VALUE CHAIN ANALYSIS OF INDUSTRIAL HEMP: AN EXTENSIVE REVIEW AND A CASE OF NEPAL

A Thesis Submitted by

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ABSTRACT

Recently, many countries ended the early 20th century-imposed sanctions on industrial hemp to invigorate the hemp-based economy. Following the revival, studies aimed at assessing the environment and economic sustainability of industrial hemp and products along (entire or certain) value chain nodes have become the priority of the research realm. Systematic assimilation of such studies may cater to comparison among diverse hemp-based products and their fossil-based counterparts. Therefore, the first objective of the current study was to conduct a systematic literature review aimed at evaluating the industrial hemp value chain from enviro-economic perspective. We searched databases, namely Science Direct, Scopus and Web of Science to retrieve articles on industrial hemp related to lifecycle assessment (LCA), value chain (VC) and financial feasibility components. The results of the literature search highlight hempcrete as an environmentally friendly product due to the carbon negativity. From the economic perspective, industrial hemp may not be viable for the entire value chain actors, however, addressing key intervention (such as harvesting and processing) nodes and capitalization of value addition and valorisation opportunities may foster promising future potential. Similarly, the second objective narrows the research gap in the global south (indicated by the review study) as it provides insights from Nepal where the hemp value chain may be legally contested. Using the case of Nepalese western mountain farmers and employing a mixed-method approach, we uncovered the tapestry of the illegal hemp value chain, evaluated the contribution of industrial hemp to pro-poor households, and analysed the structure, conduct, and performance of the industrial hemp value chain. Based on our findings, we conceptualized 'dark,' 'opaque,' and 'transparent' visions, which respectively illustrate the compassionate ground for production allowance, created opacity for outbound operations, and unconcealed distribution activities. Results suggest, albeit negative gross margin for hemp farmers, profit-making opportunities for downstream actors. Industrial hemp legalization, market integration, and consortium marketing are some of the identified strategies. Globally, the findings of this study have the potential to contribute to sustainability benchmarking of hemp-based products and encourage global collaboration in research and innovation. Nationally, it can guide policy intervention

and the development of the integrated framework for greater industrial hemp value chain efficiency.

CERTIFICATION OF THESIS

I Rajan Budhathoki declare that the Master of Research (MRes) Thesis entitled *Value chain analysis of industrial hemp: An extensive review and a case of Nepal* is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes.

This Thesis is the work of Rajan Budhathoki except where otherwise acknowledged, with the majority of the contribution to the papers presented as a Thesis by Publication undertaken by the student. The work is original and has not previously been submitted for any other award, except where acknowledged.

Date: 7th July 2024

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Student and supervisors' signatures of endorsement are held at the University.

STATEMENT OF CONTRIBUTION

Paper 1:

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[Rajan Budhathoki contributed 80% to this paper. Collectively Tek Maraseni, and Armando Apan contributed 20%]

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[Rajan Budhathoki contributed 70% to this paper. Collectively Tek Maraseni, Armando Apan, and Kishor Aryal contributed 30%]

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1. Background and context

Cannabis sativa L., family; Cannabaceae (McPartland, 2018), synonymously called “hemp “or ‘industrial hemp’ is an annual C3 (Rehman et al., 2021), dioeciously flowering plant (Clarke & Watson, 2007) heralded for its source of utility fibres, foods, and pharmaceuticals (Farag & Kayser, 2017). Despite some odd contentions over its origin (Small, 2015), it is widely believed to be a native of central Asia (McPartland et al., 2019); nomadic Scyths brought it to Europe around 1500 B.C (Schultes, 1970), and was disseminated to other regions including Africa some 1000 years ago (Duvall, 2019), South America in 16th century, North America, 1606 AD (Miller, 1991) and now ubiquitous across the equator through 60˚ northern hemisphere (Hillig, 2005).

In Europe and East Asia, as “hemp”, cannabis was introduced and grown as a prolific fibre-bearing crop having only an iota of intoxicating ∆9- tetrahydrocannabinol (THC) (Clarke, 1999). In contrast, South Asians selected and developed THC enriched drug type biotypes used for therapeutic, spiritual, and recreational intent (Clarke, 1999). Despite drastic variation in THC levels (Sawler et al., 2015), both drug type (marijuana) and fibre-type (hemp) look morphologically alike (Yang et al., 2020). Due to their similar appearance, most countries including Nepal (Khanal et al., 2021) imposed a blanket ban on all C. sativa (hemp and marijuana) forms at the beginning of the 20th century, initiated by the Western world which raised concern over an insidious of extensive drug-oriented use (Cherney & Small, 2016).

After the initial 60 years of 20th-century governmental crackdown, the interest in this iconic crop rekindled again (Young, 2005a). The renaissance in industrial hemp is linked to the increasing consideration of biobased products against petroleum-derived products (Dahiya et al., 2020) and the ability of this multifaceted crop to supply raw materials for a plethora of traditional and innovative industrial applications (Durán-Zuazo et al., 2023), alongside profitability that intrigued the interest on it (Dhondt & Muthu, 2021). The global trend of legalization of industrial hemp is also evident recently, especially in Europe (Simiyu et al., 2022), North America (Baker et al., 2010), Australia (2017) (The Farmer magazine, 2020) and elsewhere, under the discretion of 0.2%-0.3% THC threshold (Adhikary et al., 2021).

This global trend has reached Nepal as well with increasing calls to lift the ban on cannabis for industrial and medicinal purposes. Regarding this, the Member of

Parliament, Mr. Sher Bahadur Tamang proposed “The Cannabis Cultivation Act, 2020” with (signatory) acceptance of 40 legislators (Xinhua, 2020); the terms of which refute the licensing need for producers and distributors of food and fibre intended production. Back in December 2022, in an official vote collated by WHO to reschedule cannabis (WHO recommendation 5.1) from a perilous drug list (Putri, 2020), Nepal voted in favour. It is difficult or rather speculative to say what stance the government takes on hemp but recent national motion, government inclination and international regulation change bodes positive for hemp. Amid, this illegal status quo of hemp cultivation (Acharya et al., 2014), the smallholder farmers particularly from the rural western mountains of Nepal continued to cultivate cannabis in the small parcel of land (10-200 m^2) basically for seed and fibre production (Clarke, 2007).

