2021). The largest motivations for reshoring are the rise of labour costs in what were considered 'low-cost countries', exposure to risk in offshored production, infrastructural requirements or issues, and competitive priorities (Benstead et al., 2017; Diker, 2021). In the context of sustainability, reshoring provides a more transparent, ethically-sound, reliable and trust-based supply chain, bringing both social and environmental benefit (Ashby, 2016).

There is evidence of reshoring among textile companies, especially among SMEs due to smaller-scale supply chains (Benstead et al., 2017), and luxury brands as product costs can incorporate the associated costs from manufacturing in a high-cost economy environment (Robinson and Hsieh, 2016). In the case of Burberry, a luxury clothing brand, reshoring increased sustainability, efficiency and created an opportunity for competitive advantage by capitalising on the use of 'Made in the UK', embedding this within their brand identity (Robinson and Hsieh, 2016).

Numerous challenges remain when considering reshoring by textile supply chains, including the fact clothing supply chains are heavily buyer-driven, low unit cost is its major driver, and lack of skilled labour and infrastructure are prevalent in a high-cost economy that is largely service-based (Ashby, 2016; Pal et al., 2018). Industrial policies largely govern the competitiveness of textile economies within high-cost economies, such as the UK, and therefore, the ability to re-shore the supply chain (Spring et al., 2017). Furthermore, COVID-19 has massively shaped the global economy, having dual effects on reshoring; highlighting vulnerability in companies' global supply chains, and the fact reshoring growth is dependent on economic recovery following disruptions from the pandemic (Diker, 2021).

#### *2.3.3.2 Localisation*

Global, fragmented, 'distant', supply chains, have resulted in a disconnection between consumers and the products they use daily, including a loss of understanding and appreciation for the skillset and resources involved in a product's creation (Burns and Carver, 2021). This disconnection has stimulated the concept of place-based business models, where context-specific strategies and linkages to "sense of place" for value creation take centre stage (Di Gregorio, 2017; Burns and Carver, 2021). The concept of "sense of place" has been approached from various disciplines, defined in different ways, and gained criticism for its lack of clear definition. The general consensus is that places form a key role in shaping peoples' and communities' identities, that places are socially constructed, and place meanings and attachments change and develop over time (Convery et al., 2012). Massey (1994) stresses the construction of place out of social relations; a fluid, unbounded space within a network of social relations and understandings. Applications of sense of place within place-based business models value, respect and are deeply rooted within the geography, culture, and people of a specific location (Di Gregorio, 2017; Burns and Carver, 2021). They are also often reliant on consumers from outside those locations connected to a global world of consumption.

Place-based business models go against conventional management theories that place sustainability distinct from profitability, to tightly couple local context with product value, contributing to regional resilience and can generate competitive advantage (Di Gregorio, 2017). Embedding a business within the local community and culture enhances the economic resilience of the broader community, can recreate, and renew the identity and purpose of place, supporting a "more sustainable, culturally aware and socially sensitive growth and development" (McKeever et al., 2015, p.63). Di Gregorio (2017) provides sustainable, profitable examples from Italy, within the slow food movement and cultural tourism sector. The demand comes from international visitors seeking a more holistic and 'embedded' experience of Italy's locality. Application of these place-based business models have also been evidenced in the textile industry, such as Indigenous Designs in Highland Peru and Harris Tweed, Outer Hebrides, Scotland (Burns and Carver, 2021). These companies use the value of place to reconnect consumers with the people, culture, and geography of a location; reflected throughout the supply chains (Burns and Carver, 2021). Current applications are limited, although increasing in popularity in the emerging field of SSCM and TBL.

Both reshoring and localisation bring critical considerations between the opportunities, barriers, and trade-offs for feasibility and sustainability. Having explored applications of SSCM in fashion, addressing the second question of this literature review, this has emphasised the multifaceted approaches to promoting sustainability and uncovered the research gaps, such as for supporting research into the social element of SSCM, and provided further motivations for this research.

## *2.4 Upscaling Sustainable Business Models (SBMs)*

With interests from academics, businesses, entrepreneurs, policymakers, governments and non-profits, there is increased attention towards upscaling current niche sustainable innovations and alternatives due to persistent societal problems, such as the climate emergency, biodiversity loss, resource depletion, and inequalities and social exploitation (Lam et al., 2020; Stewart et al., 2016). Existing literature highlights the potential for businesses to facilitate sustainability transitions as part of the wider network of actors and enablers (Hernández-Chea et al., 2021). Furthermore, analysis of whether niche innovations and smaller businesses can increase their impact while maintaining their sustainability-oriented values has gained interest in transitions research and sustainable supply chain management (Lam et al., 2020; Hernández-Chea et al., 2021; Moretto et al., 2018). The following section addresses the final question of the literature review, to identify the barriers, synergies, and facilitators to scaling up local textile production.

The opportunity here for upscaling is the magnification of sustainable practices to the wider market, innovation successes that nurture climate-friendly socio-natural systems and moving away from a fossil-fuel reliant economy. Moving beyond a product- or service- centric view, organisations are embracing their ability to mobilise environmental and social movements (Jablonski, 2016). Specific to the fashion and textiles industry, scaling up sustainable innovations and alternatives to the dominant, wasteful, and highly polluting practices of the fast fashion system, is integral for transitioning to a sustainable system (Islam et al., 2020).

The idea of upscaling SMBs and innovations further brings into question, 'to what scale?' The very concepts of TBL sustainability and SSCM allude or directly conceptualise the limits to scales of production within ecological and social capacities. The discrepancy between the planetary boundaries, production capacity, and the conditions to maintain economic growth are apparent, with academics calling these relationships into question (Nesterova, 2020; Stephan et al., 2021; Jason, 2019). Degrowth, widely cited as downscaling of production and consumption while enhancing wellbeing (Schneider et al., 2010). Degrowth has received limited direct attention in SSCM literature. Nesterova (2020) explores how degrowth and business can be compatible, suggested through smaller scale production, alternative business models, deviation from profit maximisation, local embeddedness, and employer wellbeing. These align quite respectably with principles of SSCM and TBL sustainability. To bring this back to the idea of scale, in a textile sense, upscale would ideally remain small-to-mid scale, tying into other movements to slow down textile production and combat the 'throwaway society' rhetoric.

Despite literature advocating the need to upscale sustainable innovations, there is limited research on the opportunities, barriers and challenges faced by small sustainable businesses in doing so, especially in relation to the fashion and textiles industry. The literature mostly discusses the implementation of sustainable practices within existing businesses, which in most cases were not built on sustainable principles, or 'born sustainable' (Todeschini et al., 2017; Islam et al., 2020). While implementing sustainable practices across all businesses is crucial for transforming society and the economy to a more ecologically-sound and just system, there remains a gap in the literature for specifically scaling up sustainable start-ups in their attempts to scale up operations and impact.

Specific to textiles or natural dye production in the UK, previous projects and reports have explored the feasibility for this to exist at commercial scale. Riddlestone et al. (1994) investigated the potential for reintroducing cultivation and processing of flax and hemp to the South-East of England into textiles and paper industries. They concluded re-introduction is profitable, despite initial costs from reviving flax scutching and retting facilities and a desperate need for knowledgeable skill forces. To advocate for whole crop utilisation, in a closed-loop system, the proposed system would allow higher value fibres for high quality textiles and low-value short fibres be pulped for paper.

Furthermore, the SPINDIGO project that ran from 2000 to 2004, aimed to introduce indigo-producing crops into European agriculture, moving away from petro-based synthetic fibres that are highly polluting (Maule et al., 2004). Despite funding of £3.5 million, and the aim to develop a portable processing system to extract and concentrate indigo from the crop, this has not been upscaled for indigo production in the UK (Maule et al., 2004). Both these projects, reintroduction of flax and hemp, and SPINDIGO, occurred nearly twenty or thirty years ago, and there has been little action or progress since. The upscale of these projects, and required technologies, have faced substantial barriers, something which will be expanded upon in the following section.

The literature focuses on the barriers of sustainable upscale, demonstrating current barriers massively outweigh opportunities (Laukkanen and Patala, 2014; Stewart et al., 2016). The academic focus highlights a research gap for identifying the opportunities for upscaling sustainable innovations. The following section addresses the opportunities for SSCM more broadly, with some reference to upscale, and then approaches the barriers and challenges in-depth.

### *2.5.1 Opportunities for SSCM*

As Norton (2012) concisely addresses in the title of his book, is sustainable business practice duty or opportunity? To achieve sustainability, a firm must transform its entire business logic (Abdelkafi and Täuscher, 2015). The climate crisis is having dramatic consequences on planetary systems, with the fashion industry evidenced as a large contributor to atmospheric warming and ecological damage (Bick et al., 2018; Ledezma, 2017; Ninnimäki et al., 2020; Ellen MacArthur Foundation, 2017). Furthermore, the highlighted unethicality of fashion production, has seen increasing efforts from NGOs and policymakers for brands to legally comply with ethical audits and regulations, and the development of corporate social responsibility (Frenkel and Schussler, 2021; Todeschini et al., 2017).

Our fashion system is ecologically and socially destructive and must undergo a massive shift. Researchers, governments, policymakers, businesses, and consumers are increasingly made aware of this destructive impact and, to varying degrees, are advocating for change. Important, yet often voluntary, international agreements of climate action, such as working towards a net-zero economy and limiting atmospheric warming to 1.5°C, and working towards the SDGs, encourages sustainable innovations (Blok et al., 2015). The UK's Net Zero Strategy outlines billions of pounds to support decarbonisation and the green economy (HM Treasury, 2021). These begin to provide the institutional, economic, and societal support towards a more sustainable future, potentially incentivising the conception of SBMs and innovations and may further support their scale up.

Alongside the suggested forced change, the literature identifies the opportunities and benefits for a firm to implement TBL sustainability thinking and SSCM. Norton (2012) describes how the World Business Council on Sustainable Development (WBCSD) initially focused on eco-efficiency as the prime example of how businesses can reduce their environmental impact while also supporting profitability. Reducing resource demand, such as for water and energy, supports business feasibility and ability to use economic surplus to re-invest in upscale. If a sustainable innovation massively improves resource efficiency, this may attract attention for industry-wide application or high demand by other organisations, therefore competitiveness, to ensure compliance with decarbonisation strategies. Adopting stakeholder theoretical perspectives, Abdelkafi and Täuscher (2015) argue a socially and environmentally engaged organisation reduces the level of perceived risk due to development of trustful and long-term relationships with its stakeholders.

The concept of extended producer responsibility (EPR), where end-of-life costs will be the responsibility of the producer rather than local governments and consumers, holds the potential to incentivise improved textile design (Long and Lee-Simion, 2022). The EU strategy for sustainable and circular textiles aims to put EPR into effect, supporting policy measures to ensure all textiles on the EU market are durable, repairable and recyclable (Directorate-General for Environment, 2022). The opportunity here is for supply chains to react accordingly, avoiding economic costs of non-compliance, and to identify innovative design thinking which could potentially be upscaled if this successfully meets these requirements.

### *2.5.2 Barriers & Challenges for SSCM*

There are many associated challenges with, and barriers to, upscaling sustainable alternatives, innovations, and business models, with many attempts at long-term implementation of sustainability approaches frequently failing (Stewart et al., 2016; Gupta et al., 2020). These barriers have been identified as economic, technological, institutional, societal, organisational, or market limited. Interdependent in nature, barriers need to be addressed in union to facilitate an opportunity for sustainable businesses to upscale. Innovative success depends on a business' capability to upscale, therefore, those looking to upscale must identify, prioritise, and overcome barriers currently limiting them (Gupta et al., 2020). Using those listed over-arching barriers, the following sections will go into greater detail, using examples more generally from the manufacturing and sustainable business literature, providing greater detail on application to the fashion industry.

Figure 2.1 illustrates the main barriers to sustainable upscale, with Table 2.1 building on figure 2.1 to present the supporting literature. The following sub-sections explore each of these in greater detail, also offering overcoming strategies.

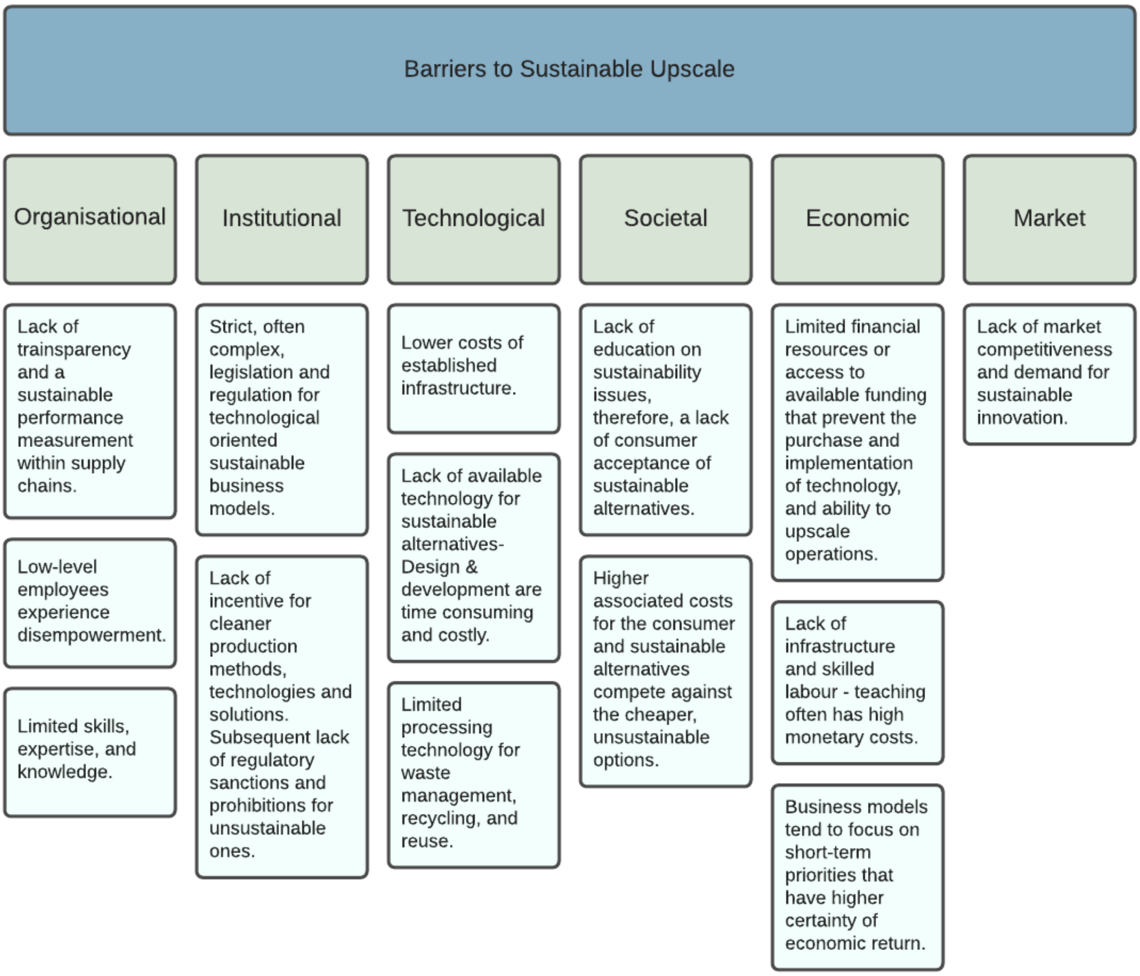



*Figure 2.1: The overarching barriers to sustainable upscale, with broad reference to textiles and fashion.*

*Table 2.1: Barriers to sustainable upscale, with reference to the supporting literature.*

| Barrier Category | *Barrier* | *Supporting Literature* | | | |
|---|---|---|---|---|---|
| | | Gupta et al., 2016 | Stewart et al., 2016 | Todeschini et al. 2017 | Laukkanen and Patala, 2014 |
| Organisational | Lack of supply chain transparency. | ✓ | | | ✓ |
| | Lack of sustainable performance measurement. | ✓ | ✓ | | |
| | Low-level employees experience disempowerment. | ✓ | | | |
| | Limited skills, expertise, knowledge. | ✓ | ✓ | | |
| Institutional | Lack of incentive for change and limited regulatory pressure for a sustainable shift. | | | | ✓ |
| | Strict, often complex, legislation and regulation for technological-oriented SBMs. | ✓ | ✓ | | ✓ |
| Technological | Lack of technology for sustainable alternatives. | | ✓ | ✓ | |
| | Lower costs of established infrastructure. | | | ✓ | |
| | Limited processing technology for waste management, recycling, and reusing. | ✓ | | | |
| Societal | Lack of education on sustainability issues, therefore, a lack of consumer acceptance of sustainable alternatives. | | ✓ | ✓ | ✓ |
| | Higher associated costs for the consumer and sustainable alternatives compete against the cheaper options. | | | | ✓ |
| Economic | Limited financial resources or access to available funding that prevent the purchase and implementation of technology, and ability to upscale operations. | ✓ | ✓ | | |
| | Lack of economic incentives for cleaner production methods, technologies and solutions. Subsequent lack of sanctions and prohibitions for unsustainable ones. | | | | ✓ |
| | Lack of infrastructure and skilled labour. | ✓ | | | |
| | Focus on short-term priorities that have higher certainty of returns. | | ✓ | | ✓ |
| Market | Lack of market competitiveness and demand for sustainable innovation. | ✓ | ✓ | | |

#### *2.5.2.1 Organisational*

Lack of sustainable performance measurements, lack of supply chain transparency and clear responsibility, lack of empowerment to lower-level employees and lack of skills, knowledge, and training, continue to prevent businesses from implementing sustainable practices or allowing a sustainable start-up to grow (Stewart et al., 2016; Gupta et al., 2016). Alleviating organisational barriers is reliant on economic strategies and developing the required skills, whether that be for developing and using technological innovations or ensuring sustainability practices are maintained throughout the supply chain (Gupta et al., 2020).

#### *2.5.2.2 Institutional*

Lack of incentive for change and further lack of regulatory pressure from governmental and legal forces, both within high-cost economies and traditionally low labour cost economies, prevent sustainable innovations and businesses from upscaling (Stewart et al., 2016; Gupta et al., 2020). In the case of technological-oriented SBMs, strict legislation, and time-consuming and expensive regulation, provide another barrier to upscaling (Laukkanen and Patala, 2014). Finally, a lack of local empowerment, short-term priorities, and lack of financial resources to promote change further prevent upscaling or innovation success (Stewart et al., 2016). A regulatory strategy to overcome these barriers involves policy implementation by governments to enable sustainable transitions and upscaling, such as tax cuts, increased access to sustainable technologies, infrastructural support, stringent environmental waste policies, and economic grant support (Gupta et al., 2020).

#### *2.5.2.3 Technological*

Firstly, there is a lack of technology for sustainable alternatives, specific to the fashion industry in processing sustainable fibres, such as linen and hemp, and applying and fixing natural dyes (Todeschini et al., 2017; Gupta et al., 2020; Riddlestone et al., 1994). Therefore, developing sustainable and innovative technologies have high resource costs, and considerable risk, deterring their development and implementation (Stewart et al., 2016). Finally, when considering waste streams, especially the high waste from the textiles industry, there is limited processing technology for waste management, recycling and reusing (Gupta et al., 2020).

Scaling back use of technological innovations, such as farming organically instead of using pesticides, has its environmental and social benefits, but no doubt has its challenges with increased weeds, labour and risk of crop failure that increase costs, that remain a barrier (Riddlestone et al., 1994; Delate et al., 2020). Furthermore, re-introduction and scaling up natural dyes is challenging due to lower costs and established infrastructure for use of synthetic dyes (Todeschini et al., 2017). In both cases of moving towards organic farming and natural dyes, collaborative support from policymakers, farmers, governing bodies, businesses, and agricultural unions will facilitate their scale up (Khattab et al., 2020).

#### *2.5.2.4 Societal*

There is increasing emerging literature on consumer behaviour and education, within and beyond the fashion industry, recognising the role of consumption patterns on moving away from fast fashion to supporting sustainable alternatives (Bick et al., 2018; Wintschnig, 2021; Todeschini et al., 2017). As a buyer-driven industry, sustainable textiles are reliant on demand. Lack of consumer education on sustainability issues, lack of consumer acceptance of sustainable alternatives (often due to marketing perceptions of 'eco-friendly'), higher associated costs, and current inaccessibility of alternatives, are the main consumer barriers (Todeschini et al., 2017; Laukkanen and Patala, 2014). Marketing and promoting the benefits of sustainable products to consumers is one pathway to overcoming some of these barriers, as this both increases demand for alternatives and increases acceptability for these sustainable products (Gupta et al., 2020). The SHIFT framework, developed by White et al. (2019) proposes psychological shifts in fashion consumption, that can be incentivised by businesses, governments, and the fashion industry. The complexity of overconsumption remains a true barrier to sustainable consumption, reliant on generational shifts with increased education and acceptance.

#### *2.5.2.5 Economic*

Current clothing supply chains are heavily buyer-driven, with low unit cost as their major driver (Pal et al., 2018). As a result, there may be a lack of economic incentive to shift from current modes of production, with current business models being highly profitable (Laukkanen and Patala, 2014). Furthermore, the economic limitations to implement technology, upscale operations, and the uncertainty of the return on investment, further inhibit sustainable upscaling (Gupta et al., 2020; Stewart et al., 2016). Start-ups are often more innovative than mainstream fashion companies but are less successful in identifying or developing the competitive advantage to appropriate value (Todeschini et al., 2017). In the case of reshoring or starting up production in a high-cost economy, lack of infrastructure and skilled labour can raise upscaling costs beyond what is economically viable for a business (Ashby, 2016). Economic support and incentive strategies for sustainability innovation, including investment in sustainability technologies and incentive for thinking of innovative ideas, is the most important pathway for transitioning to sustainable manufacturing (Gupta et al, 2020).

#### *2.5.2.6 Market*

Lack of competitiveness, low market demand, and the focus on low-risk short-term returns are identified as some key barriers to upscaling (Laukkanen and Patala, 2014; Stewart et al., 2016). When looking to overcome these barriers, it is imperative to build collaborative capabilities and competencies across business, institutions, organisations, through increased communication (Gupta et al., 2020).

## *2.6 Conclusions*

Here, I return to the three questions which guided this literature review. The first, to explore the literature of unsustainable fashion systems and the shift towards sustainable production, illustrated the wide critique of the fashion system as we know it. Global fashion has environmental and social consequences during every stage of the clothing lifecycle, from fibre production to post-consumer, massively perpetuating ethical injustices and the climate crisis (Bick et al., 2018; Ninnimäki et al., 2020). For the last thirty years, academics, NGOs, and other organisations have brought these issues to light, calling for a transition away from fossil fuel reliance and towards a more sustainable textile system (Ledezma, 2017; Ellen MacArthur Foundation, 2017).

To address the second question, to investigate the application of SSCM within clothing and textiles, I identified theoretical perspectives to analyse supply chain practices and applications to SSCM. Notably, TBL sustainability, and its growing application to address sustainability challenges within supply chains, has some application to promoting a sustainable textile system (Moretto et al., 2018; Spukotanage et al., 2018). With greater attention towards the environmental dimension of TBL, a research gap emerged for equally considering the environment and social dimensions within SSCM applications. The literature further presented exploration of less environmentally polluting and resource intensive materials for fibre and dye, implementation of strong labour standards and policies, and addressing the high volumes of textile waste (Rosa and Grammatikos, 2019; Köksal and Strähle, 2021; Frenkel and Schuessler, 2021; Khattab et al., 2020; Sandin and Peters, 2018).

Within the SSCM literature, reshoring and localisation of supply chains have received growing attention, with case studies of fashion supply chains, which is of particular relevance to the 'Homegrown/Homespun' case study (Orzes and Sarkis, 2019; Ashby, 2016; Pal et al., 2018). Despite increased interest, questions remain about the barriers and opportunities to re-shoring and its potential for a sustainable future. The exploration of coupling local context, sustainability, and supply chain viability, are limited in application but existing literature supports to movement towards more socially embedded and regionally resilient supply chains (McKeever et al., 2015; Di Gregorio, 2017; Burns and Carver, 2021).

The final question sought to explore the barriers, synergies and facilitators to scaling up local textile production. The scaling up of sustainable innovations and alternatives to the current unsustainable system is argued as integral for sustainability in textiles (Islam et al., 2020). Despite an increase in development of sustainability innovations and research into transitioning to sustainable systems, the focus is on sustainable transitions for larger businesses and reshoring production from traditionally low-cost labour countries (Todeschini et al., 2017; Stewart et al., 2016; Gupta et al., 2017; Lam et al., 2020; Hernández-Chea et al., 2021). There remains a research gap for examining the upscaling of sustainable enterprises and business models, especially in the context of SMEs and within the UK context. Furthermore, the literature predominantly focuses on the barriers for upscale, which have been categorized into six overarching themes, but further supports a research gap for the opportunities to identify opportunity for sustainable upscale.

Collectively, the findings from exploring these three questions supports the research into the feasibility to scale up a sustainable textile system, moving away from the principles of mainstream fashion production and embracing a climate and socially responsible supply chain. The research takes a TBL sustainability approach, striving to give equal attention to the economic, social, and environmental dimensions of sustainability. It further hopes to contextualise the opportunities and barriers for upscaling SMBs within the UK, drawing on the 'Homegrown/Homespun' project as a case study.

# *Chapter Three: Economic*

## *3.1 Methodology - Economic Feasibility Assessment*

### *3.1.1 Overview*

The upscale of the current ‘Homegrown/Homespun’ project to a commercially viable supply chain is underpinned by the economic feasibility, primarily the ability to grow the flax and natural indigo to transform this into viable textiles. The current scale of ‘Homegrown/Homespun’ is a volunteer-focused and localised enterprise, primarily experimenting with regenerative cultivation of flax and natural indigo for textile applications. It has previously been concluded that the revival of a UK-based flax supply chain for textiles and paper in the south-east of England is economically feasible, with sustainable land use and utilisation of intermediate scale processing technology (Riddlestone et al., 1994). Nearly thirty years later, this study attempted to re-assess and contextualise the feasibility for a UK-based flax and natural dye supply chain, primarily in the north-west of England. The following chapter addresses objective two of the research.

An economic feasibility study attempted to define and quantify, where possible, the available avenues for upscale of the ‘Homegrown/Homespun’ project. Investigating these economic and operational avenues, and identifying issues that may arise, determined the capacity for a UK flax and natural dye supply chain and whether it makes sense economically (Burton, 2017). This involved market research, conversing with experts and professionals in the related industry, and estimation of costs based on published information in the literature. There was attention to both viability and feasibility. The study identified the previous barriers which have prevented the revival of a UK-based linen industry, and commercial-scale extraction and application of natural indigo. It also attempted to recognise the potential for collaboration with other organisations and projects. Recognising the increasing interest in flax fibre and natural dyes for textiles, both within and beyond the UK, highlights potential towards developing collaborative infrastructure and capacity sharing to substantiate economic feasibility (Seok and Nof, 2013; Barratt, 2004).

### *3.1.2 Envisaged Supply Chain*

Identifying the stages involved in the supply chain, both for flax and natural indigo dye, was crucial to understanding where the opportunities and challenges existed in the potential upscaling of the 'Homegrown/Homespun' supply chain to a UK-based sustainable supply chain. Communicating with the 'Homegrown/Homespun' team and using relevant literature allowed the conceptual understanding of this supply chain. Figure 3.1 and table 3.1 outline the main stages in a flax-based supply chain, and figure 3.2 and table 3.2 detail the stages of natural indigo dye.

#### *3.1.2.1 Flax*

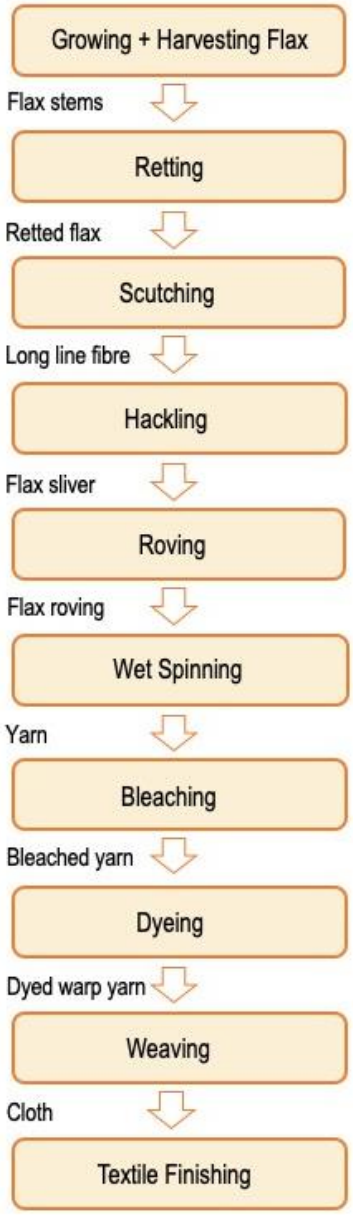



*Figure 3.1: Proposed supply chain for flax-based textile system.*

*Table 3.1: Description of each process in linen manufacturing (Kozlowski et al., 2020; Tahir et al., 2021; pers comms. with 'Homegrown/Homespun' team and industry experts).*

| Process | Description |
|---|---|
| *Flax Cultivation* | Seed is sown in April and harvested in July (close of play 100 days between sowing and harvest).<br>One noticeable difference from flax to other cereal crops, and linseed varieties, is that during harvest, the plant is pulled, not cut. Flax pulling maintains the length of the stems, producing the longest possible fibres. Flax is also pulled before seed maturity. |
| *Retting* | As used for all bast fibres, this process separates the fibre from the woody core of the plant, where the gums and pectins which bind the fibres are broken down. There are multiple methods of doing this 'degumming' process; dew retting in the fields, using water, using chemicals or enzymes. Each method has pros and cons and can produce different quality fibres. (Greater detail is listed in Appendix 6). |
| *Scutching* | Scutching aims to mechanically separate the woody part of the retted flax straw from the fibre using a scutching turbine. This removes broken stalks, shives, and some of the tow.<br>In some instances, seeds can be removed at this stage, or a separate stage (rippling/threshing) prior to scutching. |
| *Hackling (combing)* | A machine where the scutched flax fibre is pulled through ever finer sets of metal pins to refine the sliver (long line) fibre and remove the tow, along with any non-fibrous material.<br>Hackled fibre is then converted to a continuous 'sliver' by layering each piece end-to-end. |
| *Roving* | Sometimes integrated within the hackling process, roving is the stage where an initial twist is inserted to a continuous line of sliver to prepare it for spinning. |
| *Wet Spinning* | Both short and long fibres produced can be spun. The long fibres are primarily used for textiles as they can create finer and stronger yarns. Flax fibres are often spun wet, as flax fibres are stronger when wet. To achieve this, warm water or steam is applied to the roving as well as other mechanical differences in the spinning frame. |
| *Bleaching* | Raw linen yarns are grey is colour. In most commercial settings, linen yarn is bleached before further processing, but this stage is not essential to the quality of the fibre. Further pre-treatment of the yarn prior to dyeing is also common. |
| *Dyeing* | The process where dyestuff is applied to the yarns to stain them. Since the mid-20th century, synthetic dyestuff has been used for most commercially dyed products. There is often a pre-treatment with chemical before dyeing, drying between stages of wet processing, as well as the dyeing stage itself. Often large volumes of water are used for textile dyeing. |

| | |
|---|---|
| *Weaving* | The yarn is then woven on looms. A sizing agent is applied to the yarn prior to weaving to improve its weavability by minimising breakages. A weave specification will allow different weaves depending on the textile usage and garment design. |
| *Finishing* | Finishing can occur at either/both yarn stage prior to weaving or woven textile stage. The finishing of the yarn is based on the desired properties of the finished fabric, such as durability, wrinkle resistance, and low shrinkage. Finishing involves use of chemicals, such as glyoxal-based resin, butane-tetracarboxylic acid and liquid ammonia. |

### *3.1.2.2 Natural Indigo*

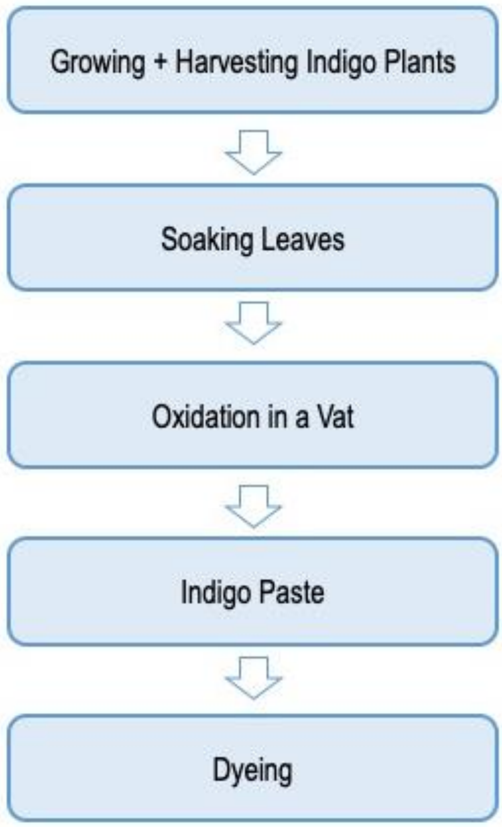



*Figure 3.2: Proposed supply chain for natural indigo dyestuff.*

*Table 3.2: Indigo cultivation and extraction description, water extraction method (Maule et al., 2000; John and Angelini, 2009; John, 2009; Wenner, 2017; Lai and Chang, 2021; Wenner and Forkin, 2017).*

| **Process** | **Description** |
|---|---|
| *Indigo Cultivation* | There are multiple plants which can be used to produce the indigo blue colour. The ones of interest to 'Homegrown/Homespun' are woad (*Isatis tinctoria*), a native UK plant, and Japanese indigo (*Polygonum tinctorium*), a non-native variety historically cultivated in China and Japan. While Japanese indigo has higher yields, there is uncertainty of viability to grow this in a temperate climate and irrigation requirements.<br>Can be sown in spring and have multiple harvests throughout the summer. |
| *Soaking Leaves* | Leaves are washed with water and then soaked in water – the times and water temperatures over this are contested. This hydrolysis process splits the indican, present in the indigo plant leaves, into two parts; b-D-glucose and indoxyl.<br>The precise method of soaking these leaves, the temperature or duration, is variable in the literature and there are many methods to achieving this step. |
| *Oxidation* | Generally speaking, alkaline is added (often lime) and then the mixture aerated, often using a pump and water circulating system. Again, there are contested methods to the duration of this process. Oxidation allows the conversion of indigo precursors into the pigment molecule, indigotin. In non-ideal conditions, other oxidation products, such as isatin and indirubin, can form, lowering the purity of the dyestuff. |
| *Indigo Paste* | The insoluble indigotin precipitates, settles, and is filtered. This can be used for dyeing as a paste, or in some cases is dried before dyeing. |
| *Dye Process* | Indigo must be chemically reduced in a dye vat for it to become soluble. This water-soluble form is known as leuco-indigo is what saturates the yarn/textile, and when removed from the vat, the leuco-indigo oxidises again to form water-insoluble indigotin. The process requires the dye vat have alkaline pH. The reduction process can be achieved both chemically (e.g. with sodium hydrosulfite, thiourea dioxide) or biologically (e.g. with fructose, ferrous sulfate, henna). |

### *3.1.2 Previous Commercial Limitations & Potential Opportunity*

Through conversations with the 'Homegrown/Homespun' team, industry experts and previous publications, the previous commercial limitations and current uncertainty in upscaling a flax-based and natural dye supply chain were identified. The market demand for flax and natural dyes was also briefly explored.