1.2. Problem statement

The revival of industrial hemp, driven by environmental and economic sustainability considerations, has sparked keen interest among researchers in evaluating the environmental friendliness and economic viability of industrial hemp-based products. Since the late 2020s, the studies on the environmental fate of hemp as a cultivated crop and finished (hemp) products have been stable and intense. Scholars have focused on the phytoremediation potential of hemp in contaminated soil (Angelova et al., 2004; Golia et al., 2023; Kozlowski et al., 1994) and its agro-inputs demand (Schumacher et al., 2020) when grown as dedicated crops. Further, the ecological footprints associated with various hemp-based products such as textiles (Turunen & van der Werf, 2007; La Rosa & Grammatikos, 2019), hempcrete in the construction sector (Di Capua et al., 2021; Pretot et al., 2014), and biocomposites (Smoca, 2019; Rosa et al., 2013) have been among the interest of the research realm. The studies related to the economic side of industrial hemp have significantly gained momentum in the recent last decade. While many researchers studied the economic viability of industrial hemp (Mark et al., 2020; Mark & Will, 2019; Rehman et al., 2013; Lane, 2017), its production budget or financial feasibility analysis has been the topic of interest for others (Aydoğan et al., 2020; Fortenbery, 2014; Wrangham, 2019; Barnes et al., 2023). Moreover, with recent developments in industrial hemp, studies related to production efficiency (Barta et al., 2013), value enhancement (Ji et al., 2021), supply chain efficiency (Hanks, 2003), and entire value chain dynamics (Garnier et al., 2007) are evident. Despite of emerging global literature, there is a dearth of synthesis of prior research on the enviro-economic facets across the entire chain (Aryal et al., 2024). This underscores the need for a comprehensive evaluation of the environmental and economic assessment of industrial hemp as an arable crop and hemp-based diverse products across different value chain processes. To this end, a systematic literature review can be a tool to ensure methodically unbiased collection, evaluation, and synthesis of studies under consideration

The western mountainous regions of Nepal are often characterized by three backward traits: inaccessibility, fragility, and marginality. Rugged terrain, cold harsh climate, and frequent natural hazards (erosion, landslides, floods etc.), are some physical barriers impeding easy access (Nepal & Chipeniuk, 2005). Steep slopes, coupled with high tectonic movement, make mountain soils fragile. Similarly, a low human and natural resource base contributes to the marginalization of the mountain communities. This hostile biophysical environment and incapacitated sociocultural settings permit only limited crop cultivation options for smallholder mountain farmers and that too yields low financial returns. On the contrary, cannabis possesses some essential characteristics like a short growing period (60-90 days) (Sature & Mache, 2015), winter hardiness, insect and pest resistance (Karche, 2019), less demanding (fertilizers, labours etc.) (Cierpucha et al., 2004) and much assured production (Ahmed et al., 2022) with the good market prospect. Owing to these competitive traits, this unconventional crop can be financially more rewarding when integrated into the mountain farming system along with other conventional crops, but this prospect has never been studied.

In general, industrial hemp can be cultivated throughout Nepal, but high mountain regions (below the snow line) are the most preferred places for hemp cultivation. Moreover, Nepal has been ascribed as an ancestral home to some unique drug types of gene pools (Hillig, 2005). Nepalese mountain communities developed simple techniques for converting these cannabis genotypes to a fibre-based production line by opting a high-density planting and early harvesting (before flowering) practices (Clarke, 2007). Cannabis stalks are traditionally grown in rainfed upland terraces in rotation or intercropped with other conventional crops, without or low nutrient supplements (Clarke, 2007). Farmers either directly sell raw or spin fibres or produce raiment which they call ‘bhangra’ and products like tumplines, storage sacks, satchels, etc. from which they generate livelihood income (Clarke, 2010). Despite being one of the very few financially productive sectors for stimulating the ailing mountain economy, study and efforts have not been geared to make the hemp sector more rewarding.

1.3. Significance of the research

The sustainability of all green products should be assessed individually, considering the attributes of each product (Zuiderveen et al., 2023). In this regard, the significance of a systematic literature review (SLR) lies in its potential to assess the environmental and economic sustainability of individual hemp products, across the entire life stages. The aggregated results obtained from SLR will provide a better understanding of the range of hemp goods in terms of rewards and risks across value chain nodes, highlighting key intervention nodes. Such a review also integrates individual piecemeal studies so that a holistic picture can be drawn based on which guides future research directions and policy initiatives.

The economic significance of industrial hemp in Nepal is highlighted by its substantial international market valued at US$4.9 billion (2019) with a forecasted figure of a staggering US$18.6 billion (2027), particularly in the Asia-Pacific regions (Chouhan et al., 2020). As Nepal shares the Asia-Pacific territory, the country is poised for a huge regional market, and this has piqued the interest of (hemp) entrepreneurs as proven by the scores of lately flourishing hemp-based businesses around the capital city. This advancement subsequently garners the interest and involvement of various actors including manufacturers, traders, logistics, wholesalers and, retailers (Ceyhan et al., 2022) so it becomes imperative to conduct a study on the industrial hemp value chain dynamics. The study to date, is limited to perfunctory narratives of successful hemp entrepreneurs covered by mainstream and fringe media and in unofficial reports; the current research (proposal) is an attempt to fill those research crevasses.

Moreover, this study has a particular significance in terms of providing empirical evidence to bolster the arguments of legislators and proponents advocating hemp legalization (Xinhua, 2020 cited by Tomat & Wilson, 2022). Utilizing the information provided by this study, multiple hemp value chain actors and stakeholders can make a more informed decision. Finally, aligned with national policy and international market demand, this research will aid in the development of co-innovative, collaborative, and trustworthy hemp value chain development in Nepal.

1.4. Aim and objectives of the research

This study aimed to summarise and synthesize existing research on the industrial hemp value chain and develop a relevant case study addressing the insights from avenues unexplored by the current literature. To accomplish this aim, the following objectives were formulated.

Objective 1: Conduct a systematic review of articles on components related to the industrial hemp value chain (Chapter 3)

Objective 2: Understand the production and operational activities of the illegal hemp value chain in Nepal

Objective 3: Conduct a value chain analysis of industrial hemp in the rural mountain of Nepal

1.5. Scope and limitations

The current study has a global scope with local impact. The systematic literature review provides an overarching understanding of the current knowledge base and identifies weaker links associated with the global industrial hemp value chain. Whereas a hemp-based case study offers a unique opportunity to gain detailed insights into local practices, opportunities, challenges, and coping strategies within a regional locus.

As a case study related to the small population fractions of Rukum East district, Nepal, the findings may not be generalised to the broader population. This limits the regional and global applicability of the study. However, the study findings are enough to develop hypotheses for more comprehensive research covering wider geographical areas. During the data collection, despite careful formulation of interview protocols fostering mutual trust and confidentiality of the participants, the response rate was relatively low, and so was the sampling size, owing to which inferential statistics cannot be performed. Additionally, due to the clandestine nature of industrial hemp markets, the non-availability of official data and statistics imposed challenges in assessing beforehand background knowledge, understanding market insights and opportunities for comparative analysis. Notwithstanding, this study may be a cornerstone for providing foundations for Nepal's industrial hemp value chain development.

1.6. Thesis structure

This thesis comprises five chapters. Chapter 3 and Chapter 4 respectively include previously published and submitted articles. A brief outlook of all five chapters is presented below.

Chapter 1 introduces the thesis and covers the background and context, a separate section for the research problem statement and the significance of the study, the aim and objective, scope and limitations and the overview of the thesis structure itself.

Chapter 2 consists of an extended literature review around previous global and Nepal-specific studies in the industrial hemp value chain dimension. This section also presents a methodological overview of the whole study.

Chapter 3 addresses the first objective of this study as it consists of a systematic literature review of the global industrial hemp value chain from the environmental and economic aspects.

Chapter 4 is a case study paper on the industrial hemp value chain based in the western mountains of Nepal. This chapter examined ground realities concerning farmers' participation in hemp cultivation and uncovered how value chain activities are being operated amid illicitness (objective 2). This chapter also analysed the industrial hemp value chain based on the structure-performance-conduct paradigm (objective 3).

Chapter 5 concludes this study by providing an overall discussion of both the review and case study. This chapter also compares and contrasts the industrial hemp value chain between Nepal and the industrialized world.

CHAPTER 2: LITERATURE REVIEW

2.1. Environmental sustainability of industrial hemp and products

Alternative biobased products have become the cynosure in response to the global urge to abate fossil fuel depletion and lower greenhouse gas emissions associated with fossil-fuel-based products (IEA,2022). In this regard, industrial hemp has received particular attention as has been touted for sustained delivery of green materials needed for clothing, housing, and locomotive parts in an ecologically amicable fashion (Yahn-Grode et al., 2021). This has led to the expansion of acreage under hemp and hemp-related studies (Moscariello et al., 2021). This unconventional fibre crop features important agronomic traits such as low input demand (Schumacher et al., 2020b), fast-growing (Mirski et al., 2017), high yielding (e.g. double the flax yield) (Robinson, 1996); soil building properties, including erosion control (Nath, 2022), soil organic carbon (SOC) built-up (Li et al., 2012), phytoremediation (Citterio et al., 2003); high CO_2 sequestration (Boutin, 2005) and inherent fibre strength and stiffness (Shahzad, 2013) owing to which provide edge over other (input) exhaustive natural fibres such as cotton, jute and flax (Yilmaz et al., 2005; Singh & Mukesh Kumar, 2018) and fossil-fuels derive synthetic fibres (Thomas et al., 2011). Moreover, hemp fibre composite matrix can be used in automobiles as an eco-friendly, cheap and sustainable replacement over expensive glass or carbon fibres (Shireesha et al., 2019; Gohal et al., 2020) and lightweight fibre-built vehicle components (panels, dashboards etc.) (Chen et al., 2017) could reduce petroleum oil consumption (Nachippan et al., 2021) thereby cutting off climate relevant CO_2 emissions (Pervaiz & Sain, 2003).

Despite some obvious environmental benefits over fossil fuel-derived products, biobased hemp materials may impose land use and input use (cultivation phase) related environmental hazards (Pawelzik et al., 2013), along with certain carbon hotspots, for instance during textile (Turunen & van der Werf, 2007) and bio-composite manufacturing phase (Recupido, Lama, Ammendola, Bossa, Minigher, Campaner, Morena, Tzanov, Ornelas, & Barros, 2023) being identified. Therefore, the environmental sustainability cult of all biobased cannot be taken for granted, rather it should be evaluated individually and across their entire life phases. To evaluate the environmental impacts of different bio-based products, lifecycle assessment (LCA) methodology has been applied in several studies (Egas et al., 2023; Mouton et al., 2023; Hashemi et al., 2024). LCA is a methodological guide for the comprehensive quantification of the overall environmental impacts of a product's lifetime starting from raw material extraction/ cultivation, to processing, manufacturing, use and disposal phases (Dahiya et al., 2020). As such, methodical tracking of entire material and energy input and output at every stage and ultimate associated impacts quantification (Katakojwala & Mohan, 2021) aids in the recognition of ecological hotspots alongside the recognition of ecologically amicable products.

2.2. Industrial hemp from an economic/financial perspective

Renewed interest in hemp is driven by a quest for economically viable and financially more lucrative crops (Small, 2016). In general, hemp fibre production can be economically feasible in any agroecological zone and under different climatic scenarios, but profitability necessitates high fibre-yielding varieties, fertilizers, improved cultivation technologies and mechanization (Wimalasiri et al., 2021a). Under traditional production methods, Ceyhan et al., (2022) estimated low farm productivity and returns and emphasized the need for cutting-edge technology, specifically an advancement over conventional fibre-spinning technology (Zimniewska, 2022). In this regard, Fortenbery & Bennett (2004), compared returns on commercial hemp cultivation among other arable crops cultivation. They projected a lower hemp profitability than a high-value crop like tobacco and lifting of restriction would mean further shrink in profits due to more financial burden on farmers raised by licensing, testing, monitoring and other compliance needs. However, a dual purpose (fibre and seeds) hemp production can be more remunerative than cereal crops like canola, wheat and corn, under medium and best price-yield cases (Fortenbery & Bennett 2004).

In another facet of the study, the potential of hemp cultivation under bio-physically compromised landscapes such as marginal soil, water scarce conditions has been described (Babaei & Ajdanian, 2020; I. García-Tejero et al., 2019; Pietrini et al., 2019). Blandinières & Amaducci, (2022) conducted a review regarding the prospects of growing hemp in the harsh condition. The review however is rather a subjective discourse on the topic, with ambivalent concluding remarks showing a propensity towards incorporating hemp production in a conventional agroecosystem without refuting the possibility of rewarding returns from a constrained landscape by trailering the production system to a single-purpose high-end product such as sublime fibres, seeds of high nutritive value or inflorescence for medicinal panacea. Overall, previous research underpinning the economic consideration of hemp cultivation is by far less fulfilling in that they are limited in volume, based on projections, and relied on secondary (and/or cross-country) data sources. More importantly, those studies are typically conducted in developed countries and may not relate to developing nations where smallholder hemp farmers are predominant.