### *3.1.3 Estimated Yields of Flax and Natural Indigo*

The yields of flax and natural indigo were identified in existing literature and publications, and informed by industry experts, as this will ultimately determine the value of the flax and indigo on the input costs per area of land cultivation. The lower the yields, the more land required to produce the amount of fibre and dye. This was calculated on a per ha basis.

Further yields of the co-products of flax and the viable fibre from initial harvested quantities, was estimated to inform the costs and scale of supply chain, taking into account the land requirements, quantities of product throughout the supply chain, and to estimate the input to output material. This was done using relevant literature, primarily Gomez-Campos et al. (2021).

### *3.1.4 Analysis of Available Options*

Through logistical research, engagement with the 'Homegrown/Homespun' project stakeholders and conversing with industry experts in flax cultivation and processing, the available options to upscaling a supply chain for the 'Homegrown/Homespun' model were explored. The innovative nature of the research meant many routes were explored and compared. Furthermore, informal conversations at the field sites during volunteering sessions with stakeholders and volunteers often contributed to guiding these explorations, which I noted in my research journal. The impact of Brexit in particular was explored, as this had produced some economic and logistical barriers in upscaling the supply chain.

### *3.1.5 Cost-Benefit Analysis*

Using the previous research within the feasibility assessment that aimed to identify avenues for upscale, these were then quantified were possible. The analysis identified the costs of stages from cultivated flax and natural indigo through the processing and manufacturing stages. These were estimated using market and economic data provided in open-source documents or through pers comms. with industry experts (National Association of Agricultural Contractors (NAAC); Grisso et al., 2010; Farmers Weekly, n.d; Farm Seeds, n.d; Kozlowski et al., 2020). Considerations were drawn for regenerative, organic-based cultivation and the impacts of this on input costs. Due to the innovative and lack of current commercial supply chain, the input costs have been quantified where possible, but information gaps were anticipated.

The focus here was on the cultivation stages, as quantifying the labour or machinery investment costs were critical to underpinning the ability to supply raw materials to the rest of the supply chain. The largest initial investments were identified. The scope of this cost-benefit analysis included both investment costs and running costs.

For consideration of initial investments, a break-even analysis estimated the viable point at which investing in a piece of machinery or infrastructure becomes economically viable. The analysis provided reasoning to determine whether an investment would be logical with the requirements and anticipated level of production for the scale up of 'Homegrown/Homespun'. The initial objective was to produce five hundred pairs of linen jeans for Autumn 2023.

## *3.2 Results & Discussion*

First, the limitations and uncertainties of the flax and natural indigo upscale have been explored, followed by research into cultivation yields, flax fibre yields and estimated pairs of jeans. Research analysis details the explored avenues for upscale, focused on the processing of the flax from raw plant to scutched fibre, with brief research into spinning. This chapter then goes on to detail the impact of Brexit on the proposed supply chain, finally followed by a cost-benefit analysis.

### *3.2.1 Previous Commercial Limitations & Current Uncertainty*

From observation of academic literature, but predominantly from conversations with the 'Homegrown/Homespun' team and industry experts, table 3.3 summarises the identified barriers to upscale and the current uncertainty of the proposed supply chain. Identification of these main barriers both provided a starting point for further research, and to realistically set out the continuing barriers to commercialisation of the proposed 'Homegrown/Homespun' model.

*Table 3.3: Commercial-scale challenges.*

| | **Supporting Sources** | | | |
|---|---|---|---|---|
| **Challenge** | *Homegrown/Homespun team* | *Industry experts, pers comms.* | *Samanta et al. (2018)* | *Indigo yield research (figure 3.5 and table 3.6)* |
| Higher priority of land is for growing food | | ✓ | ✓ | |
| Flax | | | | |
| Flax is not cultivated on a commercial scale for its fibre in the UK | ✓ | ✓ | | |
| Lack of flax agricultural machinery in the UK (flax puller) | ✓ | ✓ | | |
| No UK flax processing machinery | ✓ | ✓ | | |
| No UK flax spinning mills – only one cotton spinner and some wool spinners | ✓ | ✓ | | |
| | | | | |
| Limited examples of linen denim currently on the market | ✓ | ✓ | | |
| Indigo | | | | |
| Lack of information and expertise about growing conditions and yields | ✓ | ✓ | | ✓ |
| Lack of mechanical harvesting equipment | ✓ | ✓ | | ✓ |
| Extraction process – lack of technology and machinery for this process and is a labour-intensive process | ✓ | | ✓ | ✓ |
| Limited commercial application of natural dyes | ✓ | ✓ | ✓ | ✓ |
| Uncertainty of dyeing with natural indigo – methods and colour fastness | ✓ | | ✓ | |

### *3.2.2 Estimated Yields*

#### *3.2.2.1 Flax*

The average flax fibre yield is 6 tonnes/ha (Gomez-Campos et al., 2021; Embrin, n.d.; FAO, n.d.; Turunen and van der Werf, 2006; CELC, 2022). The yield data are variable, ranging from 1.5-7.5 tonnes/ha from both academic-based and market-based secondary data sources, prompting uncertainty for economic feasibility. Further detail of this data is shown in Appendix 1.

Only a small proportion of the original weight of harvested flax remains in the final textile product. In the initial scutching process, the fibres are separated from the remaining co-products. The yields of long line fibre and other materials from the original flax plant vary with source, with the average of these are detailed in Table 3.4 (with further information in Appendix 2). The mean suggests long line fibre is less than 20% the original weight.

*Table 3.4: Mean of data sources for the yields of fibre and co-products (Gomez-Campos et al, 2021; CELC, 2022; Embrin, n.d; Turunen and van der Werf, 2006.; pers comms. with industry experts).*

| | Percentage outcome after scutching (%) |
|---|---|
| Long fibre | 19 |
| Tow (short fibre) | 14 |
| Shives | 45 |
| Seed | 9 |
| Other | 13 |

The relevant literature often accounts for the input versus output weight of flax or fibre in a particular step. For the purpose of this study, the ratio of 'stems: sliver: yarn: fabric' is from Gomez-Campos et al. (2021) as it provides a comprehensive estimate of harvested flax to fabric. This is shown in Table 3.5.

*Table 3.5: Ratio of flax stems: sliver: yarn: fabric (Gomez-Campos et al., 2021).*

| | Weight compared to original of pulled flax (%) |
|---|---|
| Flax sliver | 14 |
| Flax yarn | 13 |
| Technical textile | 12 |

The spinning and weaving efficiency are both described to be between 92-97% (Gomez-Campos et al., 2021; Turunen and van der Werf, 2006; Eynde et al., 2015; Ecoinvent, 2016). Turunen and van der Werf (2006) estimated the flax yarn could be 8.5% of the original weight of harvested flax, slightly lower than the 13% found in Gomez-Campos et al. (2021). This is likely because the loss of weight during the retting stages is nearly double in the Turunen and van der Werf (2006) study, along with other processing differences.

Estimated calculations using data from Gomez-Campos et al. (2021) and information from the 'Homegrown/Homespun' team, indicated 7kg raw flax is required per average pair of jeans (table 4.5). Understanding the input-output relationship is useful to estimate the required quantities of flax for the desired number of garments and may provide further insight into the potential market price for garments, in this case, for a pair of jeans. The average yield per ha (6 tonnes/ha) is estimated to produce nearly 800kg yarn using long-line fibre, over 1500m$^2$ denim fabric, and potentially over 960 pairs of jeans.

### *3.2.2.2 Indigo*

As both woad (*Isatis Tinctoria)* and Japanese indigo (*Polygonum Tinctoria*) are being trialled for their indigo in the 2022 stage of the 'Homegrown/Homespun' project, the yields of these were compared. Figure 3.3 presents the findings of this from secondary data analysis.

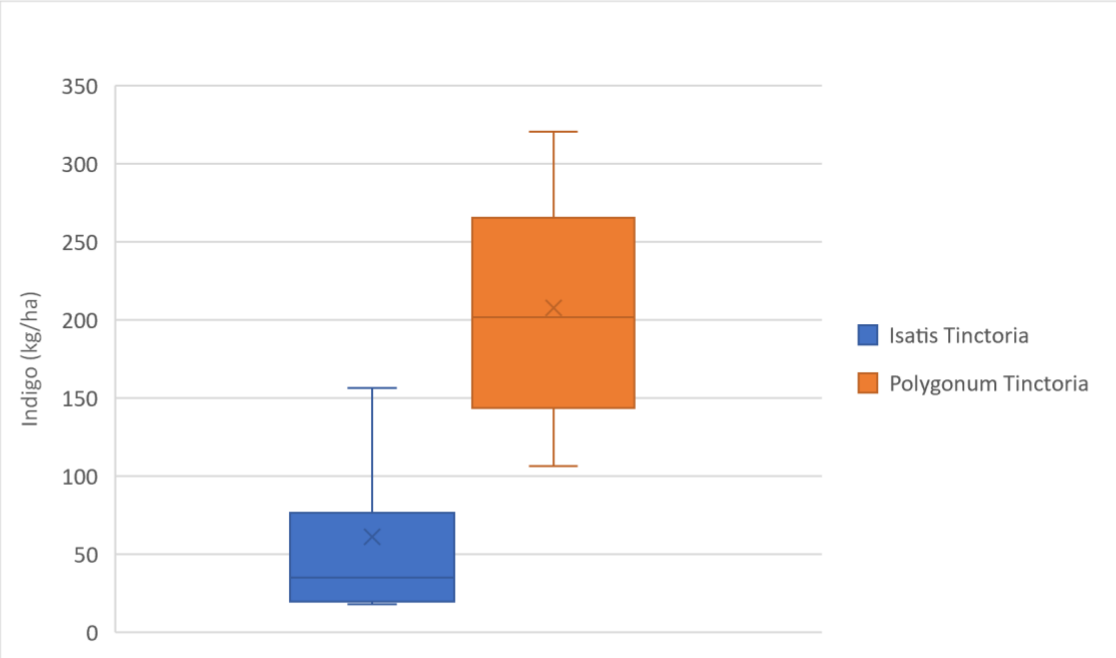



*Figure 3.3: Indigo yields (in kg/ha) comparing woad (Isatis tinctoria) and Japanese indigo (Polygonum tinctoria) (Angelini et al., 2004; Hartl and Vogl, 2008; Vetter et al., 1999 cited in Hartl and Vogl, 2008; Biertumpfel and Vetter, 1999 cited in Hartl and Vogl, 2008; Angelini and Bertolacci, 2008; Sales et al., 2006; Maule et al., 2000). Further information in Appendix 3).*

The indigo yields of *Polygonum tinctoria* are considerably greater than, if not nearly triple, the potential indigo yield than *Isatis tinctoria*. It has been described in the literature that *Polygonum* has similar leaf yields to *Isatis* but can yield three to five times the indigo content (John and Angelini, 2009). Therefore, *Polygonum tinctoria* reduces land use, and potentially input costs. The secondary data for *Polygonum tinctoria* is specific to trials where it has been grown in temperate conditions, as it is native to a tropical climate. However, these are located in Italy and Spain, with no available data about outdoor growing in the UK.

In the current stage of the 'Homegrown/Homespun' project, *Polygonum tinctoria* is being grown in greenhouses in raised beds. The viability of outdoor grown Japanese indigo (*Polygonum tinctoria)* is highly uncertain, and further trials and experimentation are required here before any conclusions or recommendations can be made. From the 2021 woad field trials, in 2022 it was surprising for the team to observe the transplanted *Isatis tinctoria* survive and exceed expectations for growth compared to the seed drilled wood. This is an example of how experimentation on an appropriate scale facilitates viability trials and challenge existing conventional methods.

A comparison between the cultivation, potential challenges and yields of woad (*Isatis tinctoria)* and Japanese indigo (*Polygonum tinctoria)* is displayed in Table 3.6, drawing on relevant literature.

*Table 3.6: Comparing cultivation of wood (Isatis tinctoria) and Japanese indigo (Polygonum tincotira) (John and Angelini, 2009; Maule et al., 2004; John, 2009; Gilbert et al., 2008; Howard, 2019; Samata et al., 2018).*

| ***Woad*** <br> ***Isatis Tinctoria*** | ***Japanese Indigo*** <br> ***Polygonum Tinctoria*** | **Both** |
|---|---|---|
| Native to Europe and the UK – known to grow in a temperate climate. <br> Two indigo precursors are present, indican and isatan B – isatan B is an unstable compound. <br> For larger scale growing, herbicides have been deemed the only cost-effective option. <br> Can be grown as a biennial – left in the ground in the autumn after leaf harvesting, to flower next Spring and collect seed, avoiding the need for a cover crop. | Higher indigo content compared to Isatis. <br> One indigo precursor is present in the leaves, indican. <br> Germination requires a warm, moist soil, and is frost sensitive. <br> Relatively fast growing so may need less weed control. <br> May require irrigation in a temperate climate. <br> Is monocarpic – dies after flowering. <br> Not considered a risk to become an invasive species. | Requires high levels of nitrogen for maximum leaf yields. <br> Modified spinach harvester or modified bean harvester considered an option for mechanized harvest. <br> Narrow planting may outcompete weeds & make harvest more efficient but may reduce yield. <br> Higher purity indigo if leaves are rinsed before extraction. <br> Requires near-immediate extraction after harvest (could be stored temporarily below 5°C). |

To produce denim, the warp yarn would be dyed blue. The estimated land requirements for growing both Japanese indigo (*Polygonum tinctoria)* and woad (*Isatis tinctoria)* are presented in Table 3.7.

*Table 3.7: Estimated area of indigo cultivation to meet yarn requirement.*

| *For 100kg yarn* | |
|---|---|
| **Indigo powder (for reference)** | 3kg |
| **Cultivated area of Japanese indigo** | Approximately 140 square meters (0.03 acres)<br>10% margin for loss – 160 square meters (0.04 acres) |
| **Cultivated area of woad** | Approximately 500 square meters (0.12 acres)<br>10% margin for loss – 550 square meters (0.13 acres) |

For 500 pairs of jeans, it's estimated 3.4 tonnes of raw flax would be required, producing around 416kg yarn, 208kg for dyeing (table 3.5). The land required to dye this ~200kg yarn using either Japanese indigo (*Polygonum tincotoria)* or woad (*Isatis tinctoria)* is relatively small, between 0.1-0.25 acres, depending on the species, cultivation methods, interrow spacing, and efficiency of weed control (table 3.6 and 3.7).

In 2022, the 'Homegrown/Homespun' project has collaborated with a local dyer to produce successful trials of applying natural indigo paste to yarn. This is a crucial step forward for the project, providing an avenue to colour the warp yarn for the proposed pairs of jeans.

### *3.2.3 Research Analysis for Upscale*

Due to the limited opportunities for a UK flax supply chain, the potential options for commercial processing were explored by the 'Homegrown/Homespun' team. Table 3.8 presents the options explored in the Autumn 2021-Summer 2022 period, identified through observation and engagement in these discussions, as well as quantifying the associated costs with each route. Further efforts were made to communicate with facilities via the European Confederation of Flax and Hemp (CELC), 2022 handbook, but unfortunately there was little success in gaining a response.

*Table 3.8: Exploration of options for upscale.*

| Name | Available facilities/ stages | Cost | Notes |
|---|---|---|---|
| Mallon Ireland, Northern Ireland | Retting ✓<br>Scutching ✓<br>Hackling ✓<br>Roving X | >£1000 for 200kg retting, scutching & transport (would be £5500-£6000 per tonne but limited room for upscale due to processing scale). | The largest cost would be transport & customs.<br>Higher risk & uncertainty - has not been applied to commercial scale.<br>Roving has not yet been restored and needs further investment. |
| Facility through the CELC, Europe | Retting ✓<br>Scutching ✓<br>Hackling ✓<br>Roving ? | ~£2000-£3000 per tonne, scutching (higher cost) & transport (retting & hackling costs unknown at present).<br>Current partnership would be R&D so unknown for scale. | The largest cost would be transport & customs.<br>As long-term experts, they offer flax expertise in processing stages with many available options. |
| Kit from Taproot, Canada | Scutching ✓<br>Hackling ✓<br>Roving X | Cost of kit + installation ~£100,000-£150,000<br>Running costs per tonne estimated £2500-£3000 to include electricity (£172.14/MWh (Ofgem, n.d.) and one employee (with renting warehouse space, could be £6000 per tonne but would need to be in constant use to make warehouse cost a worthwhile investment).<br>Capacity of 6.5-7kg/hour.<br>Cost margin would be >100 tonnes processed based on value of co-products – would take over a year to process and is not economically feasible at commercial scale. | Large initial investment.<br>Flax would need prior retting.<br>Kit would need installation, rented space, running costs.<br>Weight could be reduced by around 70% before transporting to further processing facilities, reducing transport costs. |
| Second-hand commercial kit from Europe | Scutching ✓<br>Hackling X<br>Roving X | Cost of kit £150,000<br>Larger capacity than Taproot (2-3 tonnes/hour). Running costs not explored due to high cost and beyond current scale for 'Homegrown/Homespun'. | Large initial investment.<br>Would need installation, rented space, running costs.<br>Flax would need prior retting.<br>Flax would need further processing in Europe (cheaper transport now weight is lower). |
| Harrison Spinks, UK | n/a | n/a | Briefly explored by the 'Homegrown/Homespun' team, but this was a very different processing set up to what was required for the fibre extraction for 'Homegrown/Homespun'. |

From this observation and costing calculations presented in table 3.8, the only immediate economically viable option is processing the flax with a facility in Europe, due to their available facilities and estimated costs. Options like processing at Mallon or purchasing second-hand kit could come at a later date once the processing kit is up and running or a larger scale is reached. The main conclusion from this analysis, is that Taproot's mid-scale kit would not be viable at commercial scale and is more suited to artisan natural textile artists. Further discussion and option for collaboration for a flax processing option are continually being explored, with opportunity to overcome existing barriers or find a more ideal, cost-effective solution.

The benefit to retting and scutching within the UK, or within a closer distance to Blackburn/sites of flax cultivation, is that the cost of transportation for further processing (producing roving and spinning into yarn) is reduced. Around 11% of the original weight of harvested flax is lost during retting, and a further 64-72% of the weight of the retted flax is lost during the scutching process. Essentially, by having those initial stages located closer to cultivation, the transportation costs could be reduced by three quarters for further processing.

The UK does not currently offer flax spinning facilities at commercial scale, prompting research analysis into those in Europe. The CELC (2022) directory was a starting point for locating and inquiring with spinning facilities in Europe. As with previous experience with the scutching, there was a limited response, potentially due to the research approach taken in these email enquiries or the limited room for collaboration outside existing partnerships or supply chains.

Through literature research and conversations with industry experts, there may be potential for either dry spinning similar to cotton to produce a highly overspun yarn, or through potential for 'cottonisation' of flax, where the fibres are chopped into shorter lengths to allow spinning like cotton (Kozlowski et al., 2020; Brigitte Kaltenbacher, 2022, pers. Comms., 25th May). As there are existing smaller-scale mills in the UK for wool and one for cotton, this avenue could be explored further. There is also further research and interest in spinning of the tow fibres for textiles, which could achieve this overspun yarn and would be of shorter length. Tow utilisation would increase the efficiency of flax cultivation but using a greater proportion of the co-products and reducing land requirements for yarn requirements. While contact with these facilities was not attempted, online research suggests an interest for this industry and potential for further investigation by the industry partner or researchers in the future. The options are detailed in Table 3.9.

*Table 3.9: Outcomes of spinning market research.*

| | |
|---|---|
| **Wet Spinning, Europe** | Safilin, Poland & France<br>NatUp, La French Filature, France<br>Linificio, Italy<br>Others located through the CELC (2022) directory:<br>Siulus, Italy<br>Lafil, Italy<br>Lambrecht, Belgium |
| **Dry Spinning / 'Cottonisation'** | Flax Ghekiere, Belgium – main activity is scutching flax tow spinning mills.<br>Annual capacity = 1500 tonnes.<br>Castellins, Belgium<br>English Fine Cottons, UK – the only commercial cotton spinner in the UK. |

The wet spinning options in Europe are increasing, with NatUp and the French branch of Safilin both opening in 2022 (Safilin, n.d; Phillippot, 2022; NatUp Fibres, 2022). The evidence of interest in restarting the flax spinning industry in France shows the gaining traction of flax and the re-localisation of linen production. This prompts the potential for reviving the UK flax industry, both with the availability of processing and spinning just over the English Channel and the inferred market demand.

In the example of a Lindsey-Woolsey blend in a UK micro-mill, the price per meter for labour between £20-50 for an 180cm in-loom width (Brigitte Kaltenbacher, 2022, pers. Comms., 25th May). As has been informed by the 'Homegrown/Homespun' team, there are available options for weaving in the UK.

Furthermore, exploration of linseed as a dual-purpose crop, for both seed and fibre, could utilise what is considered a by-product of linseed cultivation that is a wide-scale industry in the UK and would reduce overall agricultural carbon emissions. Khan et al. (2021) investigated the fibre length and tensile properties, concluding linseed flax fibres with similar tensile strengths and elasticity to hemp and nettle fibres and sufficient for spinning into yarn. They further shed light on the existing linseed and hemp stem harvest and processing devices, hammer mills, which break the woody stem to separate shive from fibre. This reduces the fibres viable mechanical properties, providing difficulty to imagine the seed and fibre in a co-existing supply chain without an overhaul and re-imagined supply chain. When linseed is harvested using a pulling machine and processed similarly to flax, the fibre quality is viable for yarn (Rennebaum et al., 2002). Therefore, if linseed was harvested similarly to flax, the fibre may be viable, although slightly shorter in length.

### *3.2.4 Impact of Brexit*

The withdrawal of the UK from the EU has changed the economic relationship and opportunity for business between the UK and EU. With the UK no longer a member of the EU Single Market and Customs Union, instead the Trade and Cooperation Agreement outlines the requirements of businesses to comply with new customs procedures (GOV, 2021). Predicted by the research analysis for processing flax (Table 3.8), sending this to France or Northern Ireland for processing, and potentially spinning either in France or elsewhere in the EU, would require export from the UK. This requires declaration of the flax, complying with the necessary import and export regulations.

As sending the flax from the UK to France is currently the most feasible option for processing into spinnable fibres or yarn, these export requirements have been outlined in Table 3.10.

*Table 3.10: Exporting flax to France (GOV, n.d.; GOV, 2022a.; GOV; 2022b).*

| | |
|---|---|
| *Tariff code* | 53.01.10 (flax, raw or retted) |
| *Required documents for tariff code* | Common health entry document for plants and plant products – phytosanitary certificate. |
| *Any goods moving into France* | Economic Operators Registration and Identification number (EORI number)<br>Customs documentation:<br>▪ Entry summary declaration<br>▪ Single administrative document<br>▪ Declaration of dutiable value<br>▪ Commercial invoice<br>▪ Packing list<br>▪ Certificate of non-preferential origin<br>▪ Proof of preferential origin<br>▪ Air waybill/rail waybill/waybill<br>▪ Bill of lading<br>▪ Economic operator registration and identification |

| | |
|---|---|
| *Other requirements* | Standard international goods vehicle operator licence to transport goods (potentially inclusive if a courier was arranged). |
| *Considerations to costs* | Phytosanitary certificate (potentially) - £200-300<br>Goods vehicle operator licence between £700-£1,100 + "continuation fee" every 5 years.<br>Paying for a 'customs clearance agency' - ensure correct paperwork. |

From this analysis, operationalising and scaling up of this supply chain would require further effort to ensure phytosanitary certificates and customs documentation meet the requirements. This can be categorised as a barrier in the potential for upscale, and something that would require strategic planning.

Since having done this research, a response was received from the government plant health and seed inspector from their export advisory panel, detailing that dried flax does not fall under the list of commodities that require a phytosanitary certificate to enter the EU. This would lessen the cost and required planning for preparation for export.

### *3.2.5 Cost-Benefit Analysis*

The largest initial investment costs would be for flax-specific commercial-scale cultivation equipment, as this is not currently available contractually within the UK due to the lack of an existing flax fibre industry. Informed by market research and liaising with an agricultural consultant via my industry partner, these are detailed within Table 3.11. While an interrow cultivator is not flax-specific, only a minority of UK farmers opt for mechanical weed control, as opposed to chemically via pesticides, prompting a high likelihood this would require purchase.

*Table 3.11: Machinery investment costs.*

| **Kit** | **Cost (£)** | **Source** | **Break-Even Point (ha) compared to value of flax straw** (estimated at £202/tonne) |
|---|---|---|---|
| Interrow Cultivator (Tractor Towed) | 2,700 | Small Holder Equipment | 2 |
| Flax Puller | 200,000 | Agri-consultant, pers. comms. | 165 |
| Flax Baler (Self-Propelled) | 120,000 | Agri-consultant, pers. comms. | 100 |

Second-hand machinery could be tens of thousands of pounds cheaper, as observed from the Agriaffaires website (Agriaffaires, n.d.). However, through communication with the agri-consultant who provided the investment costs for the kit detailed in Table 3.11, the degree of economic risk massively increases when purchasing second-hand equipment. The chances of requiring specialist mechanics if a part or mechanism were to fail are much higher, which in the context of a crop requiring immediate harvest, requiring a mechanic, potentially from Europe, could risk the entire crop.

Mechanisation of the sowing, weeding, and harvest is crucial for the economic feasibility, reliability and realistic for the commercial cultivation of flax and woad. While no data exists for *Isatis tinctoria* (woad), the labour hours associated with flax cultivation comparing manual and mechanised processes are listed in table 3.12, with data provided by Allam (2008) cited in Kozlowski et al., (2020). To put these figures into perspective, when considering the labour costs of manual cultivation, at a living wage of £9.50/hour, this would amount to >£2,000/ha (GOV, n.d.).

In consideration to the scale of cultivation to make investment in machinery (detailed in Table 3.11) worthwhile, the break-even point is >100 hectares cultivated. For an individual business, this is large-scale growing. There is further scope for collaborative approaches towards the investment costs of this machinery, with the increased flax growing in the UK potentially opening up an avenue for shared use, for the flax harvester and baler especially.

*Table 3.12: Comparison of manual and mechanical labour hours associated with flax cultivation (Allam, 2008 cited in Kozlowski et al., 2020).*

| | **Time (hours)** | |
|---|---|---|
| | *Manual* | *Mechanical* |
| *Sowing of seeds* | 4 | 0.75 |
| *Weed control* | 100 | n/a |
| *Harvest* | 140 | 2 |
| **Total** | **244** | **<10 (estimate)** |

Assuming this kit has been purchased, the 'running' cost of cultivating flax was estimated to determine its economic feasibility as a regeneratively grown crop. The profitability will be underpinned by the yield, which is highly uncertain and may be lower using regenerative principles (Su et al., 2021). Flax product value is listed in table 3.13, informed by an agri-consultant and yield literature in table 3.4.

*Table 3.13: Market-value of flax and its co-products.*

| **Element of Flax Fibre** | **£/tonne** | **t/ha** (average across data sources in Appendix 1 and 2) | **Estimated £/ha** |
|---|---|---|---|
| *Long strand* | 480 | 1.14 | 550 |
| *Tow* | 240 | 0.84 | 200 |
| *Shives* | 60 | 2.70 | 160 |
| *Seed* | 350 | 0.54 | 190 |
| *Straw* | 60 | 0.78 | 50 |
| *Total – Raw Flax Straw* | 202 | 6 | 1200 |

The input costs are further listed in table 3.14, detailing the requirements for flax cultivation. This has been assumed for a tank retting scenario, as further machinery, diesel and labour are required for turning during retting.

*Table 3.14: Flax input costs (£/ha).*

| | **Cost (per ha)** | **Description** |
|---|---|---|
| *Seed* | £335 | £2.80/kg (Agri-consultant, pers. comms.)<br>120kg/ha (pers comms.) |
| *Seed drill* | £70 | NAAC (2021) |
| *Tractor hire (interrow cultivator)* | £220 | Assume 4 hours (£55/hour) (NAAC, 2021) |
| *Interrow cultivator – running* | £50 | 10 litres at £1.15 (Grisso et al., 2010; Farmers Weekly, n.d.)<br>Estimated 4 hours of labour at £9.50/hour (GOV, n.d.) |
| *Pulling - running* | £30 | 10 litres at £1.15 (Grisso et al., 2010; Farmers Weekly, n.d.)<br>2 hours of labour at £9.50/hour (Allam, 2008 cited in Kozlowski et al., 2020); (GOV, n.d.) |
| *Baling - running* | £65 | 6 litres at £1.15 (Grisso et al., 2010; Farmers Weekly, n.d.)<br>Assume 6 hours of labour at £9.50/hour (GOV, n.d.) |
| *Cover crop* | £50 | Average from Farm Seeds (n.d.) |
| *Rolling* | £30 | NAAC (2021) |
| *Regenerative cultivation* | ~£850 | |
| *Rotavating* | + £75 | NAAC (2021) |
| ***Total Input + 20% buffer*** | **£990-1050** | |

With the value of flax estimated at £202/tonne, the total value of the regenerative yield/ha is £1212 if the average of 6 tonnes/ha is harvested, predicting opportunity for profit. The minimum yield to meet the input costs is 4.2 tonnes/ha. Due to the NAAC (2021) lower petrol rates (50p/litre red diesel) and general uncertainty, a 20% buffer was added, suggesting flax cultivation as economically viable. With the additional buffer increasing input cost, the minimum yield to break-even would be 6 tonnes, demonstrating the influence of input costs and yields on the economically viability of flax cultivation. Furthermore, for 'Homegrown/Homespun' at present, with flax growing over many, smaller, sites, the input costs are likely higher to include transportation and differ from the uniformity of larger agriculture cultivation.

In the case of natural indigo, Table 3.15 is in the context of *Isatis tinctoria* (woad), considering the uncertainty of outdoor cultivation for *Polgyonum tinctoria* (Japanese indigo) and the unfeasibility of using commercial-sized greenhouses due to high costs. The largest barrier to commercial scale cultivation, in terms of machinery, is the lack of harvesting equipment. Previous studies have used a modified spinach harvester and modified bean harvester (John and Angelini, 2009). Attempting to quantify the costs of this kit was not feasible due to uncertainty.

*Table 3.15: Woad cultivation costs (£/ha).*

| | **Cost (per ha)** | **Description** |
|---|---|---|
| *Seed* | ? | * ~£55 per 100g – sowing at 8.5kg/ha, >£4500/ha if commercial scale seed is unavailable for purchase. (Detail in Appendix 4).<br>'Homegrown/Homespun' quoted £100/kg (£850/ha).<br>Other option to use second year woad gone to seed. |
| *Seed drill* | £70 | NAAC (2021) |
| *Tractor for (interrow cultivator)* | £220 | Assume 4 hours (£55/hour) (NAAC, 2021) |
| *Interrow cultivator – running* | £43.25 | 10 litres at £1.15 (Grisso et al., 2010; Farmers Weekly, n.d.)<br>Estimated at 4 hours of labour at £9.50/hour (GOV, n.d.) |
| *Harvest - running* | ? | |
| *Cover crop* | £52 | Average from Farm Seeds (n.d.) |
| *Rolling* | £30 | NAAC (2021) |
| ***Regenerative cultivation*** | **Without seed & harvest ~£385.25** | |
| *Rotavating* | + £75 | NAAC (2021) |

With large data gaps for woad cultivation for natural indigo, it is unfeasible to determine its economic viability, and more specifically the required yields for cultivation to be profitable. The largest challenge with natural indigo, informed by tables 3.6 and 3.15, is the lack of scientific and technical knowledge into the cultivation. Further supported by findings from Samanta et al. (2018), this knowledge gap of cultivation is deepened by lack of technical knowledge for harvesting, extraction techniques, colour fastness and impacts on the colour. This produces high economic uncertainty, and as is concluded in Samanta et al. (2018), even if technological barriers are overcome, higher input costs mean natural dyes are predicted to only remain viable as a luxury product to serve a niche market.

Indigo extraction from the leaves and application of natural indigo to yarn are methodologically uncertain, therefore, costs were unable to be quantified.

Regenerative (or organic for the purpose of literature analysis) agriculture may not have the costs associated with tillage (see tables 3.14 and 3.15). The lack of scientific definition of regenerative agriculture (Fenster et al., 2021), instead underpinned by two central principles to reduce disturbance and increase biodiversity, results in flexibility within regenerative systems for low or infrequent tillage. As has been informed by industry experts and literature, regenerative agriculture creates a higher risk of a lower yield, potentially reducing the profitability of the enterprise (Su et al., 2021; pers. comms.). However, to briefly return to the sustainable principles of this project, there is more to this proposed business model than economic profitability.

The remainder of the supply chain, processing and manufacture, has not been investigated due to lack of information or inability to quantify current costs.

## 3.3 Conclusions

The findings from the economic feasibility study highlight the uncertainty for a flax and natural indigo to exist at commercial scale, prompted by yield uncertainty, lack of infrastructure, and therefore, the high investment costs associated with initial supply chain set-up. The current limitations lie with the missing flax processing infrastructure in the UK and the lack of natural indigo extraction facilities at scale. The market research explored the available flax processing options, with these likely involving partnerships with facilities outside the UK. Brexit has produced further complication, requiring compliance with customs regulations and import processes to send the crop outside the UK. The findings further align with the technological and economic barriers highlighted most strongly by Stewart et al. (2016) and Todeschini et al. (2017).

Natural indigo has even less supporting literature, urgently requiring further research and development. However, as the infrastructure requirements, predominantly large tanks and aeration set-up, this would not have to leave the UK, likely more feasible to exist at scale compared to flax at this current moment. For both flax and natural indigo, further research and trials is needed, and potential for collaboration to support the overcoming of current barriers.

## 3.4 Recommendations

Regenerative agriculture may reduce yields and increase cultivation costs and land usage. Exploring avenues for manual weed control would be vital, otherwise risking the crop or prompting high economic cost of labour. In sections 3.4.1 and 3.4.2, bullet points provide a comprehensive summary of recommendations.

### 3.4.1 Flax

- The minimum flax yield to meet the input running costs is 4.2 tonnes/ha.
- The flax puller is the most crucial piece of flax cultivation equipment, but the scale of production must be over 150 hectares for this to be economical, and depending on the scale of production, the break-even point could be reached sooner or later. There is further room for a collaborative endeavour to make this economical at a smaller scale.

- Most economical route at the time of writing is flax processing in France, considering processing in Northern Ireland at a future date or setting up a UK-based collaborative mill.
- Brexit has produced further challenge in getting the flax processed and spun, and there are higher costs associated with collaborating with existing EU facilities in terms of the customs regulations and transportation.
- At a later date, it appears economically reasonable to re-localise retting and scutching in relation to the weight of harvested flax, subsequently reducing transportation costs for spinning later in the supply chain.
- Spinning requires further exploration, with multiple suggested avenues for feasibility.

### *3.4.2 Natural Indigo*

- High uncertainty for economic feasibility of natural indigo, with further trials necessary. Experimenting with comparing indigo yields of woad (*Isatis tinctoria)* and Japanese indigo (*Polygonum tinctoria)*, seed availability, and growing Japanese indigo outdoors could provide further direction. If seed is not available at a more reasonable rate, or saved seed is unavailable, this would be one of the most significant economic barriers to upscale.
- Harvesting at scale proves a further barrier, as indigo is rarely cultivated at commercial scale. The literature suggests a modified spinach harvester or bean harvester could prove effective. Further collaboration and expertise would be required.
- Despite greater uncertainty, natural indigo appears more feasible than flax due to the fewer steps involved and not having to transport this outside of the UK for application to yarn.

# *Chapter Four: Environmental*

## *4.1 Methodology*

With sustainability and environmentally friendly practices some of the key principles of the current 'Homegrown/Homespun' framework, assessing and quantifying the environmental impact of an upscaled supply chain attempted to inform a low-carbon and sustainable transition. It also provided a comparison of flax to other fibres, notably cotton which is used to produce denim.

### *4.1.1 LCA Approach*

A Life Cycle Assessment (LCA) approach compiled and quantified the potential carbon emissions of the flax supply chain envisaged for 'Homegrown/Homespun'. An LCA is a framework used to estimate and assess the environmental impacts attributed to the life cycle of a product, often from "cradle-to-grave" (Rebitzer et al., 2004). The approach was informed by informed by ISO 14040 (ISO 14040. 2006, 2020). A system boundary approach, which involves setting the limits of the LCA, beyond which impacts are excluded, was informed by the purpose and goal of the LCA (further detail in 4.1.1.1).

While LCA's often determine multiple impact categories, such as eutrophication, global warming impact and renewable resource depletion, the scope of this study focused exclusively on carbon emissions. Low-carbon upscale was a primary motivator of this research, and the LCA informed a broader regard to triple-bottom line sustainability, prompting this focus on carbon emissions.

The LCA modelling approach in this study could be defined as 'consequential', considering how the flows (materials, energy and substances) involved in the life cycle of this system boundary may differ in response to possible decisions made (Ekvall et al., 2016; Finnveden et al., 2009 in Ekvall et al., 2016). This approach was most appropriate when considering the potential for upscale of the supply chain, as it facilitated understanding of the carbon consequences of decision-making at each stage.

Data were extracted, simulated and compared from existing academic and grey literature, and lifecycle inventory database Ecoinvent v3.8. Key word searches, using Google Scholar and OneSearch, and use of the snowball method, identified relevant literature. These key words included 'flax LCA', 'denim LCA', energy consumption of textiles', 'GHG emissions of textiles', 'spinning', 'weaving', 'flax processing', 'carbon emissions', 'GHG impact'. The data are predominantly specific to flax. In the manufacturing stages (spinning, weaving and garment assembly), there was a considerable lack of flax-specific data and uncertainty due to the high variability in energy inputs to these stages. Therefore, cotton, jute, and hemp data were included alongside flax data to increase the breadth and suggest a margin for uncertainty. As cotton, jute and hemp are other examples of natural plant fibres that have been considerably explored in the literature, with hemp and jute also categorised as bast fibres like flax, these were considered the next closest available data sources (Sadrmanesh and Chen, 2018). Currently, there is limited linen denim known to be available on the commercial market, prompting uncertainty for the energy requirements to weave flax to a denim pattern, and whether this will differ vastly from cotton.

#### *4.1.1.1 Goal & System Boundary*

This study set out to identify the overall carbon impact of a flax supply chain, noting the largest contributors to potential carbon emissions. The LCA followed a system boundary approach, encompassing all stages of flax fibre cultivation, processing and manufacture into woven textile. For illustrative purposes, carbon emissions were estimated for fabric requirements per pair of jeans, but this excluded additional components such as zips, thread and rivets.

The consequential modelling approach, which encompassed scenario-simulations of a potential supply chain, provided comparison of CO2 emissions from different methods and geographical contexts. This provided a comparison of conventional and regenerative flax cultivation, different retting techniques, carbon intensity of situating stages in different countries, and methods and distances of transportation.

The LCA findings allowed comparison to the carbon emissions of current textile fibres on the market and identified opportunities to improve environmental performance across the supply chain. There is further opportunity to inform the decision-makers in the upscale of flax production and potential declaration of eco credentials.

Existing LCA studies for flax textiles are limited, and there are currently no published LCA studies relating to the regenerative cultivation of flax for textiles. The study primarily aims to provide a picture of the associated carbon emissions of an upscaled supply chain and can inform future LCA studies.

#### *4.1.1.2 Functional Unit*

The functional unit is kg CO2 per unit. The defined unit is variable throughout the LCA; 1 ha cultivated flax, 1 tonne retted flax, and per pairs of jeans per 1 tonne retted flax, to best reflect each stage. The yields of flax per ha are variable, so could not be used to define processing and manufacturing stages.

#### *4.1.1.3 Scope & Exclusions*

The main exclusions are detailed here, with further detail of less impactful exclusions in subsequent sections.

As the purpose of this research is to, in part, investigate the feasibility of upscaling a flax supply chain, there is no existing UK supply chain or current supply chain that involves processing and manufacturing with UK-grown flax. Therefore, the distances of agricultural machinery between flax growing sites, and distances the flax may travel between each processing and manufacturing stage are unknown. Embodied transport emissions have been excluded for this purpose. Illustratively, carbon emissions from transporting one tonne of goods for 100km has been estimated for differing modes of transport. A major source of carbon reduction from relocalised production is not represented in the LCA, and the potential benefits of relocalisation go beyond the scope of this study.

The indirect carbon emissions of facility conditions, such as lighting and temperature control, have further been excluded where possible. This is primarily because of the lack of existing supply chain with available data to use.

Within current commercial textile uses of flax, only the long line fibre, a proportion of the product obtained during scutching, is used. The longer fibres produce finer yarns, well-known to produce the breathable and lightweight linen fabrics on the market (Kozlowski et al., 2020). The short fibres, tow, are often considered a by-product and commonly used to produce coarser yarns for products like rope or made into composites (Kozlowski et al., 2020; Gomez-Campos, 2021). As denim is often woven from over-spun, often coarser yarns, there is a potential and industry insight that the tow could also be utilised for denim fabrics. However, for the purpose of this LCA, there was only consideration for using long line fibre and carbon emissions associated with further processing or use of co-products to long line fibre were excluded.

This LCA excludes the consideration for embodied carbon emissions of synthetic indigo or the growing and extracting of natural indigo. The dyeing phase only relates to the energy and water inputs. This was prompted by both a lack of data and a lack of time to include both this and the other areas of the study.

### *4.1.2 Life Cycle Inventory (LCI)*

#### *4.1.2.1 Overview*

Energy consumption is often the main contributor of greenhouse gas emissions in a garment's supply chain (Cheng and Liang, 2021; Wang et al., 2015). For natural fibres, diesel and fertiliser inputs of cultivation stages of fibres can also be a substantial contributor to carbon emissions, depending on the growing requirements of the fibre and weed control methods (Rana et al., 2015). The LCA study by Gomez-Campos et al. (2021) further informed where the largest contributors to $CO_2$ emissions were in the flax supply chain and formed part of the data used.

The supply chain stages and their inputs to produce denim using flax fibre is detailed in table 4.1. A methodical approach was taken to attempt to first quantify the largest contributors to carbon emissions, notably electricity and agricultural inputs.

Inputs in red font have been excluded from this LCI. This is primarily due to lack of existing data, or, in some cases, lack of information about what is involved in this process specific to the envisaged 'Homegrown/Homespun' supply chain.

*Table 4.1: Flax supply chain and the associated inputs from cultivation to garment.*

| Process | Inputs |
|---|---|
| *Flax Cultivation* | Diesel |
| | Pesticides & Fertilisers (conventional cultivation) |
| *Retting* | Electricity |
| | Water |
| *Scutching* | Electricity |
| *Hackling* | Electricity |
| *Roving* | Electricity |
| *Sizing & Wet Spinning* | Electricity |
| | Water/Steam |
| | Sizing Agent (Starch) |
| *Bleaching* | Electricity |
| | Water |
| | Bleaching Agent (Chemical Input) |
| *Dyeing* | Electricity |
| | Water |
| | Dyestuff (synthetic or natural origin) |
| | Chemicals in pre-treatment |
| *Weaving* | Electricity |
| *Textile Finishing* | Electricity |
| | Water |
| | Chemicals |
| *Garment Assembly* | Electricity |
| | Other Components (Zips, Rivets, Thread) |

A comprehensive description of each stage in the supply chain can be found in tables 3.1 and 3.2. Appendices 5, 6, and 7 provide greater detail of the methodology and supporting data.

### *4.1.2.2 Flax Cultivation*

The consequential modelling approach compared conventional and regenerative flax cultivation. In a temperate climate, flax does not require artificial irrigation, as rainfall is sufficient during the growing season (CELC, 2010). Carbon emissions were calculated per hectare of cultivated flax, a comparable unit that can be scaled to the demands of 'Homegrown/Homespun'.

Data for diesel usage and land inputs was collected from CLEC (2022), Turunen and van der Werf (2007), and Dissanayake et al. (2009). These data sources were selected for their focus on flax cultivation, and occasionally informed by hemp. Notably, to compare conventional and regenerative flax cultivation, these sources provided further breakdown of the contributors to diesel emissions, or in the case of Turunen and van der Werf (2007), a detailed description of the method. Variable land inputs and cultivation approaches prompted the calculation of mean values to provide an estimate of carbon emissions.

Land inputs for the conventional flax cultivation model, provided in kg per ha, are detailed in table 4.2. The associated carbon emissions were then estimated using the Farm Carbon Toolkit, an open-source UK-based online tool providing the embodied greenhouse gas emissions for agricultural activities (Farm Carbon Toolkit, n.d.). The assumptions and exclusions for calculating CO2 emissions of land inputs are detailed in Appendix 5.

*Table 4.2: Land inputs for modelling conventional flax cultivation, provided in kg per ha.*

| Data Source | Inputs per ha (in kg) | |
|---|---|---|
| CELC (2022) | Potassium Sulphate | 70 |
| | Nitrogen Solution | 28 |
| | Triple Superphosphate | 70 |
| | Zinc | 0.46 |
| | Pesticides – cumulative of insecticides, herbicides & fungicides | 0.43 |
| Turunen and van der Werf (2007) | Ammonium Nitrate | 40 |
| | Triple Superphosphate | 30 |
| | Potassium Chloride | 60 |
| | Pesticides | 2.6 |
| | Burnt Lime (CaO) | 333 |

Diesel inputs, provided in litres per ha, are detailed in table 4.3. A mean value was calculated between these values to model a conventional flux cultivation scenario. Turunen and van der Werf (2007) does not provide a numerical breakdown of diesel usage, and the overall diesel usage includes turning the crop. However, as this value sits between the diesel consumption of the other data sources, this provided strong enough reason for it to be included in the calculated mean. As CELC (2022) is the only source of the three to include destruction on an intermediate crop, this value alone was included in the overall estimate.

*Table 4.3: Diesel usage, provided in litres, for estimating carbon emissions of flax cultivation and modelling regenerative and conventional flax cultivation.*

| Data Source | Diesel overall (litres) | Diesel breakdown (litres) | |
|---|---|---|---|
| CELC (2022) | 95 | Destruction of intermediate crop | 13.8 |
| | | Soil preparation (ploughing + rotary harrow) | 26.8 |
| | | Sowing Seed | 12.5 |
| | | Applying fertilisers & pesticides | 9.2 |
| | | Harvesting | 13.9 |
| | | Rolling/Baling | 18.4 |
| Turunen and van der Werf (2007) | 66 | No further breakdown but method is as follows:<br>'The diesel input for soil preparation is the same for both flax and generic hemp. This includes ploughing the field 26-23cm deep, two passes by tractor for fertiliser application, and seedbed harrowed. For flax specifically, the study details pesticide application (two herbicide treatments and an insecticide treatment) and harvest with a pulling machine.'<br>In this example, separation of the seed from the straw is included with turning during dew-retting. No means to subtract turning diesel usage from total. | |
| Dissanayake et al. (2009) | 58 | Tillage, ploughing | 26.1 |
| | | Tillage, harrowing | 1.7 |
| | | Sowing Seed | 4.9 |
| | | Applying fertiliser | 17.4 |
| | | Applying pesticides | 3.9 |
| | | Harvesting | 6.3 |
| | | Baling | 3.9 |

To model regenerative flax cultivation, land inputs are excluded and the LCI did not include use of organic alternatives for soil fertility, or the diesel usage to apply these to the land. There is limited information about regenerative approaches to growing flax, especially at commercial scale, therefore, no data existed to model alternative land inputs. Diesel input data used was similar to the conventionally modelled scenario (table 4.2), with tillage and fertiliser application excluded to account for regenerative practices. Data from Turunen and van der Werf (2007) was excluded as diesel inputs for tillage and fertiliser application were intangible from the remaining diesel inputs. The destruction of the intermediate crop detailed in CELC (2022) is essentially an initial plough of the land. Therefore, in this regenerative model, it was assumed the land would be rolled using agricultural machinery in line with minimum soil disturbance (Defra, 2021). This was estimated with data provided by Ecoinvent (2007).

Diesel inputs were multiplied by the relevant emissions factor (EF) in the UK GOV 2021 Conversion Factors to determine the carbon emissions (Department for Business, Energy & Industrial Strategy, 2021).

This study does not account for carbon losses from the soil that take place during tillage or potential for biogenic carbon storage in the flax fibre.

#### *4.1.2.3 Retting*

The first stage after harvesting is retting, or degumming, in which multiple methods have been applied to break down the gums and pectin's to separate the woody core from the fibre using a controlled 'rot' (Kozlowski et al., 2020). These different methods are as follows; dew retting in the field, submerging in water, enzymatic retting using different enzymes, and chemical retting by boiling and applying chemicals (Tahir et al., 2011; Kozlowski et al., 2020). For the scope of this LCI, dew retting and water retting have been modelled, as these are the most widely applied and most economically feasible methods. Further detail of all four methods mentioned are described in further detail in Appendix 6.

##### *4.1.2.3.1 Dew Retting*

In the case of dew retting in the fields, the process is optimised by turning the stems which have been laid out horizontally in the field part-way through the ret process. The inputs here are diesel, with data provided by CELC (2022).

*4.1.2.3.2 Tank Retting*

The method of water retting is more variable and there is limited available information about the detail of these methods. Through available literature and conversations with industry experts, methods can involve different immersion durations, water to stem ratios, variable use of heat, and water circulation. Carbon estimates have been based on the following method described for tank retting hemp in Turunen and van der Werf (2007) - 'immersed in pools with 28°C water with a stem-water mass of 1:14 for five days'. The associated carbon emissions from water usage are calculated using the appropriate conversion factor detailed in the UK GOV 2021 Conversion Factors (Department for Business, Energy & Industrial Strategy, 2021).

Energy to heat the water was calculated using the specific heat capacity of water, $4190J^{-1}kg^{-1}K$ (Jelley, 2017) and the following equation:

$$\varrho = c\mathrm{M}\Delta\mathrm{T}$$

Amount of heat = specific heat * mass * change in temperature

The assumption was made that the initial temperature of the water would be 15°C and that further heating would be required at periodic intervals to maintain the 28°C temperature.

The variation in methods suggested by the literature and from conversing with those in the industry, estimates were modelled for differing situations; using rainwater, mains-fed water, unheated water, different temperatures and lengths of time.

It has been assumed in all estimates that the flax would be left to air dry due to uncertainty of this stage in the process and no published information about the energy requirements to dry retted stems prior to subsequent processing.

*4.1.2.4 Scutching*

Retted stems are mechanically broken to remove the straw from the fibre, which also produces the co-products of shives, tow, and other residues. For this LCI, it has been assumed seeds will be removed as part of the scutching process and not in a previous stage, often known as ripping or threshing when hand processing flax.

Electricity usage is provided by Gomez-Campos et al. (2021), Turunen and van der Werf (2006), and CELC (2022).

#### *4.1.2.5 Hackling*

Scutched fibre is then passed through ever-finer sets of combs to remove the shorter fibres (tow) from the long line fibre, producing flax sliver. Electricity usage is provided by Gomez-Campos et al. (2021) and Turunen and van der Werf (2006).

#### *4.1.2.6 Roving*

In preparation for spinning, the flax sliver is placed on a belt to produce a continuous line of sliver and an initial twist is inserted. Data was sourced from Eynde et al. (2015) and Turunen and van der Werf (2006).

#### *4.1.2.7 Sizing, Spinning & Winding*

While flax can be spun both dry and wet, this LCI assumes the flax will be wet spun into yarn. As flax fibre increases in tensile strength when wet, it is often preferred to prevent the fibre from breaking during spinning (Kozlowki et al., 2020). Starch is used as a sizing agent in both Gomez-Campos et al. (2020) and Eynde et al. (2015). Turunen and van der Werf (2006) do not include this as an input.

In wet spinning, steam or warm water is applied to the roving, which often uses larger quantities of energy to heat and apply water when compared to dry spinning. A mean is calculated from energy and water usage detailed in Gomez-Campos et al. (2021), Turunen and van der Werf (2006), and Eynde et al. (2015).

#### *4.1.2.8 Bleaching & Dyeing*

The linen fibres are naturally a grey colour, which is often bleached to achieve a brighter whiteness. There is limited information about the detailed inputs for bleaching or dyeing in textiles, especially in the case of linen yarns. In a few cases where data is available, inputs for bleaching and dyeing yarn are intangible, which removes the opportunity to consequentially model the carbon emissions of bleached versus unbleached, and synthetic versus natural dyestuff. Furthermore, this intangibility is not applicable in the case of denim textiles, where only the warp yarn is dyed.

*4.1.2.8.1 Bleaching*

Data sourced for estimating the emissions for bleaching apply to bleaching of roving, yarn, and fabric to account for lack of data specific to yarn and includes data for jute and cotton due to lack of linen-specific information. Data is sourced from Alam (2018), Eynde et al. (2015), Turunen and van der Werf (2006), and EcoInvent (2017).

In the cases of Alam (2018), the same method detailed in the retting stage (2.c.ii) was used to estimate the energy requirements to heat the water, using the specific heat capacity and assumption of 15C start temperature. Carbon emissions from water usage are calculated the appropriate conversion factor detailed in the UK GOV 2021 Conversion Factors (Department for Business, Energy & Industrial Strategy, 2021).

The material efficiency of input to output ratio ranges from 7-25% for bleaching, which is further influenced by what stage bleaching takes place during manufacturing, with the greatest loss shown with bleaching of roving (Eynde et al., 2015; Alam, 2018; Turunen and van der Werf, 2006). In the case of this LCI, it has been assumed the energy and water inputs detailed by each data source can be applied to the assumption for bleaching at yarn stage. While this increases margin for error, it accounts for the heterogeneity of bleaching methods and uncertainty of the associated carbon emissions.

There is also potential for the yarn to remain unbleached and still produce a viable quality yarn, providing reason to assume there is a scenario for the bleaching stage to be excluded. This is anticipated to impact colour fastness qualities of the yarn, but the impact this may have on carbon emissions of yarn dyeing goes beyond the scope of this LCI (Alam, 2018).

*4.1.2.8.2 Dyeing*

The warp yarn was then assumed to be dyed with indigo dyestuff.

There is a lack of data relating to the detailed inputs of synthetic indigo vat dyeing, despite the prevalence of denim and jeans LCA in the literature. As a proxy based on available information, vertically integrated mill data from Ecoinvent (2016) for batch dyeing cotton was used to estimate potential carbon emissions from dyeing. This data details energy, water and chemical inputs for pre-treatment, drying between stages, and dying itself. Due to the scope of this LCI, chemical inputs were excluded.

The pre-treatment stages here are similar to that of bleaching the fibres (section 4.1.2.8.1), but due to limited data, it is assumed the warp yarn will undergo a second pre-treatment. Carbon emissions from water usage are calculated the appropriate conversion factor detailed in the UK GOV 2021 Conversion Factors (Department for Business, Energy & Industrial Strategy, 2021).

To calculate the carbon emissions of steam, the energy required to produce steam was estimated using the latent heat of vaporisation of water - 2257kJ/kg - in the following equation (Kleinsteuer, 2018).

$$\varrho = \mathrm{M} \times \Delta\mathrm{H}v$$

Evaporation energy = specific evaporation enthalpy * mass of water

It was assumed the start temperature of the water would be 15C and there was 100% efficiency in the production of steam.

'Homegrown/Homespun' is aspiring to use natural dyestuff in their supply chain. Calculating the carbon emissions of the cultivation and extraction of natural indigo dyestuff goes beyond the scope of this LCI, which is partly motivated by the current lack of commercial natural indigo extraction supply chain and, therefore, no definitive method available to estimate carbon emissions.

#### *4.1.2.9 Weaving*

The yarn is transformed into textiles through weaving. In the case of denim, this is a twill weave. There is limited information about the energy inputs to weave flax, so this has been supplemented with data for cotton and a hemp/cotton blend from academic literature and Ecoinvent v3.8. The energy usage is highly determined by the machinery, the fibre, and weave pattern, producing a large margin for uncertainty in the carbon emission estimate.

The energy input provided by the sources is not always exclusive to weaving, ranging to include quality control machinery, sizing warp yarn, or air conditioning. This creates a greater margin for error but provides a general idea of how weaving may contribute to carbon emissions.

#### *4.1.2.10 Finishing*

Most textiles undergo finishing or wet processing to achieve a desired outcome for the intended use of the fabric. Denim fabrics often undergo stonewashing or sandblasting to create the faded and worn visual affect and reduce stiffness, as well as softeners, flame retardants and other chemicals (Periyasamy et al., 2017). Alongside a lack of published information about energy and chemical inputs of denim finishing, the finishing process for these linen jeans is unconfirmed, and how it may differ from cotton denim. Generalised textile finishing provides an idea of how this may contribute to carbon emissions. Textile finishing has been estimated with cotton data provided by Ecoinvent (2016), which is from mostly vertically integrated mills on a global level.

Textile finishing of denim is estimated to have a minimal contribution to overall CO2 emissions of production, estimated at >1kg CO2 per pair of jeans (or >4% total emissions from fibre to garment) in the example of cotton denim production (Periyasamy and Duraisamy, 2018).

#### *4.1.2.11 Garment Assembly*

Estimated energy usage for garment assembly is provided by Palamutcu (2010).

### *4.1.3 Consequential Modelling*

#### *4.1.3.1 Conventional versus Regenerative*

As has been previously mentioned in section 4.1.2.2, scenarios were modelled to produce different outcomes depending on whether conventional or regenerative principles were applied to flax cultivation.

#### *4.1.3.2 Environmental Considerations*

Consequential modelling identified the opportunities for a low-carbon upscale of the supply chain.

#### *4.1.3.3 Geographical Considerations*

Energy data were multiplied by different carbon intensity measurements provided by Ember, the recommended data source for non-UK electricity (Department for Business, Energy & Industrial Strategy, 2021). This provided a comparison between geographical contexts of interest to 'Homegrown/Homespun' and provide comparison between a European-based on more global supply chain.

#### *4.1.3.4 Transport & Considerations for Relocalisation*

The current non-existent supply chain did not facilitate for carbon emission estimates of transportation between stages of cultivation, processing and manufacturing. 'Homegrown/Homespun' is aspiring for a local, UK-based supply chain, and assessment of the carbon emissions of different modes of transport provided consideration to how transport and distance of movement of goods between supply chain stages may influence carbon emissions. This was informed by the appropriate conversion factors for freight transport in the UK GOV 2021 Conversion Factors (Department for Business, Energy & Industrial Strategy, 2021).

## *4.2 Results & Discussion*

### *4.2.1 Overview*

The LCA approach to quantifying carbon emissions of a flax supply chain suggests regenerative farming can lead to a considerable reduction in carbon emissions compared to conventional methods. However, in the wider context of extracting and processing flax fibre into garments, the carbon savings of the 'Homegrown/Homespun' principles are not vastly different from those of conventional flax textiles production. The geographical location of the supply chain and the method of transporting goods between manufacturing stages has a variable impact on carbon emissions, prompting the changeable carbon footprint until the supply chain is fully established.

### *4.2.2 Cultivation*

The initial analysis of the contributing carbon emissions from a conventional flax system were explored. The carbon inputs to this system are diesel, to operate relevant machinery, and pesticide and fertiliser production.

As detailed in figure 4.1 and table 4.4, through removing the use of pesticides and fertilisers, removing tillage, and changing the form of cover crop destruction, regenerative cultivation has the potential to be sixty five percent less carbon intensive than conventional flax systems.

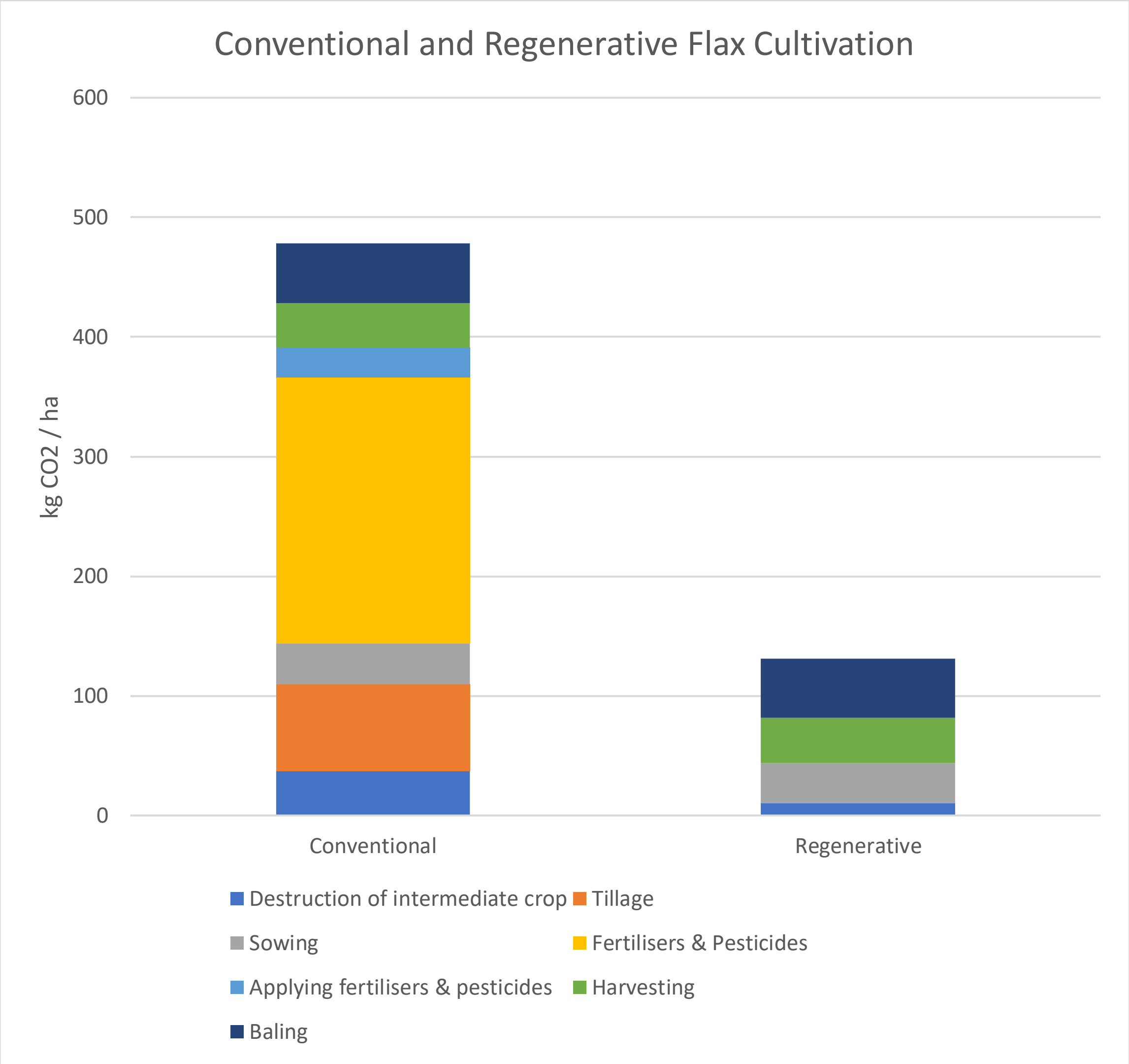



*Figure 4.1: Comparison of conventional and regenerative flax cultivation (kg CO2 per ha) (CELC, 2022; Dissanyake et al., 2009; Farm Carbon Toolkit; Ecoinvent, 2007).*

*Table 4.4: Comparison of conventional cultivation to that using regenerative practices.*

| | **CO2e (kg) per ha cultivated flax** |
|---|---|
| *Conventional Cultivation* | 480<br>50% pesticides & fertilisers<br>15% tillage<br>10% destruction of cover crop |
| *Regenerative Practices* | 130<br>65% reduction by removing tillage and pesticides<br>Cover crop instead destroyed with rollers, which is estimated at 10% of emissions. |

Most notably, the reduction or total removal of fertilisers and pesticides, as is being trialled in the 'Homegrown/Homespun' project, would dramatically reduce cultivation emissions. Beyond the diesel savings from transitioning to a low- or no-till system, there is further opportunity to gradually increase soil organic carbon by minimising disturbance. UK experiments suggest 0.31(+/-0.18) tonnes of CO2/ha could be sequestered under no-till, and approximately half this amount for mini-till (Soil Association, 2018). However, the capacity for these carbon savings is contested and has a wide margin for uncertainty (Graham et al., 2021). This highlights the uncertainty of the indirect carbon benefits, but the reduction of emissions from embodied carbon and diesel usage remain beneficial.