2.3. Agricultural value chain in developing nations

Webber & Labaste, (2009) defined the agricultural value chain as an analytical framework for understanding production and manufacturing process of agricultural products; knowing how value accrued during the tangible flow of products from producers down to consumers. According to Natarajan et al., (2022), agriculture value chain development brings significant socio-economic transformation to the rural landscape of developing nations. As such, most producers in the emerging nations are smallholder farmers and are disadvantaged as they have limited investment funds, follow traditional production practices and are secluded from key market actors (De Janvry & Sadoulet, 2005). In developing countries, value chain formation consistent with the social network approach emphasizing social norms like trust, cult and command, can strengthen social capital within the firm (Uzzi, 1997). Congenial social relations enable lucid information flow and technical and monetary support (Burt, 1997) owing to which firms can operate efficiently through a reduced transaction cost and improved market reach (Gulati, 1998). Moreover, at the community level, the creation of an agriculture value chain can also enhance mutual knowledge sharing and access to information in connection with social capital. This can be a key to a resilient village economy. The knowledge sharing on key aspects like farm management and commodity-oriented market trends among the value chain actors can help identification of strengths, weaknesses, opportunities, and underlying threats; such that all actors can cash in the pros and find solutions for cons (Liu et al., 2023). Developing nations often possess unamicable institutional settings that obstruct market buoyancy (Marti & Mair, 2009). Existing policies and regulations can hinder target product value chain upgrading due to some imposed legal impasse such as restriction of production trade barriers, and barriers to infrastructural or human resource development. In this, VC research can bring about related information on institutional and governance structure in a way that allied institutions can endeavour intervention and the government can endeavour obstructive legislation change. Thus, a much stronger value chain can be formed with the enhanced production process and the quality of the produce, efficient chain operation and better collaboration within the chain actors.

2.3.1. Industrial hemp value chain

Few past literatures analysed value chain aspects of industrial hemp. In this regard, Müssig et al., (2020) identified fibre processing methods and varietal issues as key constraints of hemp value chain development. Based on the qualitative and quantitative studies on hemp fibre extracted from field in-situ retting, Vandepitte et al., (2020) asserted, that for the development of a strong textile-oriented chain, fibre processing technology has to be upgraded to par with the industrial standards. More specifically, decortication, a process (after field retting) of mechanical separation of fibres from the inner core (Leoni et al., 2022), was identified as the most challenging (Gratton & Chen, 2004) and crucial step in fibre production chains (Wang et al., 2018). Zimniewska, (2022) found “spinning technology” as a key intervention point of the textile value chain. But according to Pari et al., (2015), the success of the global fibre production chain lies in the development of innovative harvesting technology. In the same line, Pergamo et al., (2018) pointed out the need for product-specific (seed or fibre-oriented) varieties to achieve a competitive value chain geared through breeding technology.

In another line of research, Kocić et al., (2019) revealed a value adding prospects of hemp fibres at the composite knitting step in the creation of apparel, guarding against UV radiations; Müssig et al., (2020) seem sanguine about the future value of hemp blended composites. Some lines of research turned to its alternative usage. Pretot et al., (2014) performed a life cycle assessment of hemp concrete wall and found this eco-friendlier alternative to conventional building materials. Similarly, Finnan & Styles, (2013) opined that hemp can be developed for a perpetual bioenergy supply chain by incorporating it into a dedicated cultivation in rotation with conventional crops.

Ferreting out the previous literature, we found segments specific focus rather than focusing on entire hemp value chain components. Therefore, a systematic review may aid in consolidating these piecemeal studies to gain an overarching understanding of how these components interact individually and collectively in a chain. Also, value chain inquiry following steps including structural mapping of processes, actors and distributional incomes, followed by examining the distributional issues across the chain components/ links under consideration (Herr & Muzira, 2009) may be the preferred strategy.

2.3.2. Industrial hemp value chain in Nepal

Industrial hemp has been heralded for immense livelihood potential (Khanal et al., 2021) and identified as among the few exportable items for earning foreign currency in Nepal (Khanal, 2023). However, market competitiveness on a global scale demands strong linkages between value chain actors, while the futile stage of the industrial hemp value chain acts as a barrier (Shrestha, 2024). Therefore, value chain research may be pivotal to the development of the industrial hemp value chain in Nepal. But, to our understanding, no comprehensive study has yet been conducted on the value chain aspect of industrial hemp in Nepal. Rather, the researchers and stakeholders have emphasized the value chain associated with the fibre crop *allo (Girardinia diversifolia) or* Himalayan Nettle found in similar mountain niches (Shrestha et al., 2018; Adhikari et al., 2018; Lamichhane, 2016). So, despite being financially more rewarding due to product diversity (Schumacher et al., 2020), cheap and less (processing) labour intensive than *allo (Girardinia diversifolia) or Himalayan Nettle* (Bakhundole, 2010), it is the irony of the fate of industrial hemp to be least prioritized in research and development. A dearth of research on the industrial value chain is evident though, as illustrated by legal, political and cultural barriers (Wimalasiri et al., 2023). This underscores the need for value-chain research in industrial hemp, albeit requiring careful legal complexities and ethical consideration while maintaining regulatory compliances and the confidentiality of the respondents.

2.4. Methodological overview

As depicted in Figure 1, the current study started off by conducting a systematic review (SR), employing a PRISMA (Preferred Reporting for Systematic Reviews) protocol (Wittorski, 2012) to retrieve the relevant (research and review) articles on the industrial hemp value chain components. As such, PRISMA offers rigorous yet clear guidelines for identifying the most pertinent articles as they pass through rounds of eligibility and screening criteria. In addition, PRISMA also serves consistency, transparency and repeatability of literature search (Albhirat et al., 2024). The PRISMA flow and the entire methodological process for the systematic literature review are described in detail in Chapter 3. The systematic literature review uncovered a gap in the industrial hemp value chain research in the global south. This led to the development of a subsequent case study on the topic related to Nepal. The country is ideal for conducting industrial hemp value for various reasons. Firstly, Nepal has a long history of hemp cultivation with a wealth of traditional knowledge relatively unexplored. Second, the country is ideal for testing the prior hypothesis regarding the potential of industrial hemp to offer an income opportunity for remote rural households in the temperate areas of the developing world (Young, 2005). Indeed, industrial hemp in Nepal is being produced in many production pockets of secluded temperate mountains. Third, industrial hemp is spatially unique regarding legal and social status alongside production and market dynamics variation. This demands country, context and case-specific research.

At the outset, the study faced significant ethical and compliance challenges due to the legal ambiguity associated with Nepal's industrial hemp value chain. However, ethical approval was granted to this study (Approval No. ETH2023-0320) after obtaining a no-objection letter for research from the District Coordination Committee of the study area i.e., Rukum (East), Nepal and demonstrating approaches to safeguard respondents' welfare and confidentiality.