Furthermore, there could be wider climate benefits, as well as ecological advantages, that go beyond the scope of this LCA, of 'regenerative practices', such as incorporating hedgerows and trees, restoring natural watercourses and integrating livestock (Newton et al., 2020). This regenerative approach to farming supports the Sustainable Development Goals (SDGs), through encouraging biodiversity, promoting ecosystem services, and prioritising soil health (United Nations, n.d.[a]; Shahmohamadloo et al., 2021). The holistic and systems-based approach to farming of regenerative agriculture, has piqued the interest of various groups, including producers and academics, but has also been widely critiqued for its ambiguity and limited credibility without a definition to investigate claims (Newton et al., 2020). To fully understand the carbon impact of regenerative agriculture, firstly, a clear definition and investigation into the varying carbon impact of key principles, would provide a more robust estimate of carbon differences between regenerative and conventional cultivation methods.

### *4.2.3 Retting*

'Retting' - the means for separating the fibre from the woody stem of the flax plant are diverse in their methods and consequentially variable in their carbon emissions. As is presented in the scenarios in figure 4.2, the largest contributor to carbon emissions is the electricity required to heat the water. The carbon emissions from heating the water depend on the retting duration and required water temperatures, i.e. a shorter retting time at a higher temperature will release more CO2 than a longer retting time at a lower temperature. Some facilities use heated water extraction, as described by Turunen and van der Werf (2007), others prefer to dew ret the crop in the fields, dependent on the immediacy to plant a succeeding crop, and one example of a facility using rainwater for smaller-scale extraction (Helen Keys, 2022, pers. comm., 7th March). Method variability is still able to produce high-quality, evenly retted flax, with differences likely coming down to personal and business choices, and investment variability (Tahir et al., 2011; Kozlowski et al., 2020).

The scenario with the lowest carbon emissions is using rainwater. However, this is highly reliant on weather patterns, and is unlikely to be viable at significant scales of production and in the face of climate uncertainty. Dew retting and unheated water retting have a small carbon impact. Notably, water retting produces large quantities of wastewater, characterised by an unfavourable smell and high concentrations of organic materials, which requires appropriate treatment which would contribute to down-stream carbon emissions (Tahir et al., 2011). In the context of upscale, considering retting methods, opportunities for innovation, including water reuse and renewable energy, can reduce the overall carbon impact of the supply chain.

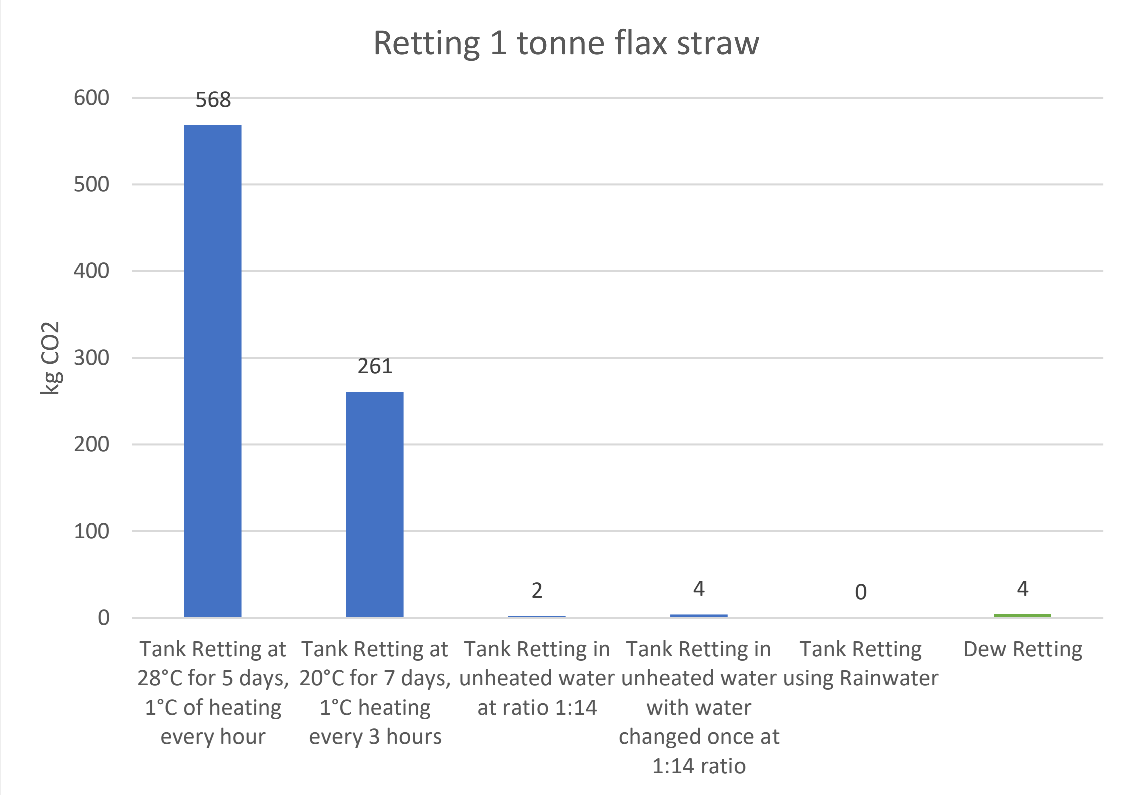



*Figure 4.2: Comparison in CO2 emissions from retting one tonne of flax straw - tank retting in blue and dew retting in green.*

### *4.2.4 Manufacturing*

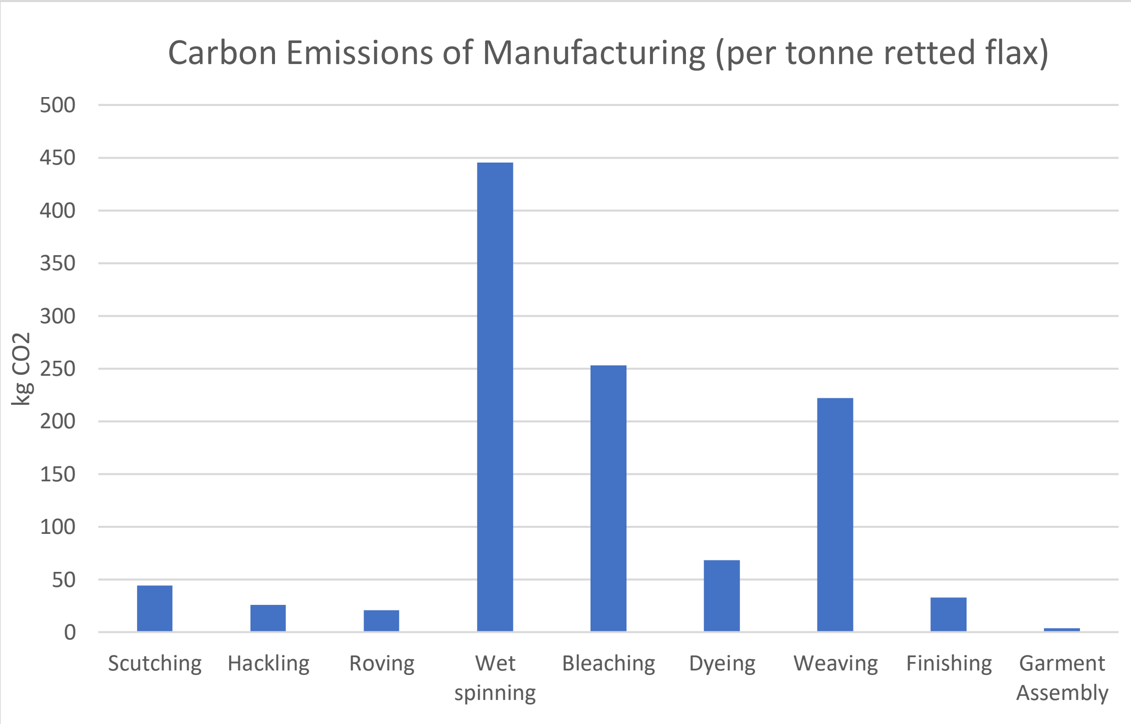



*Figure 4.3: CO2 emissions from the typical stages of taking retted flax to garment, simulated using the EU emission factor (kg CO2/tonne retted flax).*

Outlined in figure 4.3 is the carbon emission breakdown of the manufacturing supply chain, a simulated scenario using the EU emissions factor for comparative analysis between each stage (Ember, n.d.). The fibre extraction processes of scutching and hackling emit minimal carbon compared to the remainder of the supply chain. The spinning process is the most carbon intensive, accounting for almost 40% of all carbon emissions in the manufacturing stages. Spinning, which is often done 'wet' for the strengthening of the fibre and lessening susceptibility to snapping, predominantly releases $CO_2$ through high electricity usage. Even in scenarios where the yarn may be spun 'dry', the electricity usage remains high, with water a small contribution to emissions.

The manufacturing carbon emissions are predominantly resulting from electricity usage. As this LCA does not extend to the embodied emissions of the chemicals, bleaching agents, dyestuff, other components, which were excluded due to incomplete and unavailable data, there is underreporting of potential carbon emissions. Even so, energy consumption is often the main contributor of greenhouse gas emissions in a garment's supply chain, and wet spinning, bleaching, and weaving, would likely remain the largest greenhouse gas emitters (Cheng and Liang, 2021; Wang et al., 2015; Gomez-Campos, 2021). Technological innovations to produce more energy-efficient spinning and weaving machinery would be critical in reducing the carbon emissions of this supply chain, as has been academically explored in the context of apparel supply chains (Çay, 2018; Soorige et al., 2020).

### *4.2.5 Geographical Considerations of the Supply Chain*

In section 4.2.4, the EU emissions factor was used as an example of how the electricity and water usage contribute to carbon emissions. There is geographical variation to the $CO_2$ emissions per unit of electricity, as shown in figure 4.6.

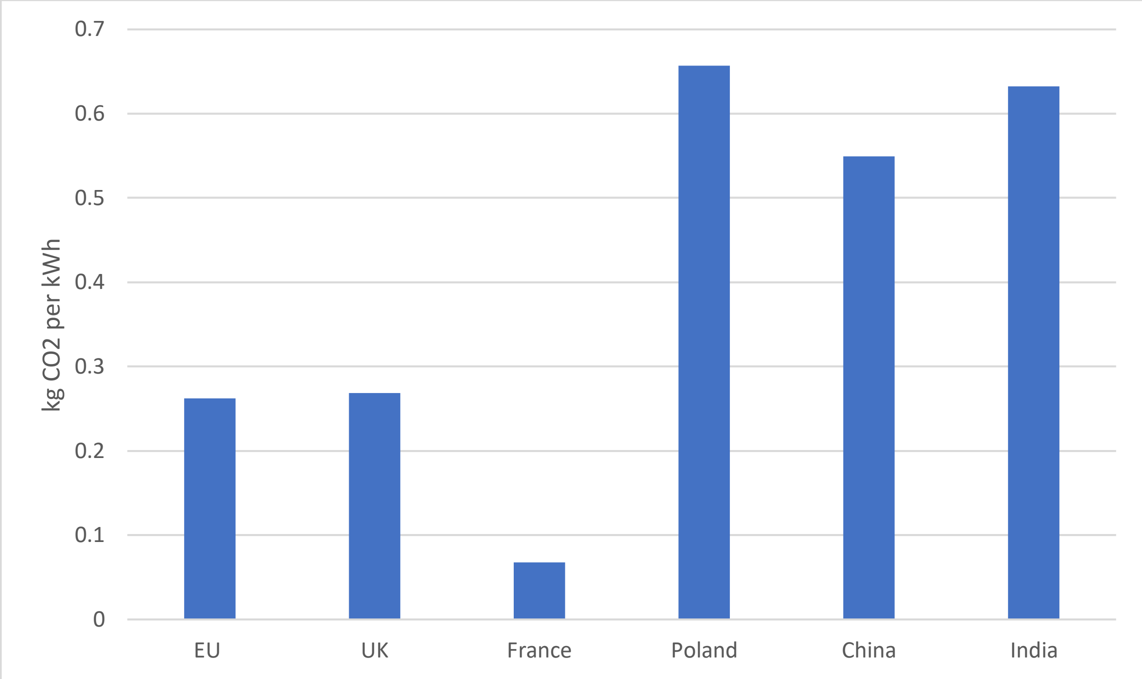
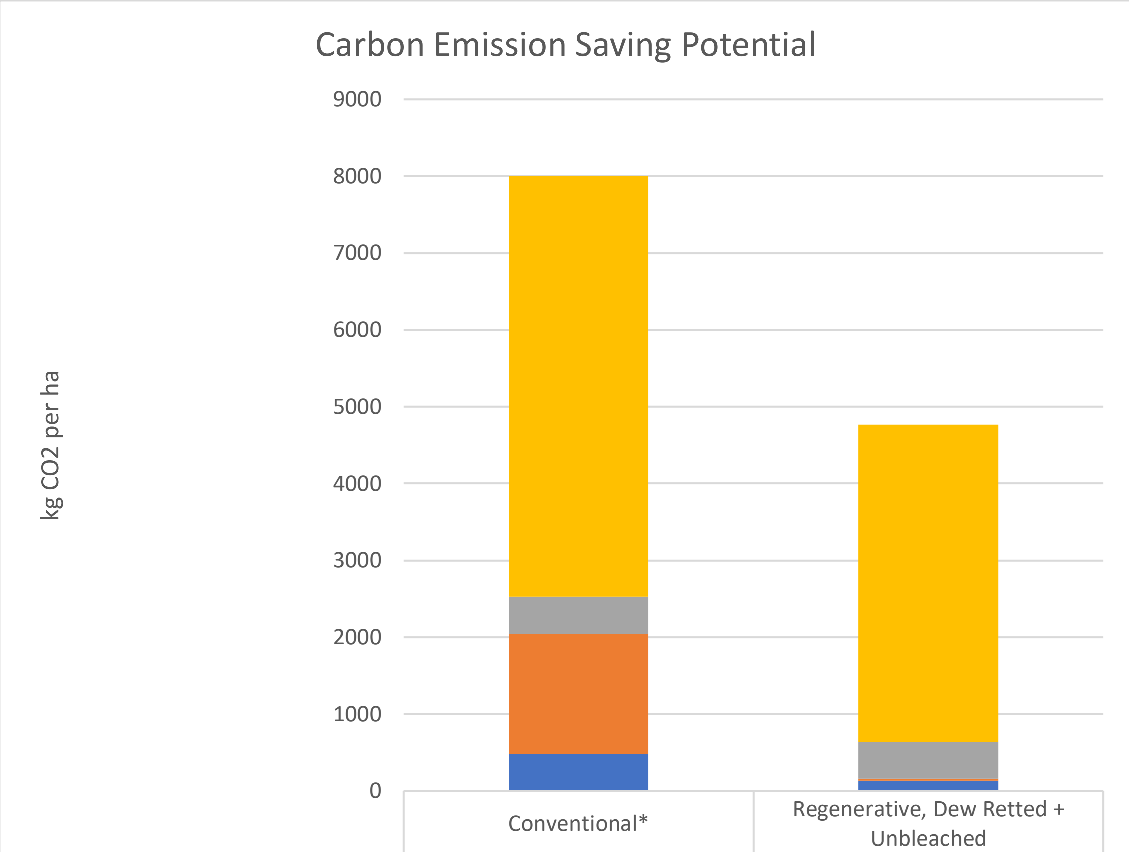



*Figure 4.4: Carbon intensity variation by country/region (Ember, n.d.).*

Figure 4.4 illustrates the potential carbon savings of a more localised supply chain. European linen supply chains have increasingly outsourced flax spinning to China for various technological and labour reasons (Gomez-Campos, 2021), where the potential carbon emissions of the electricity usage (figure 4.2), and the carbon intensity (figure 4.4), would have much higher associated carbon emissions than with production in France or the EU. Poland is an interesting case, as the high carbon intensity (in fact higher than China and India), is likely due to national coal dominated electricity production (IEA, 2022). With Safilin in Poland as one of the few remaining flax spinning mills in Europe this is of interest to the 'Homegrown/Homespun' case study. However, as a member of the coordinated European Network of Transmission System Operators for Electricity (ENTSO-E), the energy system is more interrelated and complex than each member country exclusively using the electricity it produces (ENTSO-E, 2021). To conclude, the location of the supply chain has a dramatic impact on carbon emissions emitted from electricity usage.

### *4.2.6 Conventional vs Regenerative*




| | Conventional* | Regenerative, Dew Retted + Unbleached |
|---|---|---|
| Making (Roving to Jeans) | 5477 | 4125 |
| Processing (Raw Straw to Roving) | 483 | 483 |
| Retting | 1566 | 24 |
| Cultivation | 478 | 131 |

*Figure 4.5: Comparison of carbon emissions saving potential for a flax-based garment supply chain. *It was assumed in this method that conventional retting is tank retting at 28°C.*

The potential for carbon savings for the proposed ‘Homegrown/Homespun’ supply chain would be in the cultivation, retting and making stages (figure 4.5). As explored in section 4.2.2, cultivation using regenerative principles, with the example of no tillage and no use of pesticides or fertilisers in this LCA, has the potential to dramatically reduce carbon emissions. The estimate here is based on the assumption that the average of 6 tonnes per hectare was harvested (see section 3.2.2.1). Retting methods are variable across the industry, with opportunities for low emissions explored in scenarios in section c, such as dew retting and tank retting with unheated water. Processing remains unchanged in either scenario.

The removal of bleaching from the manufacturing stages reduces emissions (figure 4.3), but the remaining ‘making’ stages are fundamental in the flax-based supply chain. As it is thought the natural indigo could be integrated into a commercial yarn dyeing facility, the water and energy requirements, and subsequent carbon emissions, remain identical in both scenarios. This LCA analysis did not support the comparison of natural indigo cultivation and extraction to the embodied emissions of synthetic indigo due to limited data and uncertainty over methods, and these would differ in their carbon emissions.

Explored in table 4.5 are examples of scenario modelling of variable influence on total carbon emissions, both on a hectare scale and per estimated pair of jeans (figures 3.3 and 3.4 and table 3.5). Further illustrated in figure 4.6, the greatest carbon emission reduction is found where the flax is grown regeneratively, dew-retted, and the yarn is unbleached. In this scenario, the jeans have an estimated 40% of the impact of the 'conventionally' grown, processed and manufactured jeans. Dew retting has the greatest contribution to carbon reduction, compared to a supply chain using tank retting at 28°C. The error bars accommodate for 10% uncertainty.

*Table 4.5: Carbon emission modelling, and estimated carbon footprint per pair of jeans.*

| | Carbon Emissions (per ha) | Carbon Emissions (per estimated pair of jeans/ha) |
|---|---|---|
| Conventional | 8004 | 8.34 |
| Regenerative | 7657 | 7.97 |
| Dew Retted | 6462 | 6.73 |
| Unbleached | 6652 | 6.93 |
| Regenerative, Dew Retted + Unbleached | 4763 | 4.96 |

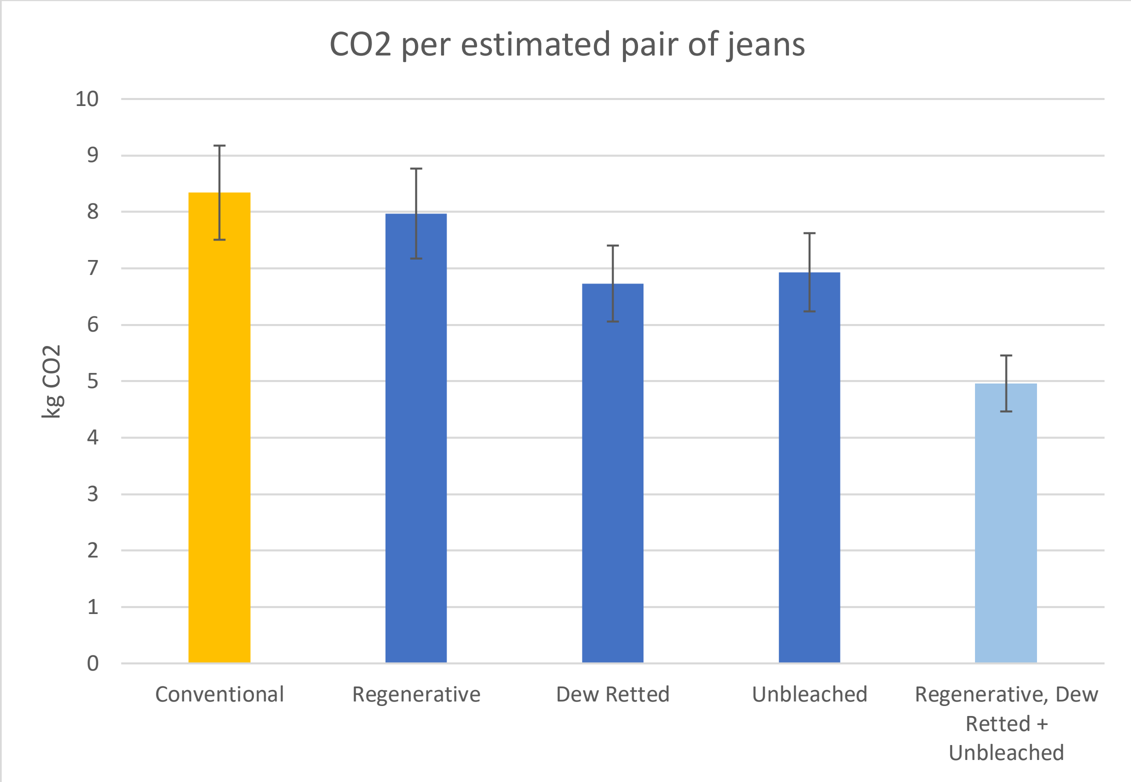



*Figure 4.6: Carbon footprint of scenario-modelled pairs of jeans, with 10% uncertainty.*

### *4.2.7 Considerations for Transport*

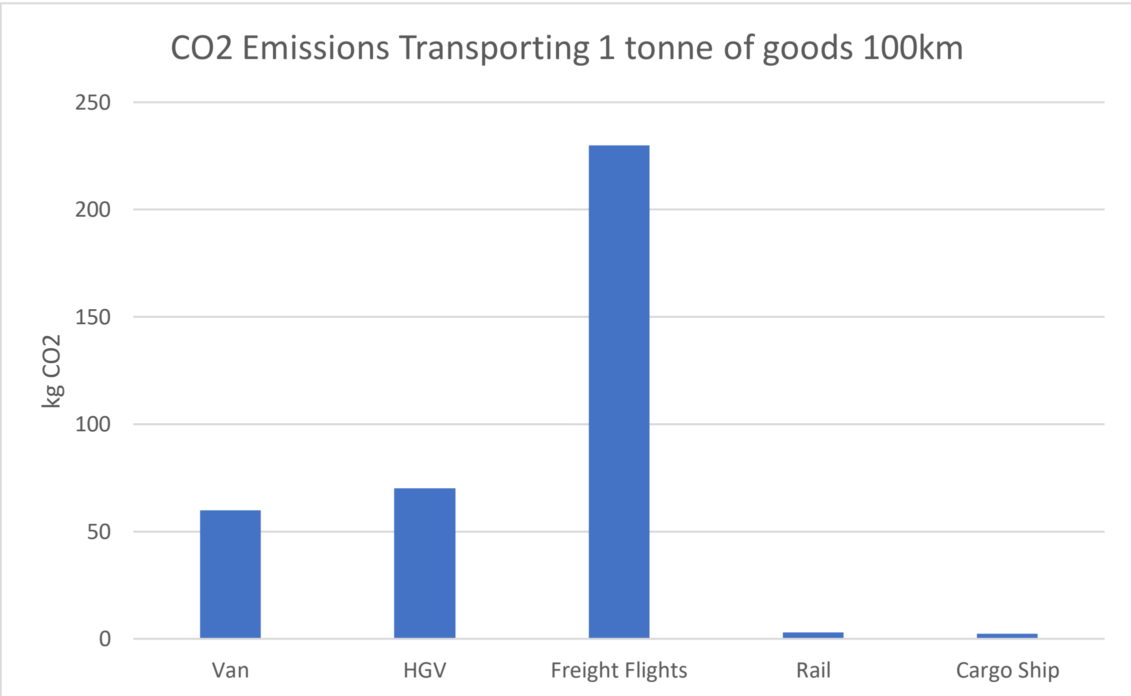



*Figure 4.7: Comparison of transport carbon emissions (Department for Business, Energy & Industrial Strategy, 2021).*

As is demonstrated in figure 4.7, the mode of transporting goods impacts carbon more so than distance alone. With cargo shipping having a low-carbon impact, this partially endorses support for global supply chains. However, in relation to what was discussed in section e, national and regional carbon intensity could result in high carbon emissions if certain manufacturing stages take place in apparel powerhouses, such as China and India. With the use of vans and HGVs a likely option for a more localised supply chain, UK- or Europe-based, the transportation could significantly contribute to emissions. This strengthens the argument to localise retting and scutching to the UK or use the Northern Ireland or French facilities that have been explored in the economic feasibility assessment, to reduce the weight of flax product that requires transportation for further processing.

Based on the findings in figure 4.7, recommending rail freight where possible would support a low-carbon supply chain. Greater potential for rail freight would potentially be facilitated by the UK Government's 2022 'Future of Freight' plan, with increased investment and research into zero emission freight technology (Department for Transport, 2022).

### *4.2.8 Market Comparison*

With a pair of Levi's estimated to produce 33.4kg of carbon dioxide (Levi Strauss & Co, 2015), flax-based alternative jeans could have at 1/3 of the impact, with regeneratively-grown, dew retted, and unbleached jeans at 1/5 of the carbon impact (Figure 8). In an example to consider transportation, if the entire supply chain is located within 1000km of cultivation, transportation could contribute 5-9kg $CO_2$ per pair of jeans, reducing the carbon savings but still remaining less carbon intensive than a pair of Levi's – estimated to have between 1/3 to ½ the carbon footprint.

### *4.2.9 Limitations of LCA*

Firstly, the limited available data to estimate energy and water inputs to the flax-based system prompts a large margin for uncertainty with few sources to rely on, supplemented by cotton, jute, and hemp data where required. As can be further explored in Appendix 7, electricity inputs can be highly variable. With limited linen denim on the commercial market, there is further uncertainty for energy requirements to weave flax yarn to a denim pattern, and whether this will differ vastly from cotton, with industry experts providing variable insights.

Furthermore, modelled calculations to estimate the energy requirements to heat water and produce steam have made various assumptions, such as 100% efficient and starting temperatures, which are simulated examples and are not informed by real-life industrial data. Some data sources provide either carbon dioxide or carbon dioxide equivalent, which have had to be cumulated to produce carbon estimates, producing a reporting uncertainty.

Defined by the boundaries and scope of the LCA, this carbon assessment fails to include all contributions to carbon emissions, such as dye pigment carbon emissions or garment components, which likely underestimates the carbon contributions. Most limiting is the exclusion of transport emissions, which as is detailed in section 4.2.7, can largely contribute to the carbon emissions of a supply chain. This can be potentially up to half of the estimated emissions depending on the mode of transport, specifics of the supply chain, and geographical scale of the supply chain. The supply chain uncertainties, such as the geographical location of facilities and what will happen where (i.e. what weight of goods would require transportation), increases the difficulty and uncertainty of a carbon estimate.

Supply chain uncertainty inhibited a robust estimate of the potential carbon impact of new machinery for currently non-rentable kit or exploring re-localisation scenarios. Utilising existing infrastructure and facilities would have a lower immediate carbon footprint, and the boundaries of this LCA did not explore the carbon 'trade-offs' in a long-term comparison. The carbon impact of new machinery (and transporting for use or installation), such as agricultural machinery or fibre processing kit, would be massive in comparison to the relatively small carbon footprint of the small-to-mid scale flax denim production explored here. For example, Edemilson et al. (2020) explored the carbon footprints of different agricultural machinery, with estimated emissions between 13,000 and 50,000 kg of CO2e per piece of kit. When broken down over a products' lifetime, this begins to emphasise the lessening carbon footprint with greater longevity. Future renting possibilities, collaboration with other flax initiatives or organisations, or purchasing second-hand machinery would have a considerably smaller carbon footprint and are viable options when considering upscale.

### *4.2.10 Opportunities for Further Carbon Reduction*

Firstly, there were discussions with the 'Homegrown/Homespun' team and industry experts (Brigitte Kaltenbacher, 2022, pers. Comm., 25th May; Patricia Bishop, 2022, pers. Comm., 25th March) about the opportunity to utilise the tow fibre, which accounts for nearly 15% of outputs after scutching, nearly as much as long line fibre (table 3.4).

The shorter fibres are often coarser and could be viable for thicker, more durable textiles, with an example mill in Belgium scutching flax tow for dry spinning (Kozlowski et al., 2020; Flax Ghekiere, n.d.). Previously, these shorter, coarser fibres were often used to produce rope or sacking, and in modern-day this is used in non-textile applications, such as insulation or composites (Roberts, 1998; Li et al., 2022). There is currently limited academic exploration of tow spinning in modern-day textile applications, with many LCAs excluding the tow from spinning and subsequent weaving (Gomez-Campos, 2021; Turunen and van der Werf, 2006; Turunen and van der Werf, 2007; Dissanyake et al., 2009). The ability to utilise the tow, and integrate this within a commercial supply chain, would result in greater yarn yields from the same land requirements to produce yarn exclusively from long-line fibre.

Secondly, a transition to renewable energy would dramatically reduce the carbon footprint of this supply chain, with the majority of carbon emissions of manufacture from electricity usage, as is further evidenced by Farhana et al. (2022). There would be further carbon reduction from an increase in the energy efficiency of manufacturing stages. This would be more challenging to achieve with the initial outsourcing of flax processing and spinning to other facilities but would tie into the wider energy savings of the garment supply chain.

## *4.3 Conclusions*

The findings of the LCA, informing the third objective of this research, suggest flax-based denim could have 1/3 to 1/5 of the carbon impact compared to a pair of standard cotton jeans (Levi's and Strauss., 2015). Including considerations for transport within a European supply chain, this could be ½ the impact of cotton jeans. Furthermore, regenerative flax cultivation could have a 65% reduction in carbon emissions compared to traditional flax cultivation that utilises tillage and pesticides and fertilisers. In any upscale efforts, regenerative principles have many carbon benefits, as well as other ecosystem and soil assets (Newton et al., 2020).

There is wide uncertainty of the carbon impact of the manufacturing supply chain, highly dependent on energy usage. For example, flax retting methods have varied carbon impacts, with heated tank retting having the highest carbon impact (600kg $CO_2$/tonne raw flax) compared to the minimal carbon impact of dew or unheated tank retting. Furthermore, geographical emissions intensity measurements, and energy sources, affect the carbon footprint. Transport could largely contribute to the supply chain's emissions, with distance and mode of transport having variable impact. Bearing both geographical emissions intensity and transport to mind, it is likely a localised, UK or EU-based supply chain would support a low carbon system, but the true capture of this goes beyond the scope of the LCA.

## *4.4 Recommendations*

In relation to upscale, further exploration of retting methods and whether the fibre requires bleaching could ensure low-carbon upscale where possible. Generally speaking, a more localised supply chain (UK or Europe), promoting renewable energy, and further support for innovation would maintain a small carbon impact.

# Chapter Five: Social

## 5.1 Methodology

### 5.1.1 Overview

The social implications of scaling-up a British 'homegrown' and 'homespun' textile industry were explored, in line with promoting triple bottom line (TBL) sustainability, utilising a mixed-methods participatory research approach. As the 'Homegrown/Homespun' initiative began as a community endeavour during the COVID-19 pandemic, with creating societal value as a core part of the vision, there are further societal dimensions that need consideration as it transitions towards a commercially viable enterprise. Hence, an exploratory approach was taken to allow for broader societal implications to come to light, focusing on the volunteers currently engaging with the 'Homegrown/Homespun' initiative.

Through a mixed methodology of focus groups, interview, and research journaling the following questions were explored in support of objective four:

1. What current social benefits are generated by the 'Homegrown/Homespun' initiative?
2. How might these (assumed) social benefits change, both positively and negatively, as the 'Homegrown/Homespun' initiative grows?
3. How might the social value of the 'Homegrown/Homespun' endeavour be retained and enhanced?

### 5.1.2 Focus Group

A focus group approach, defined as prompting discussion about a topic of interest with a group of people, facilitates collection of verbal information from the conversations and observing the non-verbal behaviours and interactions between individual participants (Acocella, 2012). It further captures synergies and potential tensions about ideas or experiences (Cyr, 2017). As community volunteering is an inherent part of the 'Homegrown/Homespun' project, having been previously observed and informed by the volunteers and organisers, capturing and analysing their interactions and group dynamic was most effective through a focus group. It was thought the strong sense of community with the volunteers may facilitate openness and honesty (Acocella, 2012). Furthermore, as a participatory researcher, the positionality and potential influence of being embedded in the volunteer community through attendance to volunteering sessions, may have allowed for further openness through a level of trust (Touboulic and McCarthy, 2020).

Addressing the questions in section 5.1, a 30-minute semi-structured focus group with six of the 'Homegrown/Homespun' volunteers explored their experience volunteering with 'Homegrown/Homespun' and discussing potential changes to the initiative with 'commericalisation' and upscale. A topic guide is available in Appendix 8. The focus group took place in the Super Slow Way office, immediately after a volunteering session, which is a familiar place to all participants. This focus group was opportunistic in the sense that those who took part were able to spare the time after the allocated volunteering session to partake, and non-probabilistic and limited to the 'Homegrown/Homespun' volunteer group. All the participants had been volunteering with 'Homegrown/Homespun' for over six months at the time of the interview, having built a strong community dynamic, as had been observed and informed by the 'Homegrown/Homespun' team and volunteers.

The focus group was transcribed manually and discretely analysed at the individual level using NVivo, with inductive codes created to capture the main themes and quotes of particular interest to the research questions. Further group analysis of the consensus and dynamic, and interactive analysis of the exchanges and interactions within the group further captured the social element (Cyr, 2017).

### *5.1.3 Supplementary Interview*

A further 10-minute semi-structured interview took place with two volunteers of the 'Homegrown/Homespun' initiative, who did not partake in the focus group, building on the topic guide (Appendix 8). This occurred the following week at the Witton greenhouses, where some of the volunteering sessions are located. Due to the on-site recording, background construction noise and talking meant notes were taken rather than a full transcription. This interview deepened the insight into volunteer experience, portraying a greater depth of experience and to complement or contrast with the focus group.

### *5.1.4 Ethical Considerations*

Ensuring ethically sound research involved distributing a participant information sheet and obtaining written informed consent. Where required, I was able to answer any questions and queries, mitigating perceived power imbalances and address my research motivations. Participants were made aware that they would be anonymised, and any identifiable language would be removed. A copy of the consent form and participant information sheet can be found in Appendix 9. Furthermore, there is no respondent profile table, ensuring respondents remain anonymous and are not identifiable for ethical purposes. The mixed demographic of the volunteers was captured in this group, bringing diversity of opinions and backgrounds to this research piece. The coded outputs in Appendix 10 and 11, reflect how the respondents of the focus group are attributed numbers 1-6, in order of first appearance, and the interview participants as a) and b). The references allow identification of different people in the responses received without compromising identity.

Ethical considerations as a participatory researcher included re-stating my name, research intent, and relationship to the project, despite many of the participants being aware of this at the time of the focus group and interview. It was also critical to ensure confidentiality was understood and that cultural sensitivities were taken into account for the anonymisation of participants.

### *5.1.5 Research Journal*

Keeping a research journal for the duration of this research period served two purposes; to make observations and reflections from interactions with industry experts and the 'Homegrown/Homespun' volunteering sessions, and to practice self-reflexivity. Reflexivity, the continual practice of consciously acknowledging the positionality of the researcher within the research context and the consequential impact, was integral to sound ethical research (Dodgson, 2019; Soedrigo and Glas, 2020). As a participatory researcher, a journal provided a space to 'actively reflect' on my experiences and the potential conflicts that occur with becoming embedded within the volunteer community (Soedrigo and Glas, 2020). This journal also evolved to encompass the difficulties of conducting interdisciplinary research into an emerging and challenging research topic, relating to the description of the diary as representing my "internal dialogue with the research process" (Engin, 2011 p.299).

Returning to the idea of being a participatory researcher, this style of research gave me the opportunity to familiarise myself with the 'Homegrown/Homespun' volunteer community. Conceptually based in the post-colonial, post-Marxist, and post-modern oppositions to power, participatory action research mobilises an alternative methodology for holistic and bottom-up knowledge sharing and understanding (Keahey, 2021). Building a level of trust and understanding with this community aimed to support more insightful analysis of the social impact and implications of upscale than a traditional, top-down approach (Touboulic and McCarthy, 2020). As is highlighted by Keahey (2021), participatory research facilitates the inclusion of social sustainability, and can be used to promote inclusive decision-making in any efforts to upscale the 'Homegrown/Homespun' initiative.

## *5.2 Results & Discussion*

### *5.2.1 Overview*

The initial impression from the focus group was the articulation of the benefit of volunteering with the 'Homegrown/Homespun' project to the volunteers at an individual scale, and the sense of the community they have fostered between them. The observation I took note of in my research journal from the focus group was 'lots of laughter, storytelling and a sense of pride in what they have achieved together in the past year'. The interview with the two volunteers the following week complimented the opinions expressed of the participants of the focus group.

The following section is structured to answer the questions outlined in the methodology, first focusing on the social benefits from volunteer involvement, followed by how these benefits may change in the face of upscale and how the social value may be retained and enhanced in the future. Finally, there is a discussion about being a participatory researcher and the role of the research diary in this element of the research.

### *5.2.2 Social Benefit from Volunteer Involvement*

The overall attitude towards volunteering with 'Homegrown/Homespun' was that it had built a community of like-minded people, empowering them to learn new skills and make a difference, bringing further benefit to their wellbeing and supporting their life values. The following sub-sections explore each thematic code in turn and concluding this section with non-verbal analysis. Further detail of these codes and supporting quotations, and supplementary notes, can be found in Appendix 10, 11, and 12.

#### *5.2.2.1 Sense of Community*

Much of the conversations focused on the sense of community that has developed between the volunteering team, prompted by their "shared purpose". Importantly, the beginning of the project coincided with the COVID-19 pandemic, which the following quotation details finding some positivity during this time.

"The thing that was really great about it to begin with, is that it was during those times of lockdown that we'll talk to our grandchildren about it, when you weren't really allowed out and you weren't really able to do much, but you were able to go to this field of like-minded, smiling people."

'Homegrown/Homespun' facilitated a "supportive" environment and "friendships" during a time when our society was socially distancing and limited in building meaningful connections within communities. This potentially influenced participants' interest in nature, wellbeing, and aspiration to build social connections.

There was a light-hearted honesty towards the initial nerves of coming along to the sessions and being unsure of what to do but going on to describe their experience as a "fantastic big journey" and collectively being "a very close team" or "family", where "no one will ever feel left out", having had "some really good laughs" and "supportive, no matter what you do". As detailed in the following quote, and met with supporting comments from the group, the social element is considered by some as the most impactful or important aspect of volunteering.

"I think it's the friendships that we've got, isn't it? I think that more than anything."

Emphasised in both the focus group and the interview, the volunteering has given participants the opportunity to develop meaningful social relationships, with these friendships continuing to motivate attendance, providing stronger motivation than potentially the initial motivations of environmental sustainability, and learning opportunity. There was an indication of a continuously evolving group identity of environmental determinism, shared learning and curating passions and hobbies.

#### *5.2.2.2 Non-financial Return*

Drawing on the sense of community and ability to engage with "like-minded" people, participants shared a plethora of personal benefits, mentioning the simplicity of having "fun", considered a "lovely way to end the week", and "get something productive done". One participant described this as "not a financial transaction, but you're giving something of yourself and receiving something from other people". Furthermore, one participant detailed, "for my mental health, it's been amazing", met with nods and supporting remarks from the group, sharing how participation supported their wellbeing. These conclusions are further supported by the literature, with findings suggesting volunteering with environmental initiatives positively impacts participants' wellbeing, even if this is as simple as spending time in green spaces (Molsher and Townsend, 2016; Houlden et al., 2018).

#### *5.2.2.3 Learning*

Many participants also detailed the learning process of volunteering, with few having prior experience with growing flax and natural dyes, even those with a textile background. There was an open-minded perspective expressed here, with "you know, you don't know what skills you have until you try it!" and "there's a lot that I've found out I'm not good at". One volunteer posed a question to the group "we've learnt all sorts of wonderful things, haven't we?" There was acknowledgment to how much they have learnt during their time volunteering, as well as an interest to continue to learn about flax and natural dye.

#### *5.2.2.4 Environmental Sustainability*

Sustainability was described by a couple of participants as being the motivator to initial attendance to the volunteering sessions, with one volunteer saying, "well it can't get any more sustainable than growing your own fibre!" In a light-hearted way, participants drew on how "pollution", non-local, and resource-intense production, especially in relation to textiles, prompted them to volunteer with 'Homegrown/Homespun'.

#### *5.2.2.5 Empowerment & Environmental Action*

Expanding on the environmental sustainability motivations of initial attendance, participants drew on the optimistic outlook volunteering has given them and "feeling you're making a difference, even if it's in a small way." One participant detailed "to be even a tiny part of doing things differently is kind of enlivening, it's kind of energising, and kind of entertaining". Of particular interest, which emphasises the empowerment and scale of impact, is "because we've grown at the field, there's quite a few of us who have been growing a patch of land at home." The wholehearted interest in natural fibres and dyes, goes beyond the allocated weekly volunteering sessions, to planting at home, potentially allowing further knowledge sharing with family and friends and encouraging wider climate-positive behaviours.

Comprehending the empowerment alongside the wellbeing of the volunteers explored previously holistically connects the individual-scale empowerment into the wider impact of community climate action, towards building resilient communities (Kragh, 2017). Furthermore, volunteering makes a unique contribution to the Sustainable Development Goals, supporting goal 13 'climate action', with 'Homegrown/Homespun' encouraging a climate-dedicated community through education, experience and skill sharing (Paine et al., 2020)

#### *5.2.2.6 Regeneration of Place*

In the interest of local context and the proposed idea of place-based business models, it was insightful to hear about people's relationship to Blackburn and the ties or motivations this may have towards volunteering. For some, the project was in their local area, providing a way to give back to their local community and improve the green spaces. For others, involvement in the 'Homegrown/Homespun' project was the beginning or the development of their relationship to Blackburn, with previous connotations of Blackburn "not a place to go" or unattractive for having "suffered years of neglect". Both those immediate local and not-so-local participants shared their thoughts on how volunteering in Blackburn was "improving the area" and supporting “a new lease of life” to the Witton Park greenhouses that were previously owned by the local council and now the Lancashire Wildlife Trust.

A few participants also expressed how they are engaged with multiple volunteering projects located in Blackburn and East Lancashire more broadly, involved in a network of local initiatives around creativity, nature, and skill development. This further encourages the benefit of having a network of initiatives and projects that share a common goal of supporting local development, community support, and wider social and environmental movements.

#### *5.2.2.7 Nature / Green Spaces*

Often tied into other discussion around community, non-financial return, empowerment, and regeneration of place, “to be out in the fresh air” was considered beneficial, especially when experiencing difficulties in their personal lives. Participants grasped the potential for creating wildlife friendly environments, both as part of the project and more generally. There was a brief discussion about the transformation of the field site in Blackburn, noting how it was originally a fly tipping site, but this had lessened when the group returned to the site for 2022. Describing this was met with smiles and optimism for how with some effort and dedication, communities can actively re-claim unused land for wildlife, nature, and community learning.

### *5.2.3 Non-verbal Analysis*

Taking a reflective lens to the focus group, the closeness of the volunteer participants was reflected in their relaxed body language, the frequent laughter and sharing of memories, and their comfort in speaking in sync or speaking over each other. While notably a difficulty in the transcription process, the multiple voices were often reinstating the same point or agreeing with what another had said. Memories were frequently recounted by multiple people, having miniature dialogues within the primary focus group discussion. Ultimately, observing the dynamic of the group further evidenced and confirmed the strong sense of community described by the participants.

### *5.2.4 Upscale*

The latter part of the focus group discussion, and briefly addressed in the interview, were the thoughts and challenges with upscaling the project. Evidenced in section 5.2.2, 'Homegrown/Homespun' is of high importance to the volunteer community members, with this discussion coded into 'risk to benefits', 'inclusion', 'reimaging textiles production', and the 'economic dimension'. Further detail of these codes and supporting quotations can be found in Appendix 10.

Firstly, in the context of upscale the participants were apprehensive to "lose the kind of feeling and ethics and everything that we've built up" and "if we're honest, we feel a bit worried about it (the project) really". As detailed in the following quotation, the management of the future of the project and the transition from the current scale or re-structuring of 'Homegrown/Homespun' is something the volunteers should be involved with.

> "I think what's important as well for this particular group of volunteers is being involved and consulted, as well as part of the process, so that we are sort of aware of what the plans are and what's happening."

Exploring the idea of how 'Homegrown/Homespun' could transform into multiple strands or grow in the future, there was a brief suggestion of rewarding through employment and increasing engagement as part of an accredited course for a commercial route. Recognising and being aware of the novelty of the aspiration for a flax and natural dye industry, these comments complement the necessary skill development and employment opportunities for this industry and greater regional autonomy and economic resilience.

With the future or upscale of 'Homegrown/Homespun' described as "tricky" and "interesting", navigating next steps in a way to continue to serve the volunteering community to retain and enhance the social value evidenced from engagement should be a high priority of the main stakeholders. The observed benefits of learning the expertise of this heritage industry and engagement with climate action risk stunted potential if the commercial viability alone is prioritised.

Throughout this part of the conversation, the volunteers maintained a light-hearted attitude, joking about each needing a pair of these jeans, if they are produced, as "we're gonna be out in them fields for quite a long time!". It was raised how being appreciated for their contribution and given the opportunity for their opinions to be heard, would support longevity of volunteering and the associated benefits that have been reported. As further explored by Kragh (2017), ensuring fulfilling experiences for volunteers by developing mutual understanding between managers and volunteers of the motivations and wellbeing of the volunteers as well as the environmental objectives, would support this longevity and wider community-focused climate action.

### *5.2.5 Researcher Reflexivity*

#### *5.2.5.1 Data Collection Process*

Reflecting back, being a participatory researcher that had been engaging with the volunteer group during the volunteering sessions, potentially enabled openness and honesty in the responses, supporting this suggestion from Touboulic and McCarthy (2020). There were a few moments, a more formal research approach should have been taken, such as re-introducing myself fully and being non-leading in a question where I asked about 'benefits of volunteering', having previously heard these benefits through more informal conversations.

When a participant asked me, "What's it been like for you?", I was slightly taken aback to be included in the discussion, before remembering my position in the research to include being a volunteer. My response, "I've had a great time", was wholeheartedly honest, having become well acquainted with the other volunteers during this research process.

#### *5.2.5.2 Research Diary*

The research diary was a useful tool for adding further depth and breadth through observation and informal conversations during the 'Homegrown/Homespun' volunteering sessions.

Reflecting on the sessions, I frequently took note on the sense of community and dedication volunteers have to the 'Homegrown/Homespun' project, also having interesting conversations about people's motivations and the individual impact of coming along. I had also noted the multiple times people had raised concern over the ethical considerations of potentially selling jeans produced by volunteered labour and the potential for stronger communication and inclusion within discussions about next steps. These conversations were naturally brought up with building raised beds, shovelling compost, planting seeds, weeding, and other related work at the field. As was mentioned in the focus group about 'shared experience', it felt these conversations became a way of socially bonding, and the honesty facilitated by including myself in these activities.

Attending the volunteer-organised exhibition of their experience of 'Homegrown/Homespun' in June 2022 further shed light on their positive experiences from involvement with the initiative. Part of this exhibition included quotes from each volunteer about their motivations, memories, and benefits of taking part, along with photographs displaying the journey in visual form. As a participatory researcher, I also spent time preparing the exhibition space and talking with visitors about the project. As has been previously iterated, becoming involved with this volunteer community through participatory action research, facilitated a deeper level of understanding of this community, their motivations, and the individual impact, supporting similar findings from Keahey (2021).

### *5.2.6 Limitations*

Due to the localised network of 'Homegrown/Homespun' volunteers, this focus group and interview illustrate the perceptions and opinions of a small sample. The application or scalability of these evidenced social value and opinions to environmental volunteering are limited, with further questions about what degree of impact the frequency of engagement as a volunteer or influence of external factors has. Operating in a group dynamic, participants are more prone to agreeability, potentially minimising the sharing of contradictory opinions and exaggerating the opinion of the consensus (Cyr, 2017). Therefore, the research findings are likely biased towards positive experiences. Nonetheless, the analysis of this study shed light on the potential for the shared learning and community-scale empowerment, supporting bottom-up approaches to climate action and local resilience.

## *5.3 Conclusions*

Returning to the fourth research objective, and, specifically, the three guiding questions for section 5.3, the individual level observed impact has been overwhelmingly positive. The social benefits included improved wellbeing, changing attitudes towards the environment, learning valuable skills, and providing an opportunity for climate action. A strong sense of community has been observed from the group, suggested from both verbal and non-verbal analysis, with these friendships and other benefits, stressed as the most valuable part of engagement with ‘Homegrown/Homespun’.

The current social value is localised to a small community, with apprehension towards upscaling the initiative due to a fear of losing the friendships and learning opportunities. The is a risk of losing the social benefit observed here if the upscale hinders the ability for local engagement and education. The observed benefits of learning the expertise of this heritage industry and engagement with climate action risk stunted potential. Long-term, there is a likely divergence between any commercial supply chain and community focused initiative, with the aspirations of each not marrying up.

To retain and enhance the social value of ‘Homegrown/Homespun’, further communication between the existing volunteer group and the ‘Homegrown/Homespun’ team, and inclusion of the volunteer community with decision-processes related to potential upscale, would support and respect the contribution the volunteers have made towards the initiative. The benefits outlined by this research suggest upscaling the initiative to facilitate more volunteering opportunities and further engage the community, could diversify and multiple the social impact and contribute towards resilient local communities.

## *5.4 Recommendations*

Strategic management and inclusive stakeholder communications to discuss the next steps of the project. Discussions surrounding the vision, goals, and divergence between commercial aspirations and community-level growing project would provide further clarity and direction.

# Chapter Six: Social-Environmental

## 6.1 Methodology – Pro-Environmental Behaviours

### 6.1.1 Overview

It was requested by the 'Homegrown/Homespun' team to develop a research task that involved the link between volunteering and people's engagement with environmental issues and the impact on lifestyle. Building on the analysis and narrative of the focus group and interview with the 'Homegrown/Homespun' volunteers previously in this research (section 5), there was a suggested strengthened relationship to nature and outdoors spaces as a result of volunteering. Therefore, the following section addresses the fifth objective of this research, to explore the potential impact of volunteer on pro-environmental behaviours.

There is a growing body of interdisciplinary research focused on pro-environmental behaviours (PEB). Value-belief norm (VBN) theory proposed by Stern et al. (1999) and contextualised to pro-environmental behaviour (Stern, 2000) captures the causal chain of variables leading to behaviour, presented in figure 6.1 and has been widely applied in literature to explore impacts on pro-environmental behaviour.

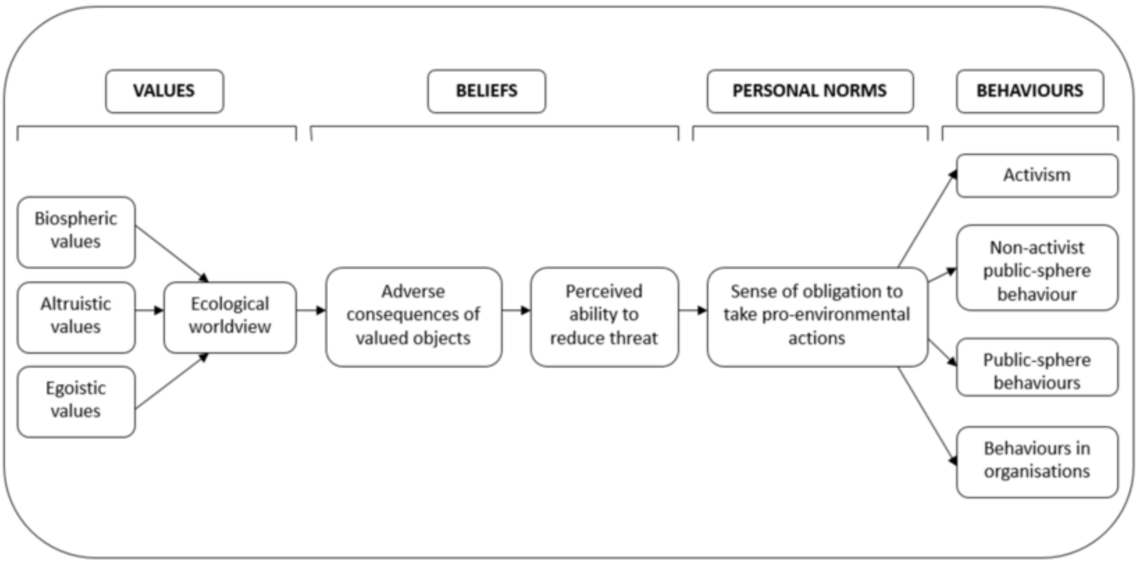



*Figure 6.1: Value-belief-norm theory (Stern et al., 1999; Stern, 2000).*

There is a range of way pro-environmental behaviours are categorised or included within research, such as volunteering within environmental stewardship and ecological programmes and community environmental action (Lope and Weave, 2021; Lengefeld et al., 2020; Peter et al., 2019; Seymour et al., 2018; Dunkley and Franklin, 2017). 'Homegrown/Homespun' does not hold specific environmental educational sessions. Instead, the volunteering sessions invite an opportunity to engage directly with a sustainable and regenerative fashion project. There are opportunities for shared learning through these activities and the social influence of the volunteer community. 'Homegrown/Homespun' could be categorised as 'outreach & relationship building' and 'social influence', two of the five categories identified for encouraging pro-environmental behaviour by Wallen and Daut (2018) and reviewed by Grilli and Curtis (2021).

The nature of 'Homegrown/Homespun' prompted interest in the theoretical relational pathway of nature-empathy-compassion and its catalytic impact on environmental behaviour proposed by Thiermann and Sheate (2020), as is presented in figure 6.2. Building on previous literature, the theory proposes a strengthened connectedness with nature is associated with higher motivation and effectiveness to partake in pro-environmental behaviours. With application to explore sustainable lifestyles (Böhme et al., 2022), agri-tourism (Brune et al., 2022), and more broadly towards climate change responses and ecological well-being, the exploration here was specific to the climate-oriented, community volunteering of 'Homegrown/Homespun'.

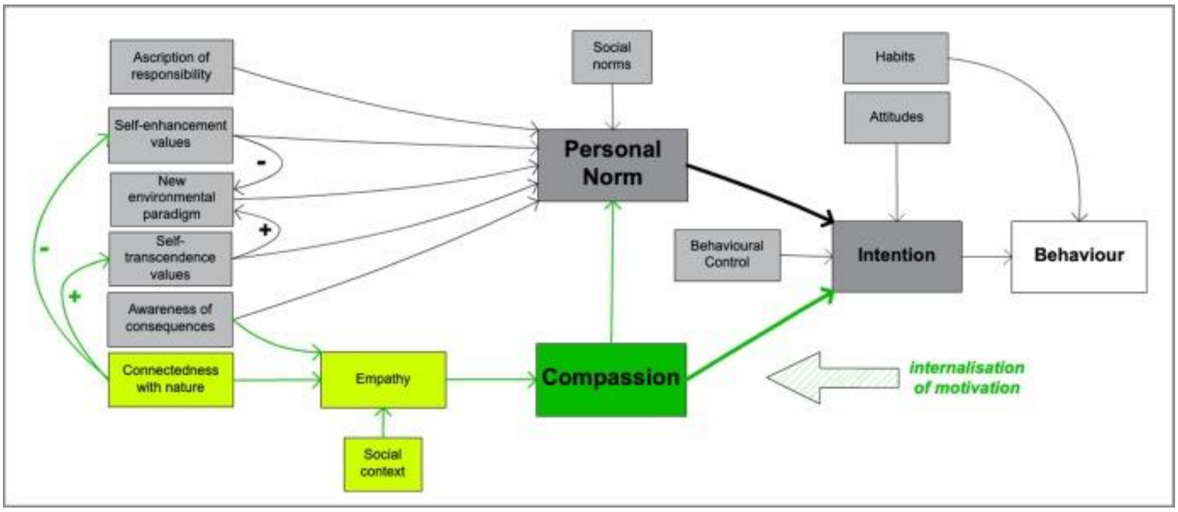



*Figure 6.2: 2-pathway model of pro-environmental behaviour, suggesting nature-empathy-compassion pathway motivates internalised motivation for behaviour (Thiermann and Sheate, 2020).*

Larson et al. (2015) highlights pro-environmental behaviour literature has previously focused exclusively on conservation lifestyle or private-sphere consumer behaviour. Their categorisation of pro-environmental behaviours that builds on Stern's (2002) VBN theory; conservation lifestyle, social environmentalism, environmental citizenship and land stewardship, capture the multi-faceted structure of PEB extending into the public-sphere, and shaped the design of this research approach. The research approach is further influenced by the survey design by Lope and Weave (2021), capturing the "spillover effects" from participation in environmental volunteering. Their survey included a question regarding time spent outdoors, but this was unrelated to nature-empathy-compassion theory.

### *6.1.2 Two-Stage Approach*

Focused exclusively on the volunteers engaging with the 'Homegrown/Homespun' project, a small sample allowed greater depth to the information collected, that would not necessarily be available in an interview (Easterby-Smith et al., 2021).

An initial, open-ended task held at the field during a volunteering session, attempted to capture initial thoughts to the statement 'Share whether volunteering with Homegrown/Homespun has impacted your lifestyle & how you feel about the environment…' This deliberately broad question attempted to capture an honest snapshot into what the potential main impacts have been. Furthermore, the collaborative and interactive approach allowed volunteers to discuss and read each other's responses. It was thought this in-place reflection at the field site and surrounded by their fellow volunteers could enrich the results of the more-formal survey to come. Before the task took place, the research task was introduced and it was explained how the written statements would be used in a research study, describing how partaking was consenting to the use of the recorded data. By the end of two sessions where this task took place, fifteen statements had been written on this paper. The 'Homegrown/Homespun' sessions receive around ten to fifteen participants on a regular basis, with around twenty to thirty at the bigger, more pivotal sessions, such as planting and harvesting.

This initial task was followed up by a formal, online survey. The survey was sent to the WhatsApp group chat, where there are around forty members. Estimated to take between ten and twenty minutes, this included both quantitative and qualitative questions in the form of matrix tables and text entry, exploring nature connectedness, prompted by nature-empathy-compassion theory (Thiermann and Sheate, 2020), the degree of impact from volunteering, shaped by value-belief-norm theory (Stern, 1999) and the breadth of pro-environmental behaviours (Larson et al., 2015).

Included in the survey was a question specific to fashion and textiles because 'Homegrown/Homespun' is centred on sustainable textiles and ideas surrounding environmentally friendly fashion. This was followed by questions addressing private and public sphere environmentalism, influenced by previous studies from Larson et al. (2015), Seymour et al. (2018) and Lope and Weave (2021). The survey structure is detailed in Appendix 13. The survey was live for four weeks, with two reminders sent into the volunteering group, recording eight responses in this time. The introduction to the survey detailed the consent and use of the data provided.

This two-step, synergistic research approach attempted to facilitate reflection through collaborative, in-place narrative writing, and to compliment and contrast this through a more formal-online survey. Themes emerging from both research tasks may differ in prominence and exploring the complementing and contradicting material provided a rich space for analysis.

Due to the limited time availability of the research and the concluded inappropriateness to explore behavioural paradigms (because the nature of the volunteering is not explicitly linked to education), self-reporting was deemed most suitable to the context of the research study (Larson et al., 2015). Furthermore, in light of the inclusive, non-judgement atmosphere that is advertised for the volunteering sessions, the survey attempted to avoid hierarchical associations with environmental behaviours, with this of concern in the research process.

### *6.1.3 Analysis & Interpretation*

The written responses in the first task were transcribed and

coded into information related to 'individual scale', such as knowledge or benefits, 'community', and 'pro-environmental behaviours'. There were limited examples about nature connectedness in this section. The quantitative data from the survey was presented as graphs for interpretation but was not statistically analysed due to the localised scale. The qualitative data was coded into the same categories as the first task, but with the addition of 'nature connectedness' as a code due to the emergent themes.

## 6.2 Results & Discussion

### 6.2.1 Overview

The analysis suggests long-term volunteering with 'Homegrown/Homespun' increases environmental awareness and facilitates greater connection to nature, influencing pro-environmental behaviours at the individual and wider community scale. This two-step approach received fifteen written statements for the first task, and eight responses for the online survey. With the survey not being an on-site activity and a greater time commitment, this may partially explain the fewer responses. The following section first presents the analysis from the first task, followed by the analysis of the online survey, drawing parallels and contrasts between these two research tasks. The section concludes with a summary of findings and opportunities for further research.

### 6.2.2 In-place Method

Figure 6.3 gives an idea of the nature of the research task, with people taking a few minutes away from the field activities to write their thoughts.

*Figure 6.3: Photographs of qualitative approach at the field site in Blackburn.*

The broadness of this first task received a multitude of responses, including mention of their individual lifestyles, relation to wider environmental and social discourses, and beginning to touch on pro-environmental behaviours. The transcription of these written responses can be found in Appendix 15.

Most prominent across the responses was the positivity of being involved in 'Homegrown/Homespun', complimenting the social findings of this research. Their involvement was described using words such as "therapeutic", "happier", "empowering", and being "the opportunity to be the change". One response, "happier, healthier, and mad as hell about the state of the world" was suggestive of the contrasting wellbeing benefits to the educational aspect encouraging wider thinking of what could be climate change, politics, or current mass production/consumerism. 'Homegrown/Homespun' can be considered a facilitator of providing people with physical and psychological capability to engage in environmental action, supporting both wellbeing, education, and encouraging pro-environmental behaviours (Soga and Gaston, 2022).

As with the social research and analysis, the sense of community is at the heart of 'Homegrown/Homespun', described as "meeting likeminded people", considered a "close-knit team working towards a common goal", and being a "flax family". There were expressions of gratitude towards the project stakeholders and other volunteers for this opportunity to learn and engage with the project. This gain of knowledge was most frequently mentioned, suggested to be the most impactful takeaway from volunteering, in line with findings from Peter et al., 2019).

Nine of the fifteen responses began to explicitly engage with pro-environmental behaviours. This does not discredit the other responses, as these begin to engage with the social elements and educational purposes of 'Homegrown/Homespun', both considered spheres of influence of pro-environmental behaviour (Grilli and Curtis, 2021). The most frequently mentioned impact was on consuming clothing, becoming more "appreciative", "conscious", "thoughtful" and being "more aware of fashion industry issues" and what it takes to produce a garment. The indirect educational element is translating into direct action to consume clothing more consciously, critically engaging with questions like "Do I really need this or just want it?". In addition to private-sphere changes, there was mention of public-sphere influence, with people “more confident to talk to others about these (fashion) issues”, “repeating what I hear”, and “having more power and information to spread the word”. The volunteers engaging with ‘Homegrown/Homespun’ potentially contribute towards a catalytic movement of information-sharing and empowerment at the community level, supporting a bottom-up approach to wider climate action (Lope and Weave, 2021).

> “Nature has no choice but to use the materials available and actually seeing nests created with plastic for me was devastating. To provide an environment that can be fully sustainable is the future of the world. Growing from seed to fabric has been an amazing project, creating lots of new friends and helping the environment.”

This quote above sheds some light on the thought process of one volunteer, with an experience while volunteering beginning to parallel the ‘nature-empathy-compassion' pathway potentially encouraging pro-environmental behaviour (Thiermann and Sheate, 2020). The exposure to the realities of the ecological crisis indirectly through volunteering engages with Stern et al.’s (1999) value-belief-norm theory and continuing to engage with the ‘Homegrown/Homespun’ project as an inferred avenue of activism and participation in community action. While this quote did not explicitly mention seeing the plastic polluted nest at the field, having seen a photograph and adjoining description on display at the volunteer-led exhibition, and previously speaking to this volunteer about this experience, I understood the contextual picture. Without having been positioned as a participatory researcher and engaging with this volunteering community over many months, this level of analysis would have been unfeasible. This observation supports the greater depth and consequential analysis achieved by being a participatory researcher (Keahey, 2021).