During the field study, in particular, the household survey, the survey team led by the researcher invested some time in winning the trust and building the confidence of the villagers. The researchers adopted an emic approach (Sánchez-Pérez et al., 2023), to understand the local context by immersing themselves in the local community. The entire survey amicably took place, enabling the researcher to inductively explore dominant themes about production and operational activities. Accordingly, both qualitative and quantitative data were collected by implementing a mixed-method research approach. The qualitative data was obtained through key informant interviews (KII) using a semi-structured questionnaire checklist whereas a standardized structured questionnaire was used for the household surveys to collect quantitative data. Similarly, relevant qualitative and quantitative data was collected during the value chain actor interviews. The detailed methodology of the case study has been illustrated in Chapter 4.

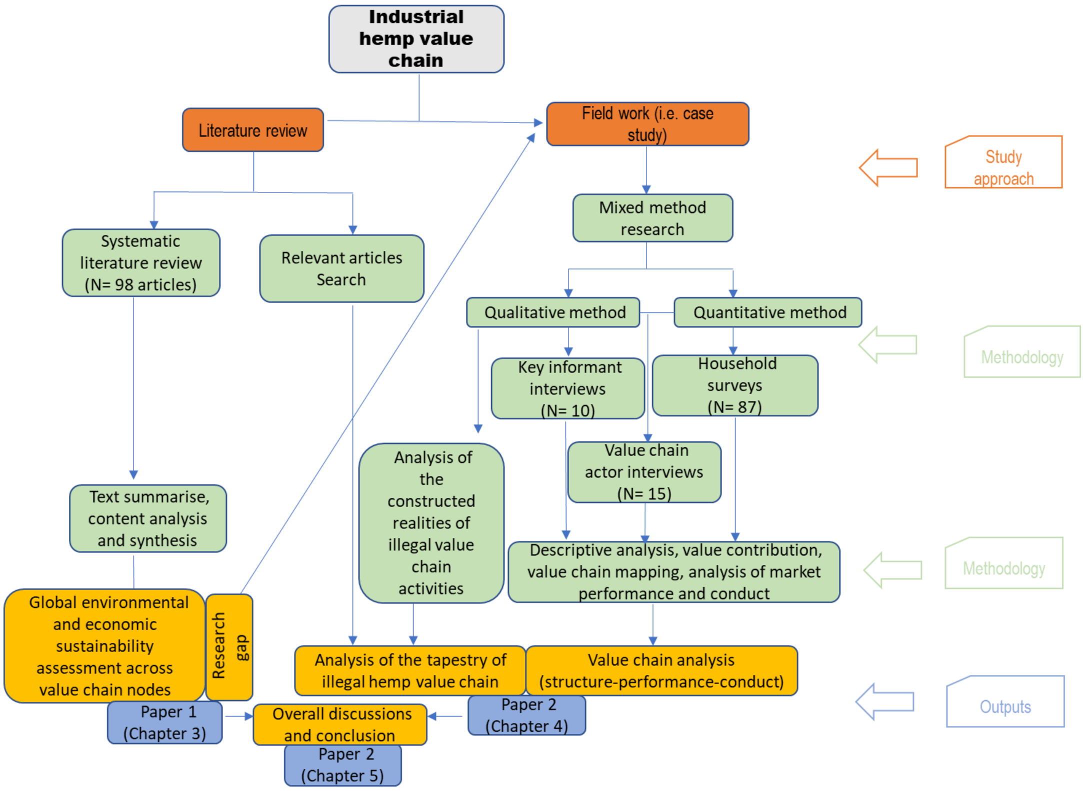

Figure 1: Methodological overview of the study

CHAPTER 3: PAPER 1: ENVIRO-ECONOMIC AND FEASIBILITY ANALYSIS OF INDUSTRIAL HEMP VALUE CHAIN: A SYSTEMATIC LITERATURE REVIEW

3.1. Introduction

This study systematically assimilates global literature conducting life cycle, value chain (VC) and feasibility assessment. Based on the synthesis of the life cycle assessment (LCA) study, it evaluates the ecological burden of individual hemp-based products across various local and global impact categories. We evaluated existing VC articles across different themes and critically analysed dominant VC themes from an economic perspective. Further, we conducted a feasibility assessment to know the financial feasibility of hemp goods to different actors. Based on the assessment we identified environmentally and economically amicable hemp products. We also identified a research gap in this facet.

3.2. Published paper

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REVIEW

Enviro-economic and feasibility analysis of industrial hemp value chain: A systematic literature review

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Abstract

A recent renaissance of industrial hemp has been driven by a plethora of ecologically amicable products and their profitability. To identify its environment and economic fate across the value chain (VC), this study conducts a systematic review of 98 studies published in ScienceDirect, Web of Science, and Scopus-indexed journals. The thematic content of the articles is categorized using three deductively derived classification categories: lifecycle analysis ($n=40$), VC analysis ($n=30$), and feasibility analysis ($n=28$). Bibliometric analysis indicates that the majority (>90%) of the studies were conducted in selected regions of Europe or North America, with further findings around regionally prioritized industrial hemp products, such as hempcrete in Southwest Europe, solid biofuel in North European states, and textile fiber and bio-composites in East Europe and North America. Lifecycle analysis studies highlight nitrogenous fertilizer use during industrial hemp cultivation as a major ecological hotspot, which is taking a toll on the climate change index. However, hemp-based products are generally climate-friendly solutions when contrasted against their fossil fuel counterparts, with hempcrete in particular a highly touted carbon-negative (−4.28 to −36.08 kg CO_2 eq/m^2) product. The review also identifies key issues within the hemp VC and presents innovative solutions alongside the recognition of value-adding opportunities. Furthermore, feasibility analysis indicates unprofitability in using hemp for bioenergy production and there is a relative cost worthiness of hemp bio-composites and hempcrete at the upstream level. Positive returns are observed under co-production schemes. In contemplating the literature findings, we discussed and identified gap in existing literature for future exploration, including more studies to provide insights from the Global South, and the production of industrial hemp under a biophysically constrained landscape.

KEYWORDS

enviro-economic, feasibility, industrial hemp, systematic review, value chain

1 | INTRODUCTION

Cannabis sativa L., synonymously called "hemp," is a prehistorically iconic crop, heralded for its millennia-old source of utility fibers, foods, and pharmaceuticals (Farag & Kayser, 2017). In Europe and East Asia, as "Industrial hemp," it was introduced and grown as a prolific fiber-bearing crop having only an iota of intoxicating Δ^9-tetrahydrocannabinol (THC) (Clarke, 1999). However, due to its morphological similarity to THC enriched drug (marijuana) biotypes (Yang et al., 2020), most countries imposed a blanket ban on all *C. sativa* forms at the beginning of the 20th century (Cherney & Small, 2016). After the initial six decades of the 20th-century government prohibition, interest in this prehistorically iconic crop reignited globally, in part due to the recognition of a diverse range of hemp products (Dhondt & Muthu, 2021).