### *6.2.3 Online Survey*

The analysis of the survey results is exclusive to a small group of the volunteers, and only those who have been volunteering with ‘Homegrown/Homespun’ long-term and who attend sessions most frequently. All responses were from volunteers who had been with the project for over a year and those who attend every week/fortnight or once a month, with this greater engagement potentially facilitating an openness to share their views or describe the impact volunteering has had on their lives. Overall, the results of the survey suggest there is a positive relationship between volunteering and both nature connectedness and pro-environmental behaviours. Importantly, some behaviours were reported to have 'seen no change' and suggest volunteers were engaging in certain pro-environmental behaviours prior to involvement with 'Homegrown/Homespun'. The quantitative results can be found in Appendix 15.

#### *6.2.3.1 Nature Connectedness*

Connectedness to nature was reported to have increased, with two participants reporting no change or, on the other end of the spectrum, only now building a relationship with nature. Participants shared now their gained ecological knowledge and attention to nature, having a "wider knowledge of different types of plants and their uses", being "more in tune with the growing seasons", and "slow(ing) down to look and see the plants". A few responses detailed experiences or memories from sessions at 'Homegrown/Homespun', drawing on learning more about plants and sustainability. One participant wrote they "no longer see some plants as weeds", suggesting a cultural shift in the perception towards plants and the purpose they serve.

Two responses detailed a greater appreciation towards nature and the benefit to their mental health, complementing the responses seen in step one of this method and the potential for these to encourage pro-environmental behaviour (Soga and Gaston, 2022). One participant noted the negative side of feeling more connected to nature, feeling "more stressed about how others treat their surroundings". There is potentially an emotional pathway here that connects increased nature connectedness with feelings of eco-anxiety, which in some cases could promote pro-environmental behaviour (Stanley et al., 2021).

Increased connection to nature was not homogenous across the responses, with one participant sharing, "aside from perhaps a little more awareness, my relationship with nature is unchanged". Regardless of whether this individual feels strongly connected to nature or not, they mentioned "spending more time outside" and "enjoying the community aspect", seeing personal benefits and these suggest other avenues for encouraging pro-environmental behaviours. This response and another, where they describe having made "fantastic friends", linked being in nature with the social element of volunteering with 'Homegrown/Homespun'. Drawing parallels with the social research and step-one of this pro-environmental behaviour inquiry, the sense of community could facilitate greater connection to nature, acting alongside the volunteering sessions to provide both motivation and opportunity for nature interactions (Soga and Gaston, 2022; Grilli and Curtis, 2021).

#### *6.2.3.2 Fashion & Textiles*

The impact of volunteering was most prominent in the fashion and textiles category, complementary to prior findings. Responses described an increase in education through volunteering, although it was not shared whether these were the sessions themselves or the volunteer community (potentially a mixture of both of these elements). One response suggested their environmental awareness was from the 'Homegrown/Homespun' volunteer network, prompted by discussions with others.

> "Being out on the field and connecting with nature has definitely had an impact on the way I view the textiles industry and its links with agriculture and ecosystems."

As suggested in the quote above, one respondent alludes to adopting a systems-thinking approach, considering the complexity of interactions between textiles and the environment. This was further strengthened by another response that detailed being "much more aware of the impact the fashion industry has on the environment". They have evidenced a causal relationship between volunteering and nature connectedness with changing attitudes, one avenue for encouraging pro-environmental behaviours (Thiermann and Sheate, 2020). Critically, changing attitude does not necessarily correlate with increased pro-environmental behaviour, with this conceptualisation of knowledge-attitude-practice widely critiqued for its simplicity and assumptions in citizen science projects (Somerwill and When, 2022).

However, it was described how increased education and awareness manifested into private-sphere lifestyle changes to "buy second-hand", "mend and alter existing clothes", "make clothes", "buy less", and purchase from "sustainable, ethical brands".

> "I've even started darning my socks! I'm making more of my own clothes to gradually replace the fast fashion items I'm currently embarrassed to possess."

The self-surprisal exclaimed at darning socks alludes to the unanticipated behaviour changes as a result of involvement with 'Homegrown/Homespun'. Furthermore, their feeling of 'embarrassment' is insightful into the newfound conscious consumer, motivated to move away from fast fashion and evolve their clothing to reflect their social identity, potentially the group identity of 'Homegrown/Homespun' (Fielding and Hornsey, 2016).

> "I've considered starting a vintage online store...I used to shop for clothes with eco credentials but have now bought into the 'you already own it' message... If it doesn't fit me I'll swap with someone from HH if possible."

Here, a volunteer details their thought process, sharing their engagement with multiple strands of pro-environmental behaviour in relation to fashion. Firstly, the individual scale and moving from being a conscious consumer to actively supporting less consumption, and in bringing in the beyond-individual scale of clothes swaps within the 'Homegrown/Homespun' network and contemplating with pursuing a vintage clothing business.

These findings further suggest alongside nature empathy and the role on pro-environmental behaviours, the volunteering may support the reduced "attitude-behaviour-gap" (Wintschnig, 2021). By facilitating an indirectly educational and community-centric space for pro-environmental behaviour change, this allows people to consume in a more sustainable manner.

#### *6.2.3.3 Private- and Public- Sphere Pro-Environmental Behaviour*

The conservation lifestyle responses are more variable, but there is an overall positive trend on the impact of volunteering on household, transport, and consumer towards more environmentally friendly behaviours. Aspects such as recycling and saving water, reducing car usage, and changes to diet and purchasing decisions, are reported to have increased, but no impact on other aspects, such as energy supplier choice or investment choices. There was also an increase of those 'greening' their outdoor spaces and growing food. But around 25% of participants shared they were already engaging with private-sphere pro-environmental behaviours prior to engagement and have seen no change, suggesting 'Homegrown/Homespun' attracts a sub-set of people already engaging in pro-environmental behaviours.

> "Meeting people that share concerns and encouraging positive behaviours and action."

Detailed by one participant in the quote above, volunteering with 'Homegrown/Homespun' was reported to have increased survey respondents' engagement with public-sphere pro-environmental behaviours, both under 'social environmentalism' and 'environmental citizenship'. All but two respondents said they are more frequently communicating and discussing environmental issues, participating in environmental events/groups, and encouraging others to get involved in environment-related events. There is little engagement with contacting local MPs or councillors about environmental issues or donating money to environmental action, but greater support for signing petitions, engaging with movements or reading environmental-oriented news, and voting to support environmental policy. This diversity of responses here, none superior, sheds light on the numerous avenues for supporting climate action. 'Homegrown/Homespun' potentially provides a space to empower individuals and localises climate hope, promoting holistic collective action in the broader environmental-political sphere. This is particularly important in the context of community projects supporting the Sustainable Development Goals and 2030 Agenda for Sustainable Development, working towards an equitable, climate resilient world (United Nations, n.d.[b]).

In the qualitative responses, participants shared how they were "growing herbs and flowers", "growing food", "gardening", "swapping plants and cuttings with other volunteers". Further mention was made for going to a "refill shop" and making "shorter journeys on foot rather than driving". Participants mentioned being "much more aware of environmental issues" and "more conscious of greenwashing". A large emphasis was placed on the social influence of having this community of "like-minded people, sharing ideas and supporting each other". "Talking" and "attending events" with other volunteers "has led to a more thoughtful approach to what we buy and wear". Collectively sharing skills related to sewing, willow weaving, weaving, natural dyeing, consuming medicinal herbs and foods, presents the knowledge-rich hub of the volunteering community. The quantitative and qualitative responses of the survey grasp the role of 'Homegrown/Homespun' as a facilitator in increasing environmental awareness, directly impacting private- and public-sphere behaviour.

“I’m still making bad decisions – going on holiday, driving a dirty [non-environmentally-friendly] car etc. But I’m striving to change where possible.”

Finally, the honesty and reality of the quotation above highlights the limits of private-sphere pro-environmental behaviours alone. While ensuring not to discredit the optimism and agency of this individual, acknowledging the limits to individual action in economic and social contexts, emphasises the multi-scale transformation embedded within systematic climate action (Newell et al., 2021). ‘Homegrown/Homespun’ is an example of a project appearing to transcend these scales, providing a space for collective action and encouraging new forms of thinking and engagement within fashion and farming systems, while encouraging pro-environmental behaviours at the individual- and community-scale. In what Newell et al. (2021) describes as ‘feedbacks’ and ‘learning loops’ in a ‘spiral of sustainability’, ‘Homegrown/Homespun’ provides a critical space for individual empowerment and to support climate action at multiple levels.

## *6.3 Limitations*

As a form of self-reported behaviours, this research approach can be critiqued for its validity, specifically the large margin for reporting biases from optimistic views of self, evaluation anxiety and multiple forces at play behind pro-environmental behaviours (Larson et al., 2015; Lange, 2022; Gifford, 2014 cited in Lange, 2022). In an idealised context, the research approach would be a longitudinal study, capturing the pro-environmental behaviours of volunteers at the beginning of their volunteering, and explored at semi-annual or annual intervals to more appropriately explore behavioural changes.

## *6.4 Conclusions*

To address objective five, it is suggested long-term, frequent volunteering with ‘Homegrown/Homespun’ has encouraged pro-environmental behaviours at the individual and wider community and political scales. However, this can only be attributed to a niche group of the volunteers. There are some findings to suggest volunteering with ‘Homegrown/Homespun’ facilitates ‘nature-empathy-compassion' thinking and this has “spillover effect” to encouraging environmentally friendly behaviour (Thiermann and Sheate, 2020).

The 2-step approach supported the conclusion above and provided an insightful analysis of complementing and contrasting responses. However, the online survey more robustly and critically considered the impact of volunteering on pro-environmental behaviours, uncovering the degree of prior engagement with pro-environmental behaviours and extent of influence.

‘Homegrown/Homespun’ is an example of an initiative that begins to transcend the scales of climate action, a space to engage and learn about sustainable and regenerative fashion, which fosters a network of highly motivated individuals that engage in collaborative learning. Both this space and network empowers individuals to make behavioural changes. However, investigating pro-environmental behaviours from volunteering with ‘Homegrown/Homespun’ requires further research and analysis, as there are critiques for self-reported environmental change methodologies and a longitudinal study would comprehensively assess this degree of influence on environmental behaviours.

## *6.5 Recommendations*

These findings indicate ‘Homegrown/Homespun’ provides direct and indirect climate benefits at multiple social scales, and the opportunity to upscale this project and its community reach could play a critical role in empowering the community of Blackburn and Lancashire to partake in collective climate action.

# Chapter Seven: Triple Bottom Line Sustainability

## 7.1 Overview

The following chapter explores triple bottom line sustainability (TBL) tensions in relation with scalability and commercial transition. This discussion is guided by objectives six and seven of this research, bringing together objectives one to five. The following questions give this chapter further structure:

1. What are the contextualised barriers to scaling up 'Homegrown/Homespun'?
2. What are the tensions between the economic, environmental, and social aspects of sustainability in the face of upscale?
3. Are there identified avenues for strategic tension management when exploring different scales of production?

## 7.2 Scaling Up 'Homegrown/Homespun'

Revisiting the sustainable upscale barriers identified in the literature review (figure 2.1 and table 2.1), table 7.1 expands upon the barriers identified in the literature and further draws parallels, contrasts and greater depth to the barriers applicable to the 'Homegrown/Homespun' initiative. The left-hand column illustrates the categorisation of the barriers; organisational, institutional, technological, societal, economic, and market. The subsequent columns draw parallels with the literature, providing explanation of these in context to 'Homegrown/Homespun'. This research provided greater insight into the specific barriers faced by reshoring textiles, and the capacity to upscale linen and natural dye production.

Some barriers in the literature specifically illustrate the challenges with transition to a SBM while also upscaling operations. Therefore, some barriers suggested by the literature (presented in table 2.1) are less applicable to 'Homegrown/Homespun', more so to a sustainability transition, such as transparency and a lack of sustainability incentive.

*Table 7.1: 'Homegrown/Homespun' barriers to sustainable upscaling and parallels with existing literature.*

| **Barrier Categories** | **Barriers Supported by Literature to 'Homegrown /Homespun'** | **Contextualised Barriers** | **Upscaling barriers identified in existing literature less applicable to 'Homegrown /Homespun'** | **Explanation of less applicable barriers** |
|---|---|---|---|---|
| *Organisational* | Limited skills, expertise, knowledge. | At the community-scale, there is evidence of skill- and knowledge- sharing, but not to the sufficient scale/large audience required for upscale of operations.<br>Transparency and sustainability main principles of 'Homegrown /Homespun' (not a barrier in itself). | Lack of sustainable performance measurements.<br>Lack of supply chain transparency.<br>Low-level employees experience disempowerment. | Sustainability performance and transparency have been stressed as key themes in the business model. |
| *Institutional* | Strict, often complex, legislation and regulation for technological-oriented sustainable business models. | Current uncertainty about the degree of legislative and regulatory barriers to exporting/importing flax.<br>Existing difficulty has been accessing flax seed for the 2022 crop due to Brexit and reliance on larger seed distributors.<br>Institution can bring in strict regulations for natural fibres – most applicable to hemp but also for re-using seed for cultivation. | Lack of incentive to change and lack of regulatory pressure.<br>Lack of local empowerment and short-term priorities. | Inviting and encouraging long-term change as part of the proposed upscale.<br>Volunteering has encouraged local empowerment. |
| *Technological* | Lack of technology for sustainable alternatives.<br>Lower costs of established infrastructure. | Remains the largest current barrier for flax processing and natural dye extraction & processing.<br>Flax processing is limited in the UK – with closest available facilities in Northern Ireland (non-complete processing line) and in Europe. | Limited processing technology for waste management, recycling, and reusing. | Not enough research into the available options for waste management, but the proposal includes commercial composting. |

| | | | | |
|---|---|---|---|---|
| *Societal* | Higher associated costs for the consumer and sustainable alternatives compete against the cheaper options. | Unknown affordability of any products from this proposed supply chain.<br>Community-level offers sustainability awareness and education through the social dimension.<br>Further unknowns about acceptance of flax-based denim and natural dye fastness but may be attractive to a niche market. | Lack of education on sustainability issues, therefore, a lack of consumer acceptance of sustainable alternatives. | Stakeholders have sustainability high on their agenda.<br>Consumer acceptance may need further research – the closer to standard denim, the more likely to be accepted. |
| *Economic* | Lack of infrastructure and skilled labour.<br>Limited financial resources or access to available funding that prevent the purchase and implementation of technology, and ability to upscale operations. | Flax and natural indigo remain uncertain and with limited trials using regenerative principles.<br>High economic uncertainty of a flax and natural dye supply chain.<br>Currently limited infrastructure for commercial scale and lack of specialised skillset.<br>Reshoring textiles to the UK is going to have higher costs than more global supply chains, driven by higher wages.<br>Issues with available UK labour for agricultural and low-wage work. | Lack of economic incentives for cleaner production methods, technologies and solutions.<br>Subsequent lack of sanctions and prohibitions for unsustainable ones.<br>Focus on short-term priorities that have higher certainty of returns. | This proposed sustainable business model is centred on more sustainable operations with long-term perspectives in mind. |
| *Market* | n/a | Sustainable alternatives are becoming highly competitive, and flax and natural dyes have both achieved increased interest. | Lack of market competitiveness and demand for sustainable innovation. | (See column to the left). |

This research contributes a further organisational barrier. The multi-stakeholder design of the initiative produces many opportunities for collaboration but also conflicting sustainability and organisational priorities that may further harness upscale. It is the direct exploration of the ‘Homegrown/Homespun’ case study which has demonstrated this as a potential barrier to upscale.

## *7.3 Tensions, Upscale & TBL*

The equal importance of the environmental, social, and economic dimensions of sustainability, coined by Elkington (1998) as TBL, is a pragmatic approach to sustainable supply chain management. Approaching the scalability of SBMs often produces tensions between the social, economic, and environmental elements of TBL, requiring strategic management. This strategic management would include how to appropriately address and communicate these tensions, which may take into account a timeline towards achieving TBL sustainability.

Figure 7.1 illustrates the outcomes of prioritising each of the dimensions of TBL, drawing attention to these conflicting themes that are of particular relevance to the 'Homegrown/Homespun' case study. The stronger the priority, the closer the point to the corresponding theme. Notably, the key observation here is the dramatic difference in priorities, and understanding there will be some trade-offs, in the short term, towards working to achieve TBL.

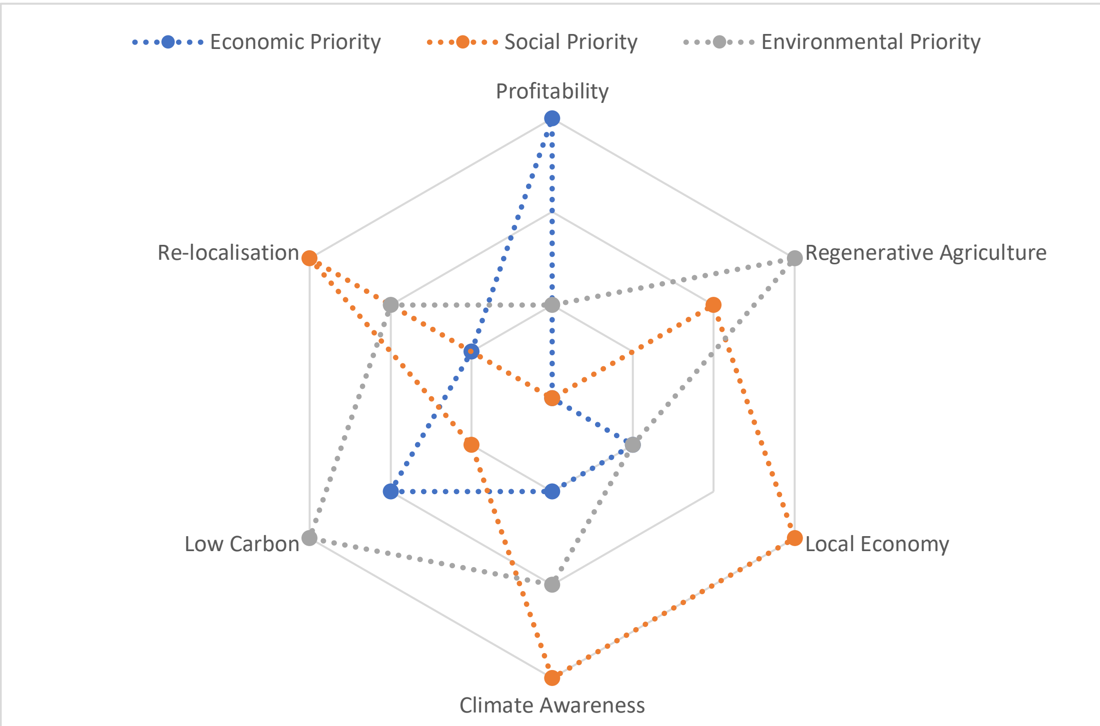



*Figure 7.1: Conflicting priorities for each dimension of TBL sustainability, in the context of 'Homegrown/Homespun'.*

Figure 7.2 outlines the three dimensions of TBL sustainability; economic, social, and environmental, and detailing the ideals of each dimension (Jablonski, 2016), and suggesting a few overlapping example management approaches between each pair (Diaz-Correa and Lopez-Navarro, 2018). The central overlapping space for 'TBL sustainability' can be fulfilled using a diverse set of supply chain approaches. One such approach is the idea of 'hybrid organisations', which can exist "either side of the for profit/non-profit divide, blurring this boundary by adopting social and environmental missions like non-profits, but generating income to accomplish their mission like for-profits" (Jablonski, 2016, p.13). Moving away from conventional business models that primarily seek economic growth, the ideas of success when promoting TBL sustainable lean towards harmony between economic viability and the social-environmental aspirations.

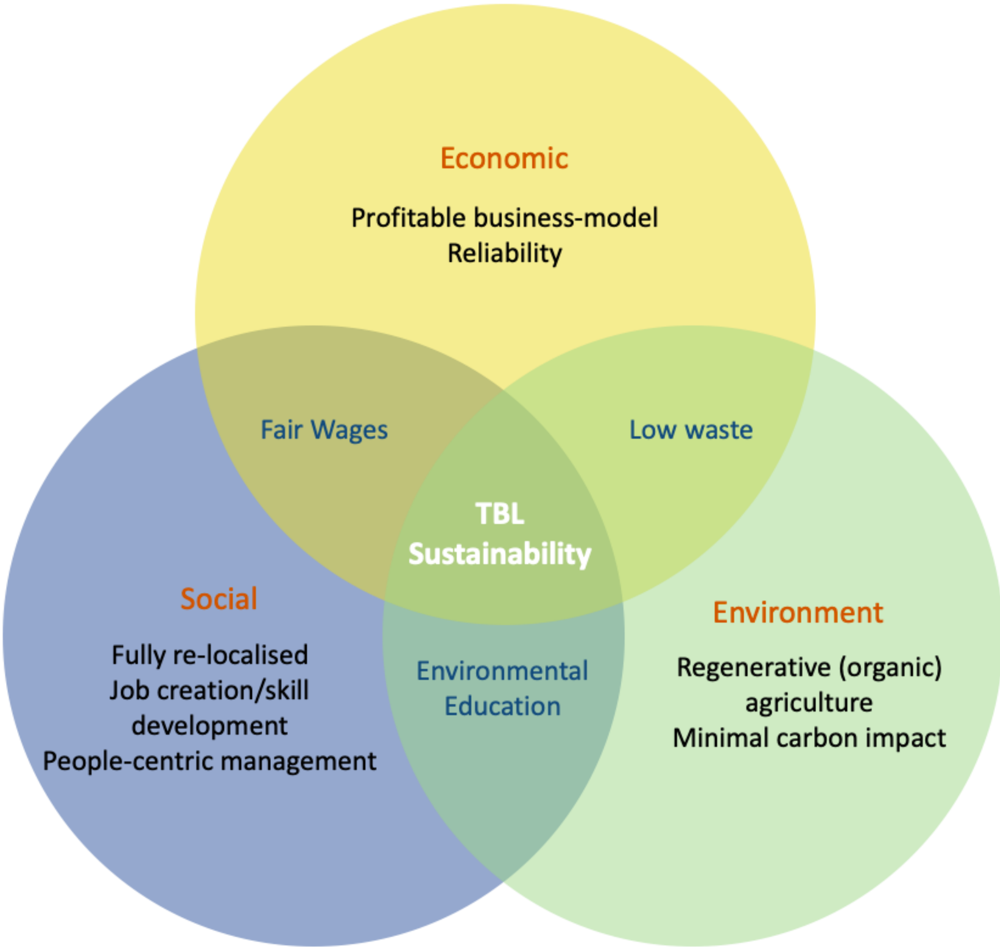



*Figure 7.2: TBL Sustainability, with reference to aspirations of 'Homegrown/Homespun', informed by Jablonski (2016) and Diaz-Correa and Lopez-Navarro, 2018).*

It is useful here to return to a definition of sustainable business models, proposed by He and Ortiz (2021) as 'extensions of conventional business models to include values relating to the environment and society, often considering these as primary stakeholders, and utilising long-term perspectives'. 'Homegrown/Homespun' in its current community-scale initiative offers the innovation and aspiration of a flax and natural dye-based supply chain underpinned by sustainable principles. In efforts to upscale to an operational supply chain and re-localise this to the UK, a high-cost production location, tensions arise between the aspiration and sustainability priorities and existing barriers. Explored by Harper (2022) in the context of the EU apparel industry, in what is known as 'paradoxical tensions', there are multiple challenges to effective implementation of small-scale production in high-cost environments, most commonly centring around sustainability priorities.

The immediate TBL tensions, and potential tensions in transition to a commercial supply chain, are outlined in table 7.2. The tensions here exist not just between economic-social-environmental, as might be suggested by the three elements of TBL sustainability but expand to include organisational and technological tensions. The tension is identified in the left-hand column, with a detailed description of this in the adjacent right-hand column. There are ten identified tensions described here.

*Table 7.2: Upscaling tensions of 'Homegrown/Homespun'.*

| **Upscale Tension** | **Description of 'Homegrown/Homespun' Tension** | **Tension Relationship** | | | | |
|---|---|---|---|---|---|---|
| | | Economic | Environmental | Social | Technological | Organisational |
| Technological requirements and transition of production scale to commercial supply chain. | Short-term orientation of the available processing options for 'Homegrown/Homespun' versus the long-term aspiration for a local flax processing supply chain for social value, local economy, and long-term environmental benefit. Due to infrastructural, temporal, and limited capacity, the supply chain options further afield (Northern Ireland or Europe) are most appropriate for short-term but are misaligned with the environmental and social principles of 'Homegrown/Homespun'. | ✓ | ✓ | ✓ | ✓ | |
| Regeneratively grown versus conventionally grown in context of yields, | Current uncertainty between the output and profitability of flax and natural indigo yields, especially using regenerative principles. There is potential for regenerative principles to produce smaller yields and, therefore, require greater land area. Economic profit margins may be | ✓ | ✓ | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| economic risk, and land usage. | smaller or regenerative-based system may be classed as non-economically viable. | | | | | |
| Commercial viability versus current social value at the community scale. | Quantity, quality, harvesting & processing requirements, and operational supply chain to a sufficient standard that is not possible to achieve at the current volunteer scale.<br>To transition to a commercial supply chain, this would require professional labour and partnership with specialised facilities. | ✓ | | ✓ | | |
| Inclusion of the volunteer community with organisations and structural decision-making. | The volunteer community can be considered a stakeholder, and in this transition to a commercial supply chain, potential for tensions between their visions and aspirations and those of the shareholders/key stakeholders. | | | ✓ | | ✓ |
| Personal versus organisational sustainability agendas. | Different social, economic and environmental perspectives of the key stakeholders and the organisational aspirations for upscale, considering the inability to achieve TBL in the near future. Varying priorities may produce tensions between each perspective of how to upscale and whether to prioritise the social or environmental aspects. | ✓ | ✓ | ✓ | | ✓ |
| Limitations of current textile manufacturing compared to sustainability aspirations. | Considering the limited available options for processing flax and technical extraction process for natural indigo, both constantly evolving but limited by available resources/infrastructure, environmental and social values produce tension with the organisational aspirations. Whether this be energy requirements and subsequent carbon emissions, or the social working conditions, collaboration with other facilities, these compromise TBL. | | ✓ | | | ✓ |
| Temporal and spatial opportunities for flax and natural indigo that may complement or contradict. | Flax and natural indigo are independent industries, developing and evolving at different paces. There is a potential tension if one progresses at a faster pace than the other; difficulties with sufficient quantities, production, and quality, producing organisational and economical tension.<br>Natural indigo may face challenges with growing yields, pigment yields, pigment purity, and | | | | ✓ | ✓ |

| | | | | | | |
|---|---|---|---|---|---|---|
| | application but is expected to be able to exist entirely within the UK.<br>The biggest challenge with flax is harvesting, extraction, processing and spinning, currently unlikely for the supply chain to exist entirely in the UK, producing further organisational complexity. | | | | | |
| Re-localised supply chain to UK or Europe in the face of political and financial uncertainty prompted by Brexit. | Added organisational complexity prompted by Brexit, requiring further customs and regulatory considerations for movement of flax for processing and spinning. This may impact European facilities' ability to collaborate with the 'Homegrown/Homespun' project, or proposed supply chain, and will raise the economic cost. | ✓ | | | | ✓ |
| Economic investment in localised supply chain and technical innovation. | Long-term aspiration for re-localisation of flax and establishment of a natural dye industry to the UK provides primarily social and organisational benefits. The scale for this to become economical, and the large investment costs, produce tensions between the social benefit with economic barriers.<br>Technical innovation for a lower carbon impact and re-localisation, such as for retting and extraction machinery, produces tensions between economic and environment. | ✓ | ✓ | | | |

## *7.4 Avenues for Strategic Tension Management*

The following section details some potential scenarios where the barriers and tensions outlined in table 7.1 and 7.2 differ at different scales of production.

### *7.4.1 Collection of <500 Garments*

At the smallest of commercial scales, the immediate barriers and tensions are those detailed in tables 7.1 and 7.2. To achieve the quantity of flax and natural indigo aspired by the 'Homegrown/Homespun' project for a small collection of jeans, this involves relying on volunteer labour to grow the crop and collaboration with existing infrastructural facilities. In this state, the supply chain is not considered commercially viable, centred on environmental education and community outreach within a volunteer group, rather than business management. To take the harvested crop to yarn and indigo pigment, this requires business partnerships with existing flax processing and yarn dyeing facilities, research and development, and learning from and collaborating with other small-scale projects.

### *7.4.2 Annually >500 Garments*

Producing a reliable and operational supply chain is the most challenging aspect of re-localisation/upscale, producing multiple tensions and a divergence between the commercial-scale production and community-centric educational aspect. This assumes both flax and natural dyes would be used. Categorised into different stages of the supply chain, the following sub-sections explore these tensions and potential navigation.

#### *7.4.2.1 Cultivation*

Further efforts to upscale cultivation requires collaboration with farmers. This begins to introduce professional agricultural labour and requires further research around take-up of regenerative practices. The 2021 Farming Practices Survey indicates there is motivation to take action to reduce greenhouse gas emissions, and further suggests information sharing, economic incentive or risk reduction could prompt action (Department for Environment, Food & Rural Affairs, 2021). In the initial upscale, there could be a deviation away from regenerative principles in the efforts to integrate growing into existing farming systems.

Due to the higher indigo pigment yields in Japanese indigo (*Polygonum tinctoria*) compared to woad (*Isatis tinctoria*), further field experiments should explore the ability for this to yield in UK climate (temperate maritime).

Cultivation would also require investment into agricultural harvesting machinery, a pulling machine for flax and modified harvesting machinery for woad, such as modified spinach or bean harvester mentioned by John and Angelini (2009). These investments require mass scale cultivation, likely over 100 hectares of flax and unknown scale for natural indigo, or collaboration with other initiatives to make economically feasible.

*7.4.2.2 Processing Flax*

The decision to either continuing to ret flax in the fields or consider tank retting should be determined by quality, cost and environmental footprint. Dew retting at scale would require turning the crop, which requires further investment into machinery. Similar to harvesting equipment, this could be shared between initiatives.

As retting massively reduces the weight of the crop, when considering water retting facilities, necessary investment into establishing a UK-based facility would largely reduce costs of further transport to flax processing facilities in Northern Ireland or Europe. This is especially considering the further costs associated with compliance with Brexit customs and regulations.

As at this scale it is unlikely to be cost effective to purchase flax scutching and hackling equipment (second-hand, or new), even if collaborating with other flax initiatives. Collaboration with Northern Ireland or European facilities to take retted flax to roving would be most economical, but this reduces the social value.

Alternatively, conversation with an industry expert and detailed in Maule et al. (2004), suggested flax processing should all occur at the farm scale, which would require alternative research and development. If this were a possible avenue for upscale, this could be achieved more locally and with fewer miles between processing facilities, potentially improving the environmental sustainability.

Flax spinning facilities are currently limited within Europe, but there are new flax spinning facilities opening in France and Italy in 2022. It would be uneconomical at this scale to develop UK-based flax spinning facilities.

Further exploration into the usage of flax tow would be recommended at this scale, reducing land usage and increasing flax co-product usage. This 'cottonisation' process would produce shorter fibres which could be spun similarly to cotton. Further research and development could explore the viability and quality of this yarn using UK or European spinning facilities. This has both economic and environmental benefit.

#### *7.4.2.3 Extracting Dye*

This research has focused less on the dye process. The 'Homegrown/Homespun' team have explored the possibility for indigo dye extraction and application to occur within the UK. This would have greater local benefit if this could involve educational and job opportunities.

The literature suggests potential methods for indigo extraction, notably reliant on temperature control, large volumes of water, and the requirement for appropriate wastewater management. Further research and development are necessary here, potentially collaborating with other natural dyers, both commercial and artisanal. The notable barrier is the ability for the natural dye extraction to yield sufficient pigment and application to be of sufficient quality for commercial usage. At this larger scale, it is assumed the colour palette would need diversification from indigo, comprehending the different methods for extraction and application for each natural dye category, something which goes beyond the scope of this research.

#### *7.4.2.4 Manufacturing*

The separate flax and natural indigo industries produce tensions between their development, timescales, and commercial viability. As these will likely diverge and develop at differing paces, these should be considered as such.

Garment manufacturing is being re-introduced into the UK, suggesting this stage of the supply chain could absorb the demand to produce these garments. In general, if there is a greater movement towards re-localisation of garment supply chains to the UK, some competitiveness may arise here. The manufacturing supports triple bottom line, assuming this can be economical, ethical, and moving towards low carbon.