Some estimates have identified a repertoire of 25,000 industrial hemp-based products derived from its seed and biomass (Fike, 2016). Hemp seeds have more of a nutritional and therapeutic value (García-Tejero et al., 2019), while the fiber-rich stem (outer phloem fiber and inner xylem wood) of hemp biomass is deemed economically valuable (Cherney & Small, 2016; Kremensas et al., 2017). The latter is due to a diverse range of applications for biomass, ranging from textiles (Gedik & Avinc, 2020; Pergamo et al., 2018), to construction (Kallakas et al., 2018; Liao et al., 2022; Martínez Martínez et al., 2022; Yadav & Saini, 2022), and to the automobile industry (Chen et al., 2017).

Accrued global interest in industrial hemp is not just because of its myriad of products, but also for its capacity to provide eco-friendly alternatives that lower over-reliance on conventional fossil-based materials (Summit, 2020). For example, textile quality hemp fiber has potential to lower the dependency on both fossil-derived synthetic fibers (Aishwariya & Jaisri, 2020) and (water and fertilizers) input demanding cotton (Abbas et al., 2022). Additionally, the use of lightweight hemp fiber-built components in vehicles (Chen et al., 2017) in lieu of glass or carbon fibers can curtail petroleum oil consumption (Nachippan et al., 2021), with a subsequent reduction in climate relevant CO_2 emissions (Wazeer et al., 2023).

However, like most bio-based products, industrial hemp can have agricultural input related consequences, such as eutrophication and ozone layer depletion during the biomass cultivation phase (Weiss et al., 2012). There is also the impact of land use change on greenhouse gas (GHGs) emissions (Lange, 2011). As is common across the wide categories of bio-based products (Zuiderveen et al., 2023), hemp-based products may also have variation in their environmental impacts. Therefore, the sustainability of hemp products should be assessed individually and thoroughly. This involves examining the whole product value chain (VC), from cultivation, to processing, to manufacturing, to use, and, finally, to disposal (Zuiderveen et al., 2023). To this end, life cycle assessment (LCA) offers a methodological tool to quantify environmental impacts related to the entire production chain of a product (Tukker, 2000). During the conduct of LCA, important phases of a product are divided into segments to enable the meticulous examination and recording of data related to the most significant inputs and outputs around resource and energy (Rebitzer et al., 2004). Then, based on the types and magnitude of input used, output impact categories (e.g., climate change impact, eutrophication, and ecotoxicity) are quantified.

So far, LCAs have been utilized across numerous hemp-based products, including hemp-for-textile fibers (Van Eynde, 2015), hemp-reinforced automotive parts (Wötzel et al., 1999), hemp-based insulation solution (Zampori et al., 2013), and hemp shives for ethanol production (González-García et al., 2012). Some assessments also include life cycle costing (LCC) to estimate the economic aspects across the life phases (Harvey et al., 2016; Mastura et al., 2018; Torres-Rivas et al., 2018). The systematic integration of evaluated results on individual hemp products helps make a lucid statement about the sustainability performance of particular products compared to other bio-based or petrochemical substitutes. Regarding this, some specific reviews on products, such as hempcrete (Di Capua et al., 2021; Füchsl et al., 2022; Ingrao et al., 2015), hemp fiber composites compared with glass fibers (Shahzad, 2012) and reinforced composites (Manaia et al., 2019) have been conducted. However, a comprehensive systematic review quantifying the environmental effects associated with a range of hemp products compared with other bio-based and fossil fuel alternatives has not yet been performed.

The recent development in the hemp sector has also garnered the interest and involvement of various economic actors and stakeholders, resulting in the value chain analysis (VCA) of industrial hemp becoming another field of interest (Ceyhan et al., 2022). As such, due to this rapid evolution of the hemp industry and with multiple hemp products (Aryal et al., 2023), the economics of hemp has become more complex, leading to economic uncertainties among the VC actors (Mark & Will, 2019). Thus, a study that aggregates global VC knowledge pools can help identify market economic products, improve economic attractiveness of the products, and increase opportunities within the hemp VC.

Scientific queries on the feasibility analysis of hemp seed and fibers (Aydoğan et al., 2020; Fortenbery & Bennett, 2004; Fortenbery & Mick, 2014; Hanchar, 2019; Schluttenhofer & Yuan, 2017) show regional variability in profit (Dogbe & Revoredo-Giha, 2022; Johnson, 2013). Additionally, many studies (e.g., Brar et al., 2022; Finnan & Styles, 2013; Prade, 2011; Rehman et al., 2013) are unequivocal about the economic benefit of hemp feedstocks for bioenergy generation. Recent studies comparing the cost efficiency of manufactured hemp-based products against the slew of bio-based and synthetic bio-based products has resulted in ambiguity about the relative competitiveness of individual hemp products. So, the recognition of regional feasibility, actual fate, and relative competitiveness of industrial hemp products needs careful consideration.

To address these issues, this study aims to systematically review the current state of research articles that focus on the environmental and economic facets of industrial hemp products and associated VCs. The specific objectives are to (a) identify and document key bibliometric information of ongoing studies on the topic under consideration; (b) analyze the industrial hemp VC from an economic and environmental perspective based on the analysis and synthesis of emerging literature; and (c) find the research lacuna where further studies are needed.

2 | METHODS

2.1 | Classification framework

The study considers VCA, LCA, LCC, and economic feasibility analysis of the hemp value/supply chain and associated products. The deductively derived classification framework for analysis, consistent with the objectives of the study, is presented schematically in Figure 1. While VCA is a wider concept that analyses different phases (e.g., raw material extraction, processing, manufacturing, transportation, use, etc.) of the products, LCA components (of VCA) examine environmental impacts as they pass through these phases. VCA can typically capture the economic dimension of the products along the chain from the financial perspective (Maraseni et al., 2018). However, based on the assumption that hemp VC studies are in their early stages, we propose further classification bubble to assess the economics of individual hemp-based products. Thus, three classification bubbles evaluate the enviro-economic aspects of industrial hemp chains.

2.2 | Systematic review and protocol

This systematic review adopts the reporting protocol called the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA; Moher et al., 2010). Key characteristics of a systematic literature review are that it minimizes the authors' propensity towards the research topic, ensures replicability, and imparts clarity in the review and synthesis process (Lau & Kuziemsky, 2016; Grant & Booth, 2009; Mengist et al., 2020). In addition, PRISMA is a robust reporting format prominently used in health sector research (Liberati et al., 2009), while also gaining in popularity in research realms such as social and agriculture sciences research (Nor Diana et al., 2021).

2.3 | Eligibility criteria

The list of eligible articles considered for final review was guided by the PICO (Population Intervention Comparison

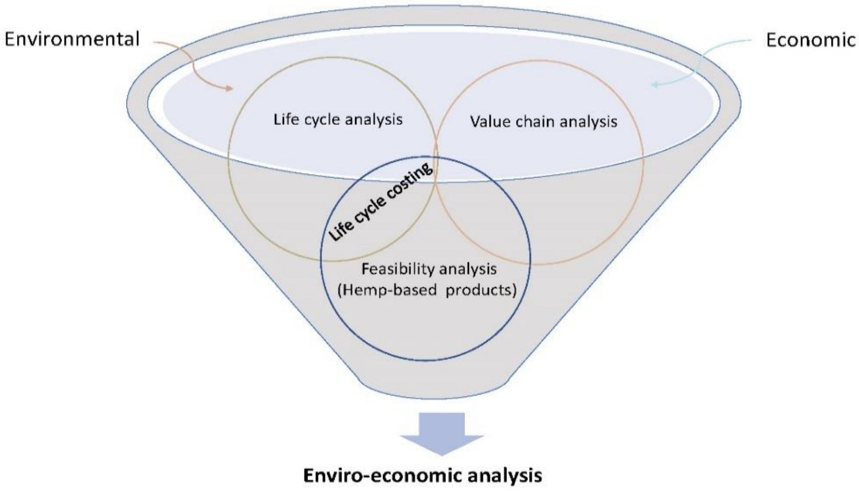

FIGURE 1 Classification framework for enviro-economic analysis of industrial hemp.

and Outcome) framework (Methley et al., 2014). PICO is a tool that originated from health and allied sciences to critically search and assess relevant literature (Eriksen & Frandsen, 2018). We modified the decision criteria of the PICO scheme in our context to remain within the scope of our study (see Table 1). We discarded all articles that considered medicinal, and pleasure uses of hemp, only populating our results with studies related to industrial hemp use. In subsequent rounds, the articles that dealt just with products physical or mechanical properties characterization were dropped and those studies with intervening parts leading to improvements in product value were considered. Then, we excluded perspective and narrative papers with no formal comparators. During our inclusion stage, we retained literature with approaches that compared industrial hemp products against alternative bio-based and synthetic products, demonstrated spatial comparison across nations or landscapes, compared different production processes and/or factors such as inputs use and edaphic conditions. Finally, the outcome criterion was comprised of results showing the qualitative and quantitative variations concerning the comparators or the intervention.

2.4 | Search strategy and article screening

Three online database platforms were used with the aim of extracting the maximum number of relevant articles: (1) Web of Science (WOS); (2) ScienceDirect; and (3) Scopus. Both ScienceDirect and Scopus are internationally acknowledged databases that index the largest number of scientific articles across the globe (Bhattarai et al., 2022; Karki et al., 2021; Maflahi & Thelwall, 2016; Meechang et al., 2020). WOS was used due to the high prevalence of agriculture-related articles (Mongeon & Paul-Hus, 2016) and to acquire related articles not found in the previous two databases. Identical search strings of ("cannabis" OR "hemp") AND ("chain" OR "LCA" OR "economic" OR "financial" OR "profitability" OR "feasibility") were applied to the title and/or abstract and/or keywords fields (see Table 2) to source the repertoire of articles. There was no restriction on the publication year and included English peer-reviewed articles only. Initially, these databases yielded 8684 hits of publications, which were then narrowed down to 7864 hits by applying a database filter to include only research, review, and data papers. This list

TABLE 1 Population, intervention, comparator, and outcome (PICO) framework for inclusion and exclusion decision.

	Included	Excluded
Population	Articles related to industrial hemp	Articles of therapeutic and recreational cannabis
Intervention	Technological, scientific, or policies leading to improvement in production chain and product value	Hemp-based product characterizations
Comparator	• Intercomparison between alternative products • Spatial (between different geographical locations) • Comparison within hemp genotypes, hemp-based products, under different climatic and edaphic conditions	Opinion papers; perspective papers; narrative reviews
Outcomes	Articles focusing on how strategic shift leads to knowledge creation; position relative to the comparators (outputs)	

TABLE 2 Combinations of keywords and Boolean operators for literature search.

		Title-abstract-key words
Operator	Aspect of analysis	Boolean
OR, AND	Value chain analysis from enviro-economic perspective	("cannabis" OR "hemp") AND ("chain" OR "LCA")
	Economic feasibility analysis	("cannabis" OR "hemp") AND ("economic" OR "financial" OR "profitability" OR "feasibility")

was imported into the Zotero library and, using deduplication, the number of hits was reduced to 5906. A subsequent 199 articles remained after manually screening at both the title and abstract level. Finally, after the full paper screening process, 98 articles published from 2003 to 2023 were considered for an extensive review process (see Figure 2).

2.5 | Bibliometric analysis

In this step, the included articles were descriptively characterized to establish a foundation for evaluating them across different themes. This analysis encompassed the distribution of articles by journal, spatiotemporal distributions, regional distributions of hemp products, and wise segregation based on approach and methodology.

2.6 | Categorical identification

In first step, selected studies were classified across the deductively derived categories (i.e., VCA, LCA, and feasibility analysis) based on the evaluation of the abstract and key findings. Next step involved identification of key research themes through inductive analysis of the content of each article. The outcomes were then synthesized, evaluated, and discussed within the established themes.

3 | RESULTS

3.1 | Bibliometric overview

The 98 articles deemed eligible for this systematic review were published in 52 different journals (see Figure 3). The Journal of Cleaner Production held the maximum record of publications (11), followed by Industrial Crops and Products with nine publications. The third most prolific one, the Journal of Industrial Hemp (seven publications), surprisingly published related articles for only until 2009.

As shown in Figure 4, the included articles were published between 2003 and 2023 (22/3/2023) and more than half (52%) of the total number of articles were published from 2019 onwards. Out of the total, 40 articles dealt with the LCA of industrial hemp, while 30 and 28 articles were related to the VC and feasibility analysis categories, respectively.