#### *7.4.2.5 Community Impact / Local Initiative*

If the project were to transition from the community-focused volunteer scale to an operating supply chain, the social sustainability of local education, environmental awareness for climate action, and skill sharing would be lost. There are multiple avenues for maintaining this local benefit, often at a short-term economic cost. For example, a portion of generated profits could be reinvested into a social enterprise centring on regenerative food and textiles, building on Fibershed principles and could be a co-operative or community managed.

The expansion of projects or engagement with schools and other community learning hubs would provide multi-generational climate educational opportunities. Another option could be to finance apprenticeships, work experience, and short courses, to allow members of the local community to engage with the growing and manufacturing stages. Engagement with flax processing and spinning, and dye extraction, would be dependent on how and where this stage occurs. This could open opportunities for jobs in this potentially expanding industry, overcoming the barrier of lack of skills and labour for flax and natural dye industries and supporting economic sustainability in the long-term.

### *7.4.3 Potential for a Larger Industry?*

Any opportunity for a larger, functional flax and natural dye industry in a high-cost environment relies on the ability for the initial supply chain to upscale, highly dependent on the overcoming of the broad barriers outlined in table 7.2. With the annual production of natural fibres over 30 million tonnes (Towsend, 2020), and advocacy for the shift away from synthetic dyestuff, both motivated by ecological and climate concerns, the industry has a competitive future ahead. The findings of this research have begun to conceptualise and explore the sustainability impact and business possibilities, but their remains uncertainty to realistically explore prospects and resilience for a wider industry.

Crucially, considering TBL sustainability, this upscale and relocalisation is about finding a suitable scale that operates within planetary boundaries. This supply chain and resulting garment is likely to remain niche and expensive considering current barriers. Conventional business models fixate on increased scale and profit, whereas the proposed model of ‘Homegrown/Homespun’ acknowledges and promotes the environmental and social value of ethical, smaller-scale production. Notably, the technological and economic barriers for flax and natural dyes, defined by required technology and skill shortage, commandeer scalability. More so, the potential ‘road to relocalisation’ of this industry to the UK is one requiring high investment and time, partnerships with like-minded initiatives, and new ways of thinking about business and their placement within local contexts.

Place-based business models are one avenue for exploration, coupling local context with the product, as has been successfully seen by Harris Tweed in the Scottish Hebrides, to support competitiveness in the textile market (Burns and Carver, 2021). Of equal importance is the social sensitivity and local economic opportunity that can arise from place-based business models. Placing Blackburn at the heart of this proposed business model embraces the cultural context, heritage and opportunity for textile specialisms in a location that has experienced economic decline. Suited to the gradual revitalisation of textiles in the North-West, building upon its previous industrial heritage, there are prospects for rejuvenation and innovation across this geographical area.

A business model that invests profits to support local, community-based environmental education and opportunities for skill-building for employment prospects (also explored in table 7.3) would further facilitate commercial operation and scalability. At a larger scale, a clear environmental and social governance (ESG) policy and considering certifications such as B-corp, which is verified indication of meeting a high standard for environmental and social impact, would further demonstrate social and environmental sustainability (B corporation, 2022).

Figure 7.3 produces a summary of considerations of TBL sustainability and the different scales of production explored in section 7.4. As the feasibility and sustainability of upscale of the ‘Homegrown/Homespun’ business model is highly dependent on stakeholder and business management decisions, it is highly uncertain to predict the sustainability impact.

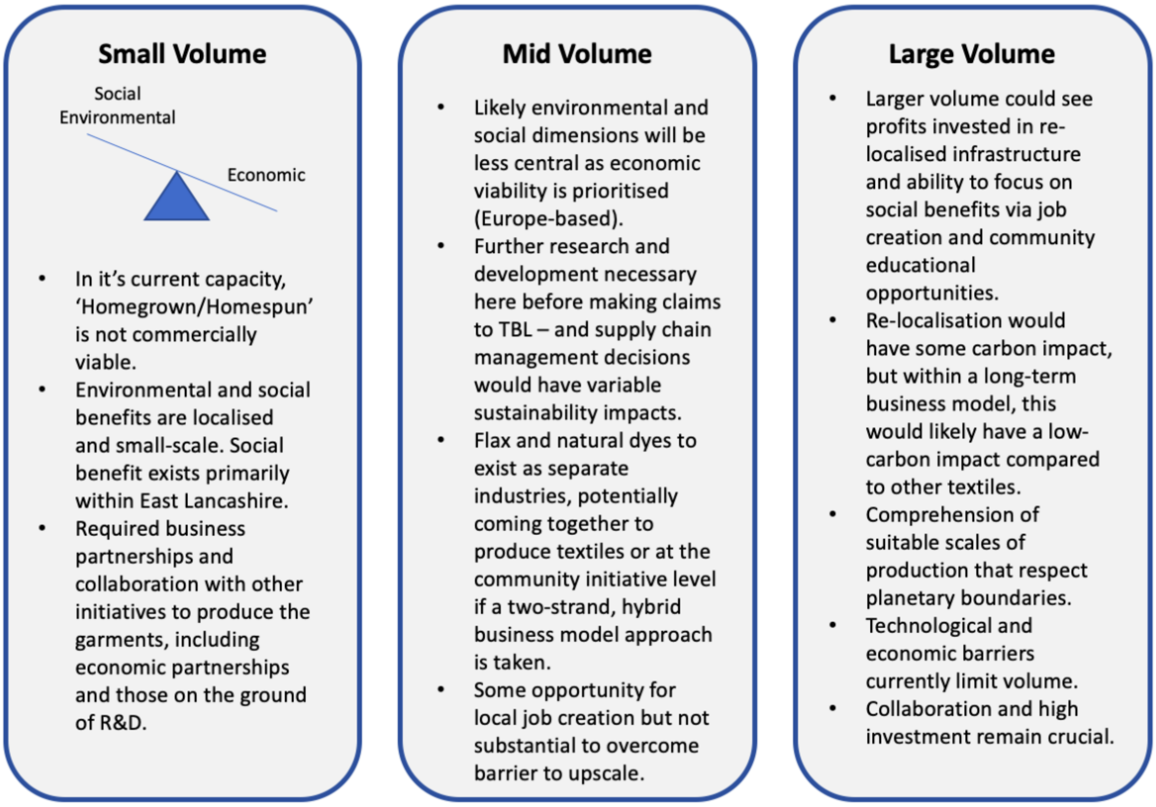



*Figure 7.3: Considerations to TBL and tensions at different scales of production.*

## *7.5 Conclusions*

This section has contextualised and explored the tensions and required strategic management for upscaling a flax- and natural dye- based industry in the high-cost environment of the UK. These tensions are diverse and non-static. In the context of 'Homegrown/Homespun', there is high uncertainty for an industry to exist at commercial scale while also fulfilling the TBL without further research and development. There is opportunity and motivation to collaborate with like-minded and innovative initiatives, together navigating the challenges and potential tensions of upscale and re-localisation.

Increased interest in natural fibres and dyes, within and beyond the UK as part of a global movement, continues to encourage and support the upscale of this SBM. The logistical, economic and technological barriers are most prominent. Organisational efficacy frequently comes at the expense of environmental and social sustainability in the short-term, despite the overall improvement in environmental and social standards of the proposed supply chain compared to many global apparel supply chains.

## *7.6 Recommendations*

The recommendation is to support a gradual re-localisation, acknowledging and accepting trade-offs between elements of sustainability as part of a long-term, larger vision towards a UK- based sustainable natural textiles industry. For example, investing into skills training and technological innovation while being open and transparent with stakeholders and consumers about current limitations to operating a fully sustainable supply chain. Gaining support from related funding bodies and local governments may provide further opportunities.

# *Chapter 8: Conclusions*

This chapter draws conclusions from the research findings, which aimed to investigate the feasibility of low-carbon upscale of a textile industry in the North-West of England. 'Homegrown/Homespun', a community focused collaborative enterprise in Blackburn, provided a specific example of a flax and natural dye project that is re-imaging our fashion and textiles industry. The research was guided by seven objectives, to consider the economic, environmental, and social dimensions of triple bottom line sustainability and produce recommendations for sustainable upscale. The research approach was varied and interdisciplinary, combining information from secondary data analysis, an LCA of carbon emissions, and embracing participatory action research to conduct primary qualitative research and discuss with industry experts.

Chapter seven drew parallels and conclusions between chapters two to six, bringing together the different elements of sustainability. The main findings, field contributions of this research, and opportunities for future research are outlined in the following section.

The results of the economic feasibility study highlighted the uncertainty for flax and natural dyes to exist at scale, prompted by yield uncertainty and lack of infrastructure that carry high economic risk. The market research explored options to collaborate with European facilities for the flax supply chain, which has an established flax industry. If a supply chain was established, there should be considerations towards re-localisation of scutching facilities, as this would massively reduce the weight of produce being transported for processing. Natural indigo poses similar economic uncertainty, with challenges focused on yields and reliable extraction and yarn application, although this has greater chance of being fully operational within the UK.

By comparing regenerative flax cultivation to conventional growing, this suggested regenerative farming supports a low-carbon system, which could have a 65% in carbon emissions when removing synthetic fertilisers and land tillage. Taking this into account, the carbon LCA suggested flax-based denim could have 1/3 to 1/5 of the carbon impact compared to a pair of standard cotton jeans (Levi's and Strauss., 2015). Including considerations for transport within a European supply chain, this could be ½ the impact of cotton jeans. The findings further supported a fibre-to-product estimate of carbon emissions, drawing together a range of data and literature, although data gaps remain prominent.

The qualitative research into the social dimension of sustainability suggested the social benefits of volunteering with the 'Homegrown/Homespun' initiative include improved wellbeing, greater awareness of environmental issues and impacts, becoming a community and learning valuable skills. Quantitative and qualitative data collected through a self-reported behaviours survey and written task suggested long-term, regular volunteering with the initiative has encouraged pro-environmental behaviours at the individual and wider community level. The research journal was also critical to draw connections and develop the research and analysis. This social value is localised to a small community, and there were examples of apprehension towards upscaling the initiative due to a fear of losing friendships and learning opportunities. Inclusive decision-making and improved communication may empower the volunteers and increase volunteer satisfaction. In turn, greater volunteer satisfaction will provide added success for the initiative.

The main findings suggest it is extremely challenging to achieve TBL sustainability considering the current supply chain opportunities and barriers. Notably, the technological and economic barriers for flax and natural dye industries to exist at commercial scale, are defined by insufficient infrastructure and skill shortages, re-enforcing the challenges faced by Maule et al. (2004) and Riddlestone et al. (1994). The potential localisation of these industries to the UK would require high economic investment and time, partnerships with like-minded initiatives, and creative approaches to business models. Opportunity remains to benefit from a re-localised supply chain, with designer and SME brands capitalising on the 'Make in the UK' marketing (Robinson and Hsieh, 2016).

Moving forward, 'Homegrown/Homespun' could consider a two-strand model, with a commercial supply chain or brand reinvesting a portion of generated profits into a social enterprise based in Blackburn, East Lancashire centring on regenerative food and textiles. Without the local aspect, the social sustainability of local education, environmental awareness for climate action, and skill sharing would be lost.

The participatory style of this research, which involved attending the volunteering sessions and becoming part of this volunteer community, supported a more in-depth analysis of the research aim, and mobilised an alternative methodology for holistic bottom-up research. Direct engagement with this community contributed to high quality insight into the social impact and implications of upscale. This model is particularly important when considering that social sustainability has received lesser attention in the relevant sustainable transitions and SSCM literature, and Keahey (2021) highlighted the potential for participatory research to facilitate inclusion of social sustainability. The research journal was an integral part of the research process, drawing together information from informal conversations and across multiple meetings, as well as to reflect on the research process. The research posed many challenges for its interdisciplinary, emerging nature, and the journal began a space to actively reflect on these and become 'reflexive' towards my role as a participatory researcher.

This case study approach has contributed to a greater understanding of upscaling SBMs and re-shoring garment manufacturing to high cost economies, appropriately addressing this research gap identified in the literature and contributing to a growing research discipline. It acknowledged the opportunities for upscaling sustainable innovations, including the embrace of alternative business models that encourage sustainability and aligns textiles to the SDGs (Blok et al., 2015). It built upon or contradicted the barriers outlined in the literature (Stewart et al., 2016; Gupta et al., 2020; Todeschini et al., 2017; Laukkanen and Patala, 2014). These were contextualised to the prospects of a flax and natural dye industry existing in a UK-based supply chain.

Notably, this research contributes a further barrier that was not identified in the literature; the multi-stakeholder design of the initiative produces many opportunities for collaboration but also conflicting sustainability and organisational priorities that may further harness upscale. This finding is particularly evident in the case study, as funding opportunities draw the initiative in multiple directions.

Despite the many barriers faced by the 'Homegrown/Homespun' initiative, the innovation and daring aspirations invite new ways of thinking about textiles, agriculture, and our relationships to these systems. The exploration of feasibly socially embedding this supply chain within North West England, and with specific ties to

Blackburn, supports a growing field of research towards socially sustainable and regionally resilient socio-economic systems (McKeever et al., 2015; Di Gregorio, 2017; Burns and Carver, 2021).

Further research is required to assess the feasibility for a sustainable UK-based flax and natural indigo textile industry. Exploration of the required technology innovations and infrastructure, such as for retting facilities and indigo pigment extraction would highly steer the course of this supply chain. Opportunity to re-localise flax spinning requires further insight and exploration of resource and infrastructure optimisation, such as whole crop utilisation. Carbon uncertainty prompts further research into the energy usage of the manufacturing stages. A longitudinal study to explore the social benefits of volunteer engagement, and opportunities for hybrid business models, would further support a climate resilient and local economic activity to the North West of England.

The research highlighted an opportunity to move away from resource-intensive apparel supply chains towards SBMs that embrace social and environmental movements within its design, contributing to the idea of hybrid business models by Jablonski (2016). Prompted by the climate emergency and ecological damage of linear fashion systems, the increased market interest in sustainable materials from consumers, researchers and businesses alike, there is a visible trend to exploring and utilising alternatives. Furthermore, as the EU and other countries move towards implementing EPR policy, it is increasingly more about a question of 'when?', with economic consequences for businesses to continue in their resource-intensive and high carbon practices (Long and Lee-Simion, 2022; Norton, 2012). The chance to pioneer and reduce land and resource intensity is beneficial for all elements of sustainability, and increasingly highlighted as the future for the fashion industry.

# Appendices

## *Appendix 1: Field yield data sources and variation.*

| Source | Flax yield (tonnes per ha) |
|---|---|
| Simon Cooper, pers. comms. | 7.5 |
| Gomez-Campos et al. (2021) | 7 |
| Embrin, (n.d) | 7.5 |
| UK Company* | 5.4 |
| Average flax 2018-2020 production in Europe (FAO) | 2.6 |
| Average flax 2018-2020 production worldwide (FAO) | 2.2 |
| UK 2018-2020 (FAO) | 1.5 |
| Turunen and van der Werf (2006) | 6 |
| CELC (2022) | 6.6 |

*Pers. comms.

## *Appendix 2: Yields of fibre and co-products, with a percentage comparison to the inputted weight to the scutching process (dry, retted fibre).*

| | **Long fibre** | **Tow** | **Shives** | **Seed** | **Other** |
|---|---|---|---|---|---|
| Gomez-Campos et al. (2021) | 24 | 12 | 40 | 6 | 18 (flakes & inert residues) |
| Simon Cooper, pers. comms. | 14 | 14 | 40 | 12 | 20 (chaff) |
| CELC (2022) | 22 | 11 | 50 | 5 | 12 (soils, justs, rocks, miscellaneous) |
| Embrin (n.d.) | 23 | 10 | 54 | 9 | 4 (straw) |
| Turunen and van der Werf (2006) | 9 | 23 | 40 | 15 | 13 (coarse plant material) |
| Average | 19 | 14 | 45 | 9 | 13 |

*Appendix 3: Yields and description of data sources for natural indigo mean.*

| Data Source for Yield of Japanese indigo (Polygonum Tinctoria) | Indigo yield (kg/ha) | Notes |
|---|---|---|
| Angelini et al. (2004) - year 2001 | 156.1 | Central Italy under temperate conditions. |
| Angelini et al. (2004) - year 2002 | 247.2 | Central Italy under temperate conditions.<br>More favourable climatic conditions compared to 2001, with higher rainfall and higher air temperatures. |
| Hartl and Vogl (2008) + Vetter et al. (1999); Biertumpfel and Vetter (1999) cited in Hartl and Vogl (2008) | 320.3 | Field trials on organic farms in Austria (Hartl and Vogl, 2008) – dependent variable is the indigo content, calculated using the mean dyestuff percentage of leaf dry matter, mean of 2.06% to 6.37% (Vetter et al., 1999; Biertumpfel and Vetter, 1999 cited in Hartl and Vogl, 2008). |
| Hartl and Vogl (2008) + John and Angelini ( 2009) | 106.4 | Field trials on organic farms in Austria (Hartl and Vogl, 2008) – dependent variable is the indigo content, 1.4% dry weight (John and Angelini, 2009). |
| Average | 210 | |

| Data Source for Yield of woad (*Isatis Tinctoria)* | Indigo yield (kg/ha) | Notes |
|---|---|---|
| Angelini and Bertolacci (2008) | 156.4 | Central Italy – irrigation variable was not statistically significant, so mean across all experiments was used. |
| Sales et al. (2006) - year 2001 | 49.6 | Mediterranean Spain. Investigating the effect of sowing date on indigo yield. Maximum variation was 7kg, so the mean was used to calculate indigo yield. |
| Sales et al. (2006) - year 2003 | 18 | |
| Maule et al. (2000) | 20 | UK study (SPINDIGO). Predicted yield (not field experiments). |
| **Average** | **60** | |

*Appendix 4: Woad seed costs (indirect via pers comms. with 'Homegrown Homespun').*

| Source | Cost per unit | Cost per gram (£) | Cost per ha (£) |
|---|---|---|---|
| Nature's Rainbow 2020 | £41.15 per 100g | 0.4115 | 3497.75 |
| Ian Howard | £50 per 70g | 0.7143 | 6071.02 |
| Pasi Ainesoja | £66 per 130g | 0.5045 | 4315.38 |
| Average | n/a | 0.5445 | 4628.19 |

*Appendix 5: Exclusions and assumptions for calculating CO2e emissions from fertiliser and pesticide inputs to cultivating flax.*

| | |
|---|---|
| CELC (2022) | In this report, nitrogen inputs were detailed as 'nitrogen solution' so this was input as Ammonium Nitrate to be comparable to input quantity Turunen and van der Werf, 2007.<br>Zinc is not listed as an input on the Farm Carbon Calculator so these emissions were excluded.<br>The report gave a breakdown of the different types of pesticides, a combination of herbicides, insecticides and funigcides. These accounted for <10kg CO2e. |
| Tununen and van der Werf (2007) | No further breakdown of pesticides, so these were input as 'herbicide, generic' into the Farm Carbon Calculator. |

All emissions are reported in tonnes and are rounded to 0.01 on the Farm Carbon Calculator, meaning as a result, all estimated CO2e emissions are rounded to the nearest 10 kg.

Dissanayake et al. (2009) also listed fertiliser and pesticide inputs but this was in the unit 'per tonne of yarn'. As this is uncertain to quantify due to differing yields per hectare, this data was not included. Data provided in Dissanayake et al., 2009 is later included in diesel estimates.

*Appendix 6: Adapted comparison for methods of retting flax (Tahir et al., 2011).*

| Name | Description | Advantages | Disadvantages | Duration |
|---|---|---|---|---|
| *Dew Retting* | Plant stems are cut or pulled out and left in the field to rot. | Pectin material could easily be removed by bacteria. | Reduced strength, low + inconsistent quality; restriction to certain climatic change & product contaminated with soil. | 2-3 weeks |
| *Water Retting* | Plant stems are immersed in water (rivers, ponds, or tanks) and monitored frequently (microbial retting) | Produces fibre of greater uniformity and higher quality. | Extensive stench + pollution arising from anaerobic bacterial fermentation. High cost, putrid odour, environmental problems. Low-grade fibre. Requires high water treatment maintenance. | 7-14 days |
| *Enzymatic Retting* | Enzymes, such as pectnese, xylanses, are used to attack the gum and pectin material in the bast. The process is carried out under controlled conditions. | Provides selective properties for different applications. Easier - enzymatic reactions cause partial degradation of the components separating cellusic fibre from non-fibre tissues. Fast and 'clean'. | Lower fibre strength. | 12-24 hours |
| *Chemical Retting* | Boiling and applying chemicals, e.g. sodium hydroxide, sodium benzoate, hydrogen peroxide. | Efficient + can produce clean and consistent long and smooth surface bast fibre within a short time. | The fibre retted in more than 1% NaOH the tensile strength decreases. Unfavourable colour and high processing cost. | 75 minutes - 1 hour |

*Appendix 7: Variation in inputs across data sources – information has been calculated to be a comparable value (e.g. kg/sliver).*

| Scutching | |
|---|---|
| Source | kWh/kg scutched long fibre |
| Gomez-Campos et al. (2021) | 0.49 |
| Turunen and van der Werf (2006) | 1.63 |
| CELC (2022) | 0.09 |
| **Mean** | **0.74** |

| Hackling | |
|---|---|
| Source | kWh/kg sliver |
| Gomez-Campos et al. (2021) | 0.83 |
| Turunen and van der Werf (2006) | 0.59 |
| **Mean** | **0.71** |

| Roving | |
|---|---|
| Source | kWh/kg rove |
| Eynde et al. (2015) | 0.60 |
| Turunen and van der Werf (2006) | 1.15 |
| **Mean** | **0.88** |

| Sizing, Spinning & Winding* | Energy | Water |
|---|---|---|
| Source | kWh/kg yarn | Litres/kg yarn |
| Gomez-Campos (2021) | 12.18 | 14.0 |
| Turunen and van der Werf (2006) | 12.19 | 13.3 |
| Eynde et al. (2015) | 12.83 | 3.1 (as steam) |

*Due to differing methods outlined by each source, mean was calculated for carbon emissions not energy and water inputs.

| Bleaching* | Energy | Water |
|---|---|---|
| Source | kWh/kg | Litres/kg |

| | | |
|---|---|---|
| Turunen and van der Werf (2006) – hemp roving | 4.35 | 55.6 |
| Alam (2018) – jute yarn | 1.05 | 10 |
| Eynde et al. (2015) – hemp sliver | 23.98 | 30 |
| Ecoinvent (2017) – cotton fabric | 0.23 | 6.25 |

*Due to differing methods outlined by each source, mean was calculated for carbon emissions not energy and water inputs.

| Weaving | |
|---|---|
| Source | kWh/kg woven textile |
| Gomez-Campos et al. (2021) - flax | 14.1 |
| EcoInvent (2016) - cotton | 3.8 |
| Eynde et al. (2015) - hemp/cotton blend* | 12.5 |
| Palamutcu (2010) - not fibre specific, jacquard | 1.9 |
| Sanches et al. (2018) - cotton denim) | 0.8 |
| **Mean** | **6.5** |

*Eynde et al. (2015) – this study compares three fibre blends. For the weaving, the data was used for the hemp/cotton blend energy input rather than the hemp scenario because the hemp scenario had dramatically higher energy usage due to 'old, slow looms'.

*Appendix 8: Topic Guide for Focus Group & Interview*

Introduction & verbal consent

How would you describe your experience of volunteering for the Homegrown Homespun project?

How has this volunteering experience for Homegrown/Homespun shaped your relationship to Blackburn?

Are there any memories or skills you've developed that you would feel comfortable sharing?

Have there been any challenges you have experienced while volunteering?

What relationship would you like to have with the project if Homegrown Homespun was to develop into a commercial enterprise?

*Appendix 9: Consent Form and Participant Information Sheet.*

Lancaster Environment Centre | Lancaster University

CONSENT FORM

Project Title: Homegrown/Homespun; Scaling Up A Low-Carbon Textile System in Lancashire.

Name of Researcher: Helena Pribyl
Email: pribyl@lancaster.ac.uk

Please read the following carefully:

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐
3. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher/s, but my personal information will not be included, and I will not be identifiable. ☐
4. I understand that my name/my organisation's name will not appear in any reports, articles or presentation without consent from me. ☐
5. I understand that in any interview's audio-recorded and transcribed, that data will be protected on encrypted devices and kept secure. ☐

6. I understand that data will be kept according to University guidelines. ☐
7. I agree to take part in the above study. ☐

| Name of participant: | Date: | Signature: |
| --- | --- | --- |
| | | |

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher/person taking the consent

______________________________________

Date ______________________ DD/MM/YYYY

Returned forms will be kept in the files of the researcher at Lancaster University

Lancaster Environment Centre | Lancaster University

**Participant Information Sheet**

For further information about how Lancaster University processes personal data for research purposes and your data rights please visit our webpage: www.lancaster.ac.uk/research/data-protection

For further information about how Lancaster University processes personal data for research purposes and your data rights please visit our webpage: www.lancaster.ac.uk/research/data-protection

**Introduction**

I am a Master's by Research student at Lancaster University and I would like to invite you to take part in a research study, 'Homegrown/Homespun; Scaling Up A Low-Carbon Textile System in Lancashire.'

Please take time to read the following information carefully before you decide whether or not you wish to take part.

**What is the study about?**

This study aims to explore the barriers and enablers to scaling up re-localised low-carbon textile growing and manufacture, since the decline of the UK-based textile industry fuelled by the rise of globalisation and outsourcing of labour and materials. It aims to help support the 'Homegrown/Homespun' initiative – a network of local community groups, industry, academics and practitioners. The group has recently finished the pilot stage of a collaborative re-localised, circular textile industry in Blackburn: manufacturing and processing textiles from flax grown in the Lancashire region. This new model has many potential benefits including for: local community health and cohesion; health of the local environment and reductions in greenhouse gas emissions; and urban regeneration of a local green economy.

**Why have I been invited?**
I have approached you because of your importance to this project and/or because speaking with you will further my understanding of the opportunities, challenges and implications of a re-localised flax textile supply chain in Lancashire.

I would be very grateful if you would agree to take part in this study.

**What will I be asked to do if I take part?**
If you decided to take part, this would involve the following:

An interview of a pre-arranged length, or in the case of core stakeholders in the project ongoing dialogue throughout the project. Interviews may take place online or, with your consent, there may be an opportunity for an in-person interview, depending on COVID-19 restrictions and travel arrangements.

**What are the possible benefits from taking part?**
By taking part in this study, your insights will contribute to our understanding of whether re-localising a flax textile system is possible within Lancashire. As above, this new model has many potential benefits including for: local community health and cohesion; health of the local environment and reducing greenhouse gas emissions; and urban regeneration of a local green economy.

**Do I have to take part?**
No. It’s completely up to you to decide whether or not you take part. Your participation is voluntary, and you are free to withdraw at any time, without giving any reason.

**What if I change my mind?**
You are free to withdraw at any time and, if you want to withdraw, I will extract any data you contributed to the study and destroy it. Data means the information, views, ideas, etc. that you and other participants will have shared with me. However, it is difficult and often impossible to take out data from one specific participant when this has already been anonymised or pooled together with other people’s data. Therefore, after 3 months of the interview taking part, it may no longer be possible to exclude your data.

If anonymous questions are used, withdrawal may not be possible because the data is anonymised, and the data provided cannot be identified to a person.

**What are the possible disadvantages and risks of taking part?**
It is unlikely that there will be any major disadvantages to taking part.

**Will my data be identifiable?**
After the interview, only I, the researcher conducting this study will have direct access to the data you share with me. This will be discussed with my academic supervisors at Lancaster University and inform recommendations made to the project's stakeholders.
I will keep all personal information about you (e.g. your name and other information about you that can identify you) confidential, that is I will not share it with others. I will anonymise any audio recordings and hard copies of any data. This means that I remove any personal information. All reasonable steps will be taken to protect the anonymity of the participants involved in this project.

**How will my data be stored?**
Your data will be stored in encrypted files (that is no-one other than me, the researcher will be able to access them) and on password-protected computers.
I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic).
In accordance with University guidelines, I will keep the data securely for a minimum of ten years.

**How will we use the information you have shared with us and what will happen to the results of the research study?**
I will use the data you have shared with me only in the following ways:
I will use it for academic purposes and to inform the recommendations made to the project stakeholders about scaling up the local clothing supply chain in Lancashire. I may also present the results of my study at academic conferences or publications.
When writing up the findings from this study, I would like to reproduce some of the views and ideas you shared with me. When doing so, I will only use anonymised quotes (e.g. from our interview with you), so that although I will use your exact words, you cannot be identified in our publications.

**What if I have a question or concern?**
If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact myself:
Helena Pribyl
pribyl@lancaster.ac.uk

Or my academic supervisors:
Professor Mark Stevenson
m.stevenson@lancaster.ac.uk

Professor Jess Davies
jess.davies@lancaster.ac.uk

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact:
Director of the Graduate School for the Environment
Professor Jane Taylor
j.e.taylor@lancaster.ac.uk

Thank you for considering your participation in this project.

*Appendix 10: Codes from Qualitative Analysis of Social Impact.*

| Theme | Supporting Quotations |
|---|---|
| Nature / Green Spaces | 2: “to be out in the fresh air”<br><br>1: “with quite a bit of imagination, there’s arguably more land around an urban areas that can be cultivated for wildlife.” |
| Empowerment & Environmental Action | 6: “I’d always be an advocate, I thought I’d never thought I would be, but I would be an advocate for volunteering now.”<br><br>3: “It’s feeling you’re making a difference even if it’s in a very small way.”<br><br>1: “do something that you thought was worth doing”<br><br>2: “Because we’ve grown at the field, there’s quite a few of us who have been growing a patch of land at home.”<br>“It really makes you like, ‘oh gosh, really appreciate your clothes’ [laughs].”<br><br>4: “I think somehow it taps into people about being able to do something positive.”<br><br>1: “to be even a tiny part of doing things differently is kind of enlivening, it’s kind of energising and kind of entertaining.” |
| Environmental Sustainability | 5: “I came along because it was sustainability was the buzzword in the industry and I thought, well it can’t get any more sustainable than growing your own fibre, so let’s go and see what this is all about.”<br><br>1: “the way in which the world produces everything, including textiles, is polluting the world, using more resources than it should and it’s not doing things locally, and it’s not involving people in the way that it should” |
| Non-Financial Return | 2: “So, mentally, for my mental health, it’s been amazing”<br><br>1: “It’s just top and great fun, and it’s just lovely stuff to do.”<br><br>6: “…it’s a transaction, not a financial transaction but you’re giving something of yourself and receiving something from other people.”<br><br>a): “lovely way to end the week” |

| | |
|---|---|
| Learning | 6: “Seeing what the opportunities are”<br><br>2: “Yeah, cos you know, you don’t know what skills you have until you try it.”<br><br>2: “The thing is, going back to what I was saying about finding out about what you’re good at. And there’s a lot that I’ve found out I’m not good at as well.”<br><br>5: “We’ve learnt all sorts of wonderful things, haven’t we?”<br><br>6: “Textiles to me was a department in the college that I went to, that is where people were making cushions and stuff and it just seemed a bit boring but actually there’s so much more to it in terms of heritage.”<br><br>3: “And you’re learning, and you’re sort of pushing yourself into different directions and learning from other people.”<br><br>2: “I’d love to learn the whole process…They could have a little museum going where you’re actually spinning on site and to see how it’s working and weaving and everything." |
| Regeneration of Place | 6: “and really what needs doing I suppose.”<br><br>4: “And it was just such a beautiful space urm and in a bit of an unlikely spot I would say.”<br><br>4: “I think what was nice, was when we back to start on the extension of the field last week, is that people, cos you know, it was originally a fly tipping area. And the original site was still as we’d left it.”<br><br>4: “I think it’s nice about the greenhouses as well because, you know, obviously they used to be the council’s greenhouses and then, that’s not happening anymore, so it’s nice to give them a new, be able to give them a new lease of life, isn’t it [mutual agreement from group]. And actually, to be able to use that space, and it’s just nice to be there. And feeling like we’re renovating something while we’re doing it as well, cos those beds will still be there when it’s finished.”<br><br>6: “I think it’s just suffered years of neglect, hasn’t it?”<br><br>1: “I think the way it’s shaped my way to Blackburn is starting one because I think I’d been to Blackburn once or twice in my life before that.” |

| | |
|---|---|
| | 3: “There’s so much coming that obviously Blackburn does have a lot more to offer.”<br><br>4: “But, when you get underneath that canal and you start going on walks, and you start taking in nature, it’s such a beautiful place but people have just given it that label.”<br><br>2: “I’d not been to Blackburn before. It’s not a place to go. But it’s opened my eyes." |
| Sense of Community | 1: “with like-minded people.”<br><br>2: “That’s just being part of a group or a network of people. Likeminded”<br><br>5: “I think it’s the friendships that we’ve got, isn’t it? I think that more than anything."<br><br>1: “So, it’s great to be involved in an interesting project and the thing that was really great about it to begin with, is that it was during those times of lockdown that we’ll talk to our grandchildren about it, when you weren’t really allowed out and you weren’t really able to do much, but you were able to go to this field of like-minded, smiling people”<br><br>3: “The second time I came, I started getting used to familiar faces and started interacting with people, made friends, and it’s just been one of those fantastic big journeys.”<br><br>2: “We’re supportive, no matter what you do. Everyone’s so supportive. No one judges you or anything. It’s great. It’s a great group of people and I don’t think I’ve ever met a group of people like this."<br><br>3: “No one will ever feel left out.” |

| | |
|---|---|
| | 4: “And I felt a bit nervous obviously, not knowing anybody, but everybody was so welcoming, and it was so lovely.”<br><br>3: “We’ve had some really good laughs… we’ve had a journey.”<br><br>3: “I’d say, we’re just a team, we’re a very close team.”<br><br>2: “Don’t you think that’s the nature of the work because you’re all outside and you’re all doing the same thing? It becomes a community. It does feel like family for that reason.”<br><br>4: “You’ve all got that shared purpose, haven’t you? All working towards the same thing.” |

*Appendix 11: Codes from Qualitative Analysis of Upscale.*

| Upscale Theme | Supporting Quotations |
|---|---|
| Risk to Benefits | 6: “I think it’s important that that, I’m sure it won’t be, that that (volunteering) isn’t lost along the way.”<br><br>6: “I just feel the, it’s almost like the relationship may change or may have to change because it comes a point, they’ll start having to pay people for their skillset, won’t they? You know, pay them to do the work essentially is what I’m saying." |
| Inclusion | b): “I think what’s important as well for this particular group of volunteers is being, being involved and consulted as well as part of the process so that we are sort of aware of what the plans are and what’s happening.” |
| Reimagining Textiles Production | 1: “One of the things that interests me so much is there’s been an awful lot of emphasis on looking back if you like. This is a heritage industry; this is to do something that hasn’t been done for 50 years da da da. But actually, more interesting is well is this the way forward. And if it’s the way forward, it won’t be like it was in the past will it. Because we all know that, that the glorious industrial revolution that made us capital of the universe was the most horrendous situation for those to live in for the working class.” |

| | |
|---|---|
| Economic Dimension | 2: “Yeah, like how’s that gonna work going forwards? How are they going to be able to sell items that we’ve created if people are working for free?”<br><br>4: “It becomes a very different relationship and that’s where it would be sort of, some tricky bits to negotiate as to how that would play out. I think that’s what going to be interesting as well, with other examples that may exist across the world.”<br><br>6: “I think but if, if also people have been trained and given those skills and then being rewarded by, through employment, that’s one way.”<br><br>6: “I wonder if that’s a route for more volunteers, at the colleges, and get people that way. When it could be part of an accredited thing, part of courses.”<br><br>5: “But how many people are involved in making 100 pairs of jeans?”<br><br>3: “We definitely, we need 1 pair each at least for all of us…”<br><br>5: “Yeah.”<br><br>3: “Cos we’re gonna be out in them fields for quite a long time…” (laughter from the group) |

*Appendix 12: Supplementary Interview Notes*

**11/03/22 -** Notes from 10-minute interview

- They arrived about the same time last year, ’right from the start’.
- The social aspect a definite aspect – common interest means gelled quite quickly and the fact it was soon after lockdown.
- Like-minded people and was quite physical to begin with.
- Had no idea about the linen and natural dye process before taking part.
- Prompted questions about career choices and interests.
- The local aspect also appealed and getting outdoors.
- The project has become a support network for everyone through difficult times and to help each other through.
- Coming to the sessions is a nice release, ‘a lovely way to end the week’ and ‘get something productive done’.
- ‘It was all quite hard work really’.
- Quite often exchange skills within the group.
- ‘The idea is to use what we learnt last year to progress a bit.’
- ‘There were hiccups and difficulties so we’re hoping it will be more prepared this year. Although, there is a new dimension of scale-up’.

Thoughts on upscale:

- It'd be 'silly' to not use their experience and what they've learnt as a group to not input into that idea of upscale.
- Lots of the volunteers can't get their head around the whole commercial aspect, and questions about how we could achieve that.
- 'We all hope we don't lose the kind of feeling and ethics and everything that we've built up, we that can be contained within'.
- Interested to know how much of a part they can play in the project.
- 'It is a massive challenge, because if we're honest, we feel a bit worried about it really.'
- The project means a lot to them.

At the end of the recording, an interesting brief discussion where they were encouraging a new volunteer to come back for another sessions.

*Appendix 13: Pro-Environmental Behaviour Survey.*

# Homegrown Homespun Volunteer Engagement

Hello, my name is Helena Pribyl, a Master's with Research student at Lancaster University and I am inviting you to take part in a research survey for a study, 'Homegrown Homespun; Scaling Up A Low-Carbon Textile System in Lancashire.'

I have approached you because you are a current volunteer with the 'Homegrown/Homespun' project. The purpose of this survey is to explore the impact of engagement with the 'Homegrown/Homespun' project on your lifestyle and behaviour, and I would be very grateful if you would agree to take part. This mostly involves tick box answers, and a few questions require a longer response.

The estimated time to complete this survey is 10-20 minutes (depending on the level of detail you wish to go into).

Your participation is voluntary, and you are free to withdraw at any time while the survey is in progress. Your identity will remain anonymous, and this survey does not collect any personal information about you. Once you have submitted your response, you will no longer be able to withdraw as your response holds no identifiable information that would allow your data to be extracted.

By completing this survey, you are consenting to the use of the answers you provide for academic purposes and for informing the 'Homegrown/Homespun' project stakeholders.

If you have any queries or concerns, please contact me.

Helena Pribyl

pribyl@lancaster.ac.uk

Thank you for considering your participation. If you click 'next' the survey will begin. Please exist this page if you do not wish to take part.

Page Break

1.a. Approximately, how long have you been volunteering with the 'Homegrown/Homespun' project?

- ◯ Less than 1 month (1)
- ◯ More than 1 month but less than 6 months (2)
- ◯ More than 6 months but less than 1 year (3)
- ◯ More than 1 year (4)

1.b. How often do you attend the volunteering sessions?

- ◯ Every week or fortnight (1)
- ◯ Once a month (2)
- ◯ Every few months (3)
- ◯ Less than the options above (4)

Page Break

The following questions (2-9) are designed to explore if your involvement with 'Homegrown/Homespun' has impacted your relationship to nature and your environmental behaviours.

Pro environmental behaviours are defined as choices made with the intention to benefit the environment.

Questions 2 and 3 have a part a and part b – part b asks for a longer response.
Questions 4-7 are tick box answers.
Question 8 and 9 asks for a longer response.

Page Break

2. Nature Connectedness

2.a. Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|
| I visit green spaces, e.g. parks, nature reserves and the canal. (1) | ○ | ○ | ○ | ○ | ○ |
| I take others to green spaces with me. (2) | ○ | ○ | ○ | ○ | ○ |
| I care about the environment. (3) | ○ | ○ | ○ | ○ | ○ |
| I spend time in nature for my physical and mental health. (4) | ○ | ○ | ○ | ○ | ○ |

2.b. If volunteering with the 'Homegrown/Homespun' project has influenced your relationship to nature, can you please describe this in more detail? What/who has had an impact? How has your relationship to nature changed? If you would like to describe a key memory from volunteering or an impactful experience please do so.

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

Page Break

3. Fashion & Textiles

3.a. Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|
| I read about or engage with issues in the fashion industry. (1) | ○ | ○ | ○ | ○ | ○ |
| I shop for sustainable fashion or second-hand fashion where possible. (2) | ○ | ○ | ○ | ○ | ○ |
| I attend events (online or in person) to engage in sustainable fashion. (3) | ○ | ○ | ○ | ○ | ○ |
| I wash and care for clothes in an environmentally friendly way. (4) | ○ | ○ | ○ | ○ | ○ |

3.b. If volunteering with the 'Homegrown/Homespun' project has influenced your engagement with fashion, can you please describe this in more detail? What/who has had an impact? How has the way you engage with fashion changed? If you would like to describe a key memory from volunteering or an impactful experience please do so.

________________________________________________________________

________________________________________________________________

________________________________________________________________

__________________________________________________________________

__________________________________________________________________

Page Break

4. Conservation Lifestyle

4.a. Household - Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|
| I recycle. (1) | ○ | ○ | ○ | ○ | ○ |
| I save water and energy, e.g. by having shorter showers and turning down the thermostat. (2) | ○ | ○ | ○ | ○ | ○ |
| I compost food and/or garden waste. (3) | ○ | ○ | ○ | ○ | ○ |
| I have a green energy supplier. (4) | ○ | ○ | ○ | ○ | ○ |

4.b. Transport - Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| I choose to walk, cycle, and use public transport for local journeys. (1) | ○ | ○ | ○ | ○ | ○ |
| I limit how often I use a car, instead opting for the train or bus for longer journeys. (2) | ○ | ○ | ○ | ○ | ○ |
| I car-share where possible. (3) | ○ | ○ | ○ | ○ | ○ |
| I take fewer flights. (4) | ○ | ○ | ○ | ○ | ○ |

4.c. Consumerism - Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|
| I have made dietary choices to reduce my environmental impact. (1) | ○ | ○ | ○ | ○ | ○ |
| I only buy what I need. (2) | ○ | ○ | ○ | ○ | ○ |
| I avoid single-use plastics where possible. (3) | ○ | ○ | ○ | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| I choose natural, biodegradable products where possible. (4) | ○ | ○ | ○ | ○ | ○ |
| I have ethical investments or am with an ethical bank. (5) | ○ | ○ | ○ | ○ | ○ |

Page Break

5. Land Stewardship

Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|
| I have made my outdoor spaces, such as balcony or garden, more wildlife friendly. (1) | ○ | ○ | ○ | ○ | ○ |
| When visiting outdoor spaces I do not leave any litter. (2) | ○ | ○ | ○ | ○ | ○ |
| I volunteer to improve the environment (including 'Homegrown /Homespun'). (3) | ○ | ○ | ○ | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| I grow my own food produce. (4) | ○ | ○ | ○ | ○ | ○ |

Page Break

6. Social Environmentalism

Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|
| I talk to others, such as family, neighbours, & colleagues, about environmental issues, protecting the environment and our communities. (1) | ○ | ○ | ○ | ○ | ○ |
| I participate in environmental events or groups, such as a litter pick. (2) | ○ | ○ | ○ | ○ | ○ |
| I encourage others to get involved in environmental events. (3) | ○ | ○ | ○ | ○ | ○ |

Page Break

7. Environmental Citizenship

Has your involvement in 'Homegrown/Homespun' led to any of the following changes in your life?

| | I do this less often (1) | No - I do not do this (2) | Yes - I do this now (3) | I do this more often (4) | I have seen no change (5) |
|---|---|---|---|---|---|
| I contact local MPs or councillors about environmental issues. (1) | | | | | |
| I sign petitions regarding environmental quality, wildlife, or pollution. (2) | | | | | |
| I vote to support environmental policy or regulation. (3) | | | | | |
| I donate money to support environmental action. (4) | | | | | |
| I learn & engage with environmental movements or read environmental-oriented news. (5) | | | | | |

Page Break

8. If volunteering with the 'Homegrown/Homespun' project has influenced your lifestyle and behaviour, can you please describe this in more detail? What/who has had an impact? How has your lifestyle changed? If you would like to describe a key memory from volunteering or an impactful experience please do so.

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

Page Break

9. Are there any other ways your engagement with 'Homegrown/Homespun' has influenced your lifestyle and behaviour that was not mentioned in the previous questions that you would like to share? If yes, please describe these. You may wish to draw on a key memory, conversation, volunteering session, or lesson you have learnt.

________________________________________________________________

________________________________________________________________

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Page Break

End of survey.

*Appendix 14: Transcribed roll of paper – stage one of PEB research approach.*

Pro-environmental Behaviours

Individual Scale

Community

Share whether volunteering with Homegrown/Homespun has impacted your lifestyle & how you feel about the environment…

"HG/HS biggest change in my life has been the amount of hope I have for future practices. To meet so many people who care enough to take dynamic action and reimagine the status quo. I'm encouraged by knowing my environmental goals are shared by so many wonderful people."

(Accompanied by drawing)

"From working with mass produced clothing production I've changed my career path to working with brands who are looking towards a more regenerative & sustainable industry" (smiley face)

"Happier, healthier and mad as hell about the state of the world."

"Yes!! It's made me much more thoughtful with clothes purchases, more aware of fashion industry issues. More confident to talk to others about these issues. BUT just love the community be have created."

"Having now seen whats needed to create fabric I'm really conscious when buying new clothing. I now ask myself "Do I really need this or just want it?" Then I ask myself is this sustainable clothing. My purse + wardrobe is thanking me too"

(smiley face)

"For sure and do it/think of it in a more informed and persuasive way I feel through listening, repeating what I hear and telling myself and others that "being part of the change you want to see in the world…" is therapeutic and empowering."

"For me the project has reinstated on how important it is the improve peoples attitude to litter. Nature has no choice but to use the materials available and actually seeing nests created with plastic for me was devastating. To provide an environment that can be fully sustainable is the future of the world. Growing from seed to fabric has been an amazing project, creating lots of new friends and helping the environment."

"Most certainly impacted the way I think & buy clothes, more conscious of fast fashion – cheap clothes. Buy or invest in one quality piece."

"The project has heightened my awareness of the negatives in the fashion industry & made me more determined to consider the impacts my actions have on the planet. Becoming part of a close knit team, working towards a common goal has benefitted my mental health a huge amount. I'm more confident & happier in my head. I love the field, the project & value the friendships!!"

"Has impacted in way I think about consumerism, buying clothes + growing practices."

"I think it's easy to become overwhelmed by the climate crisis and how complex the fashion industry is and just how much it affects the environment. Projects like HH have given people – even those who don't work within fashion – the opportunity to be the change. For me, volunteering on the project has been a journey as well as an education – I have learned so much from the stakeholders and the process of planting, growing + harvesting the flax and woad. And its all things that can help educate others. Sometimes, knowledge is truly power."

"Taking time out after work to come to the field and learning about nature, making friends, teamwork. Bringing my hobby of art alive. It's made me appreciate clothing more – how long it takes to grow flax and woad for one garment. I share beautiful pictures which have become memories for life. xx"

"Thank you, HGHS for this opportunity to be involved in this project has been a learning curve. Best thing is to see the cloth at the end of all the hard work. 'Jeans' we will have then, I envision we will grow flax and produce them soon in Blackburn (heart). Made lots of friends too. (heart) flax family."

"For me, it's been meeting likeminded people – so many 'normal' folk have buried their heads as far this damage we are causing is concerned and then having more power and information to spread the word. I have been aware of climate issues for a while its great to see people trying to make a difference."

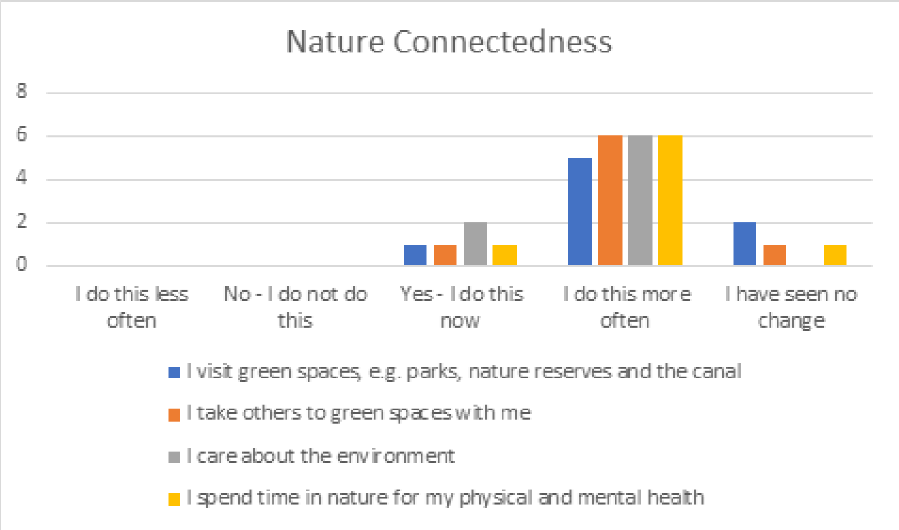
*Appendix 15: Survey Results – PEB Behaviour*

Pro-Environmental Behaviours

Individual Scale – Knowledge, Benefits

Nature Connectedness

Community




Nature Connectedness:

"I am spending more of my time outside and wanting to. I'm enjoying the community aspect of HH and the chance to do something. Aside from perhaps a little more awareness, my relationship with nature is unchanged. Also, does nature mean outdoors? We are creating outdoor spaces that are not necessarily natural, but improving access to outdoor amenity and exploring that potential. A key memory from volunteering is that the textile biennial became a priority and meant there were lots of unanswered questions around the project. Everyone is working hard to improve this aspect."

"I have a wider knowledge of different types of plants and their uses. I no longer see some plants as weeds"

"Spending more time outdoors has made me appreciate nature more and feel more in tune with the growing seasons and seasonal changes"

"More aware of the impact fashion industry has on the environment"

"I understand relationships between the plants and environments more, I plant seeds and grow at home, I go and visit places to see the planting, I walk along the canal more often, I slow down to look and see the plants.  I was took part in a session where 'X' walked us around the flax field and named the plants and talked about their uses and relationships with the environment, age and species."

"I feel like I have a greater appreciation of nature. Not just for the benefits of the environment, but for my own mental health too. The negative side however has seen me be more stressed about how others treat their surroundings such as litter dropping etc."

"I've made fantastic friends getting out in nature learning about plants sustainability there's so much… helping at workshops. I've loved every bit and much more to come."


Fashion & textiles:

"It's a great conversation to have. I enjoy good quality clothing and it's become a hobby finding interesting used pieces online. I've considered starting a vintage online store. I enjoy the detail in clothing- hidden pockets that have a function. I hate embellishment unless it's eco or hand-sewn for example. I used to shop for clothes with eco credentials but have now bought into the 'you already own it' message. A key memory is sharing finds with volunteers. If it doesn't fit me I'll swap with someone from HH if possible."

"I now buy period knickers only buy second hand clothes buy much less and have been making my own clothes"

"The other volunteers and discussion in the group has made me more environmentally aware and influenced me to make more thoughtful choices"

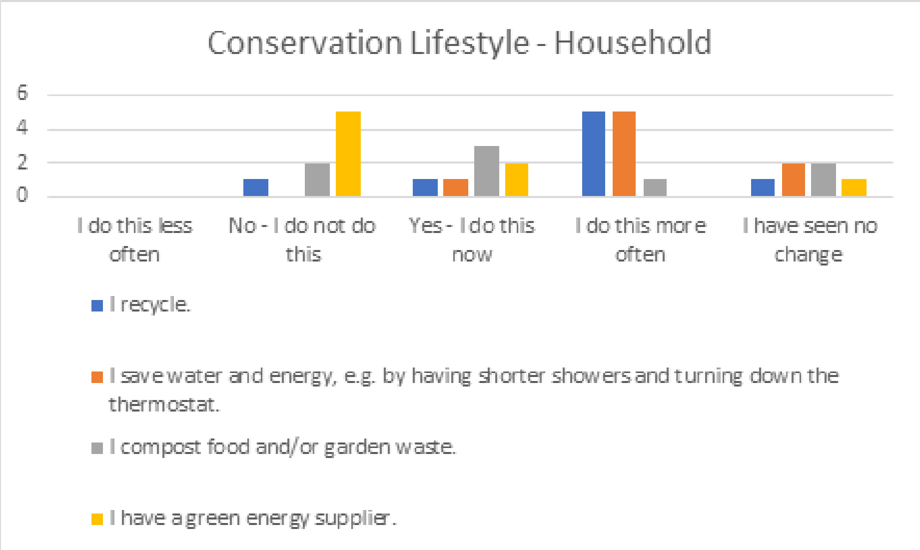
"Much more aware of the impact the fashion industry has on the environment. Shop with this in mind so, buy second hand; exchange items; sell own items; mend & alter existing clothes; make from scratch; buy more sustainable ethical brands"

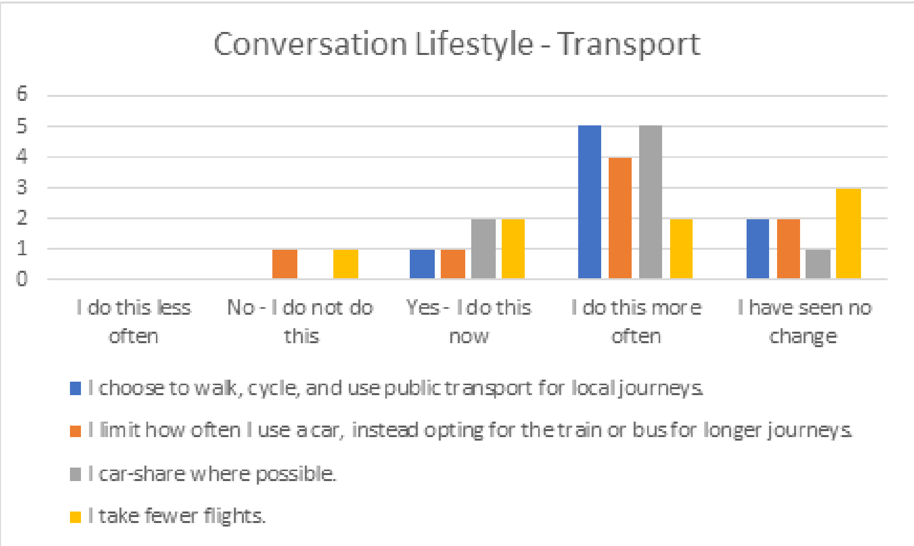
"I no longer buy new clothes on the whole, I buy second hand or sustainable brands, like Lucy and Yak for example, I have moved over to using period knickers. I follow brands or projects that promote sustainability on social media"

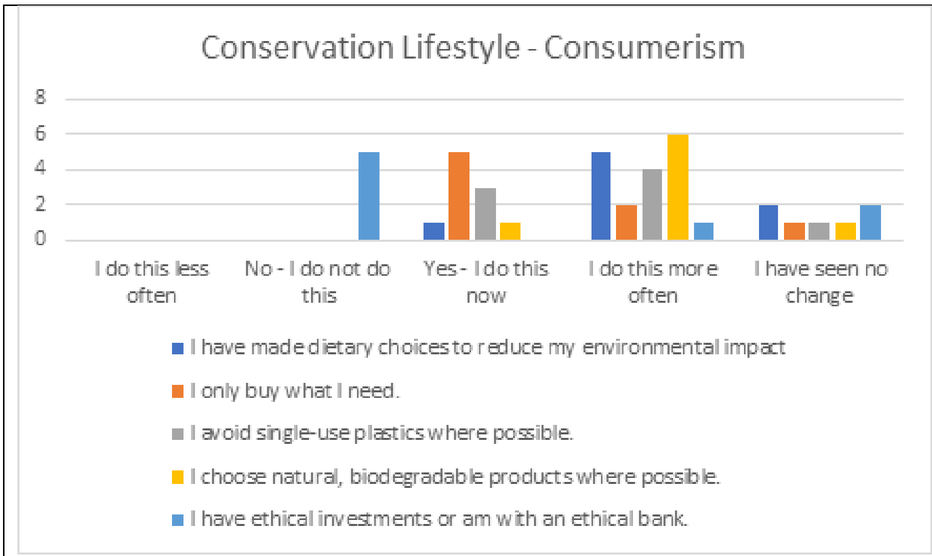
"I think all of the above have influenced my engagement with fashion. Being out on the field and connecting with nature has definitely had an impact on the way I view the textiles industry and it's links with agriculture and ecosystems."

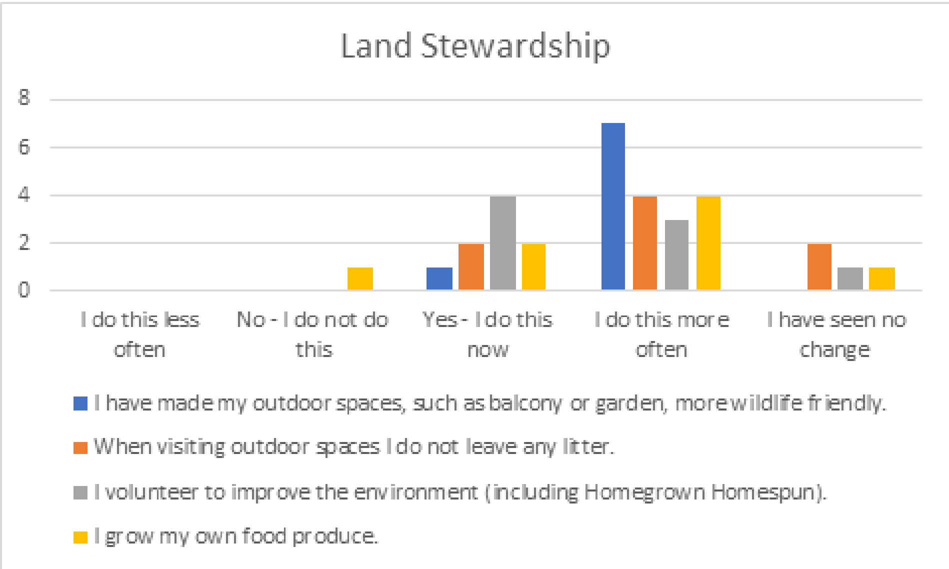
"I am making an effort to repair my clothes more - I've even started darning my socks! I'm making more of my own clothes to gradually replace the fast fashion items I'm currently embarrassed to possess."

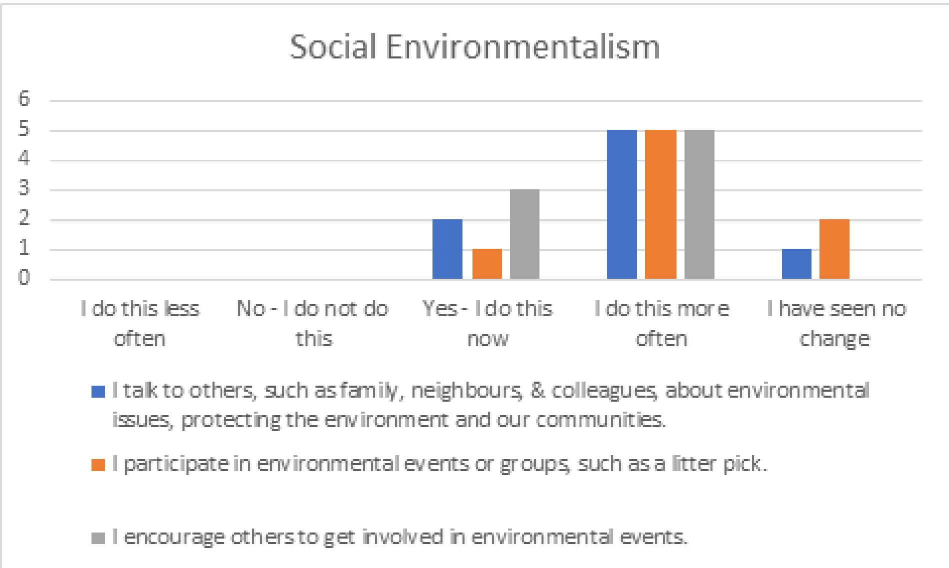
"I've enjoyed going to go Gawthorpe Textiles, touching different types of fabric learning about history it's been great. When the Homegrown Homespun fabric first got planted to watching it grow and caring for it. then to be put on display in Blackburn Museum."

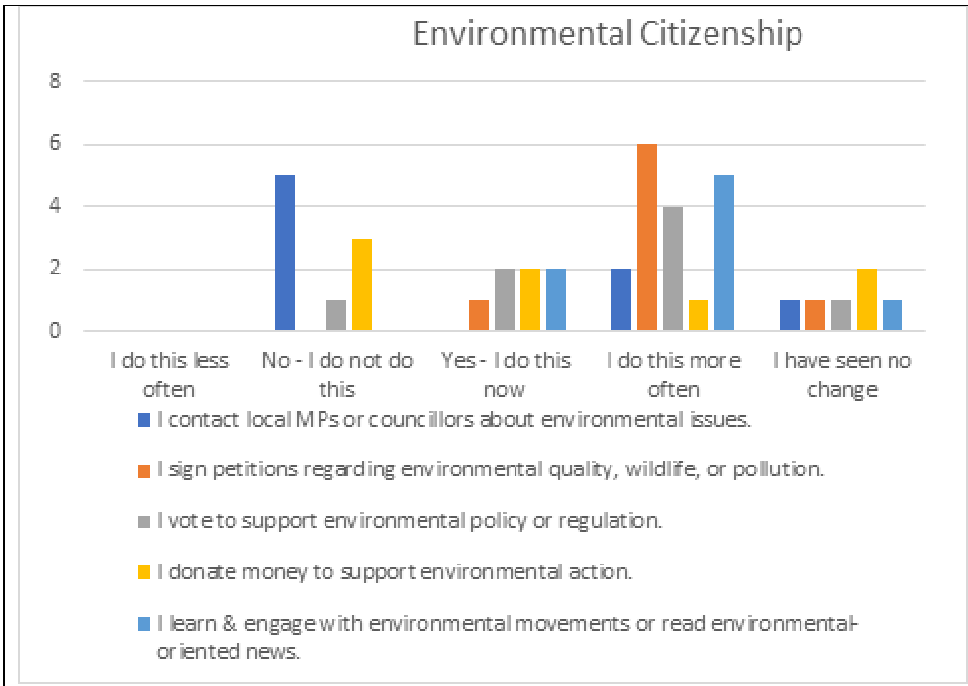



Conservation Lifestyle - Consumerism
8
6
4
2
0
I do this less often
No - I do not do this
Yes - I do this now
I do this more often
I have seen no change
I have made dietary choices to reduce my environmental impact
I only buy what I need.
I avoid single-use plastics where possible.
I choose natural, biodegradable products where possible.
I have ethical investments or am with an ethical bank.


Land Stewardship
8
6
4
2
0
I do this less often
No - I do not do this
Yes - I do this now
I do this more often
I have seen no change
I have made my outdoor spaces, such as balcony or garden, more wildlife friendly.
When visiting outdoor spaces I do not leave any litter.
I volunteer to improve the environment (including Homegrown Homespun).
I grow my own food produce.


Social Environmentalism
6
5
4
3
2
1
0
I do this less often
No - I do not do this
Yes - I do this now
I do this more often
I have seen no change
I talk to others, such as family, neighbours, & colleagues, about environmental issues, protecting the environment and our communities.
I participate in environmental events or groups, such as a litter pick.
I encourage others to get involved in environmental events.




Conservation lifestyle, Land Stewardship, Social Environmentalism & Environmental Citizenship:

"Meeting people that share concerns and encouraging positive behaviours and action. Getting involved. Feeling like I've a stake in positive change. The people with the most impact are SSW staff and the volunteers I work with. They encourage me to get involved and reward our endeavour in an way they can. I feel that 'X' gets it, the community aspect, and without 'them' pushing the project from the outset I'd never have heard about HH or SSW. Other senior stakeholders must work harder to share plans with the volunteer community, so that we can become more impactful."

"I have started growing my own food herbs and flowers. I swap and share with other members of the group"

"Talking to the other volunteers and attending events with them (ie Future Fashion Fair) has led to a more thoughtful approach to what we buy and wear etc"

"Much more aware of environmental issues. Aware of alternative options with clothing purchases. The community group has been extremely informative in numerous ways.. ..new skills ie knitting, sewing, willow weaving, weaving, natural dyeing. Dietary advise.... herbs, foods for medicinal purposes. Mental health issues discussed & guidance offered."

"I grow food, I actually garden as I did not before, I don't mow the lawn until June, I use refill shops, I only buy fruit and vege from a market in paper bags. I swap plants and cuttings from other volunteers at the HGHS project"

"Being around a group of like minded people, sharing ideas and supporting each other has had a large impact."

"I feel I'm more conscious of "green washing" and certain adverts now offend rather than entice me. I purchase less clothing. I've started to grow more in my garden including attempting my own herbs and vegetables. I make the decision to make shorter journeys on foot, rather than drive, and don't give in to my children's pleas to drive everywhere."

"It's not only about working it's about being out in the open mixing with everyone becoming friends learning key skills are becoming a great volunteer."

Are there any other ways your engagement with HH has influenced your lifestyle and behaviour that was not mentioned in the previous questions that you would like to share?

"I'm still making bad decisions- going on holiday, driving a dirty car etc. But I'm striving to change where possible. I'm dismissive when not involved and working hard to change this aspect of my personality so I can enjoy and live vicariously through others! Volunteering allows me to explore a world I wouldn't have known existed in a place not far away."

"From a well being point of view, the shared experiences and meetings with other volunteers has been helpful, the calm nature of the space and the physical work and chatting have benefitted me."

"I have made a career change in order to support a more sustainable and ethical clothing industry"

"Being back at work and trying to fit in time being at the fields it's a bit hard these days especially when you don't drive but the one thing I have learnt is just making time and trying your best. Your friends you have made with homegrown homespun are always there to help you out."

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