The spatial distribution of selected articles (Figure 5) shows that, more than 90% of the studies were conducted in European Union (EU) states, particularly Italy and France, and North American countries the United

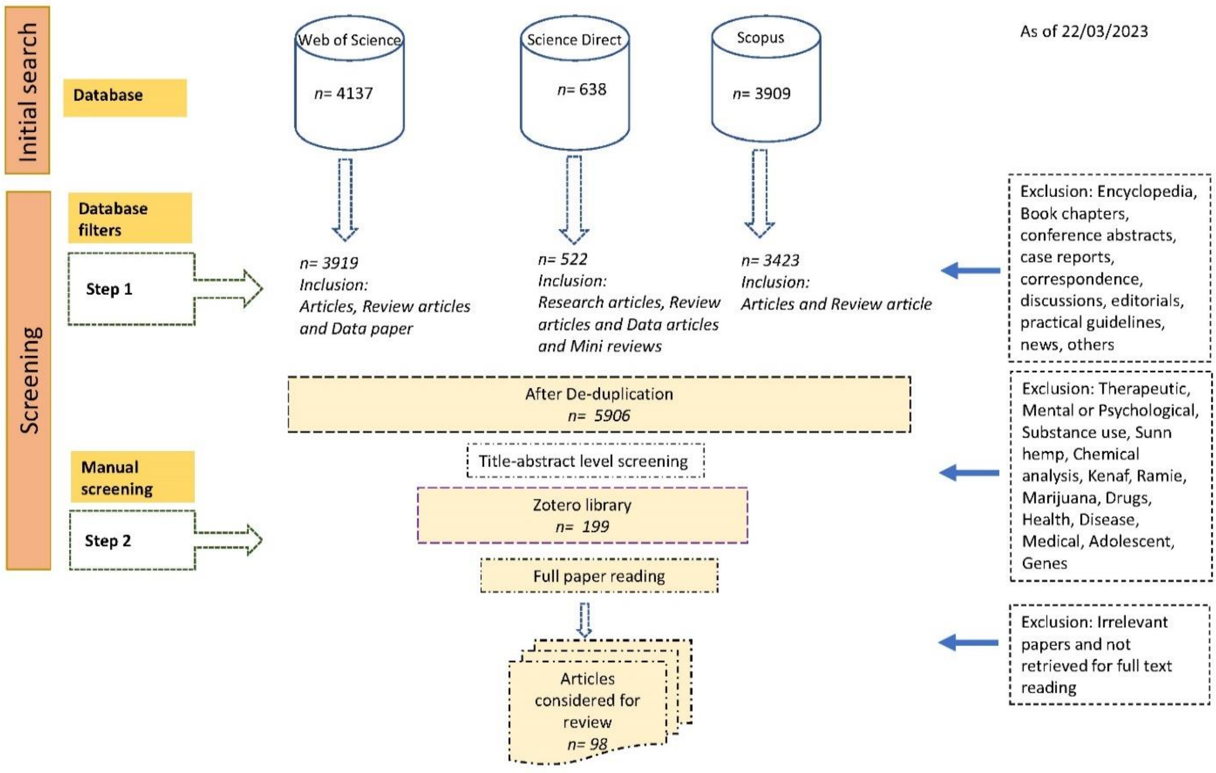

FIGURE 2 Literature search and screening process.

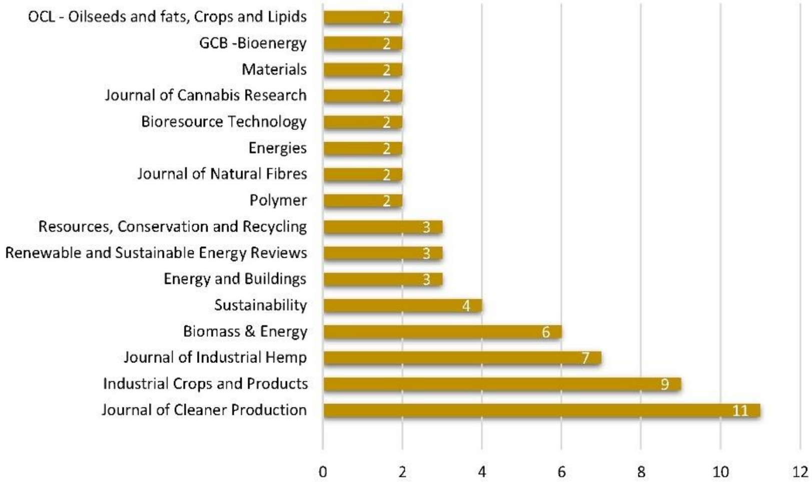

FIGURE 3 Journal-wise distribution of published articles.

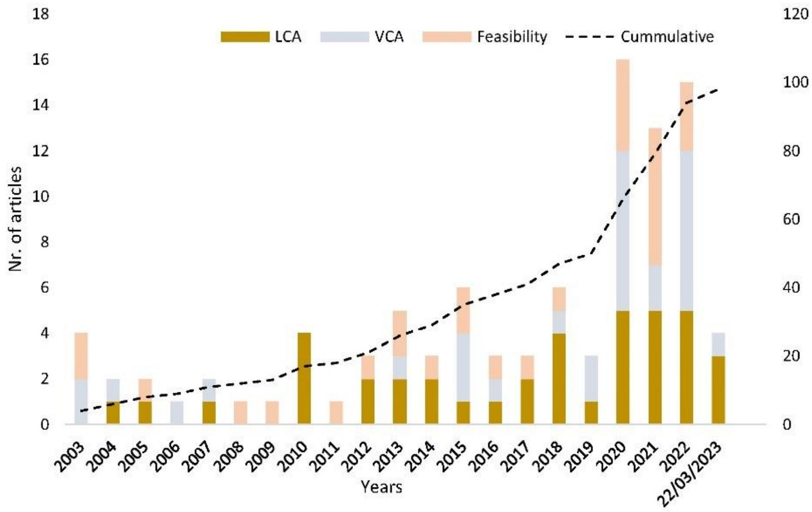

FIGURE 4 Annual distribution of articles across the domains of analysis ($n=98$).

States and Canada. Very few (<4%) studies emerged from the Global South with no research from Africa or South America.

Figure 6 illustrates the regional distribution of hemp-based products based on the bibliometrics analysis of the articles, highlighting their regional prioritization. In Western and Southwest Europe (e.g., Italy), hempcrete received more attention, while Northern European states also emphasized solid biofuel alongside hempcrete. East European countries, namely, Hungary and Poland, focused mainly on textile fiber, while in North America, bio-composites seemingly received more research priority.

The research approach and methodology employed by the researchers are presented in Figures 7 and 8, respectively. Across both the VC and feasibility dimensions, the highly sought-out research approaches were experimental designs with an empirical nature. In particular, field and laboratory-based studies were used, in which researchers investigated ways to enhance the economic value of hemp products. Similarly, based on the empirical evidence the products were valued mostly in financial terms (see Annex 3). Researchers then used content, modeling, case-based or other approaches to descriptively analyze the topics, explore new ideas, and, to a lesser extent, prescribe future recommendations. Meanwhile, all LCA studies followed a common systematic LCA approach and methodology (see Annex 1) to evaluate the environmental impacts of hemp products against other product substitutes. These studies mostly assessed from cradle (materials extraction) to gate (manufactured product outlets) segments of the product's life across several indices, such as global warming potential, eutrophication, and fossil fuel depletion.

3.2 | Categorical identification

In this section, we inductively categorized articles based on the emerging themes across a deductively derived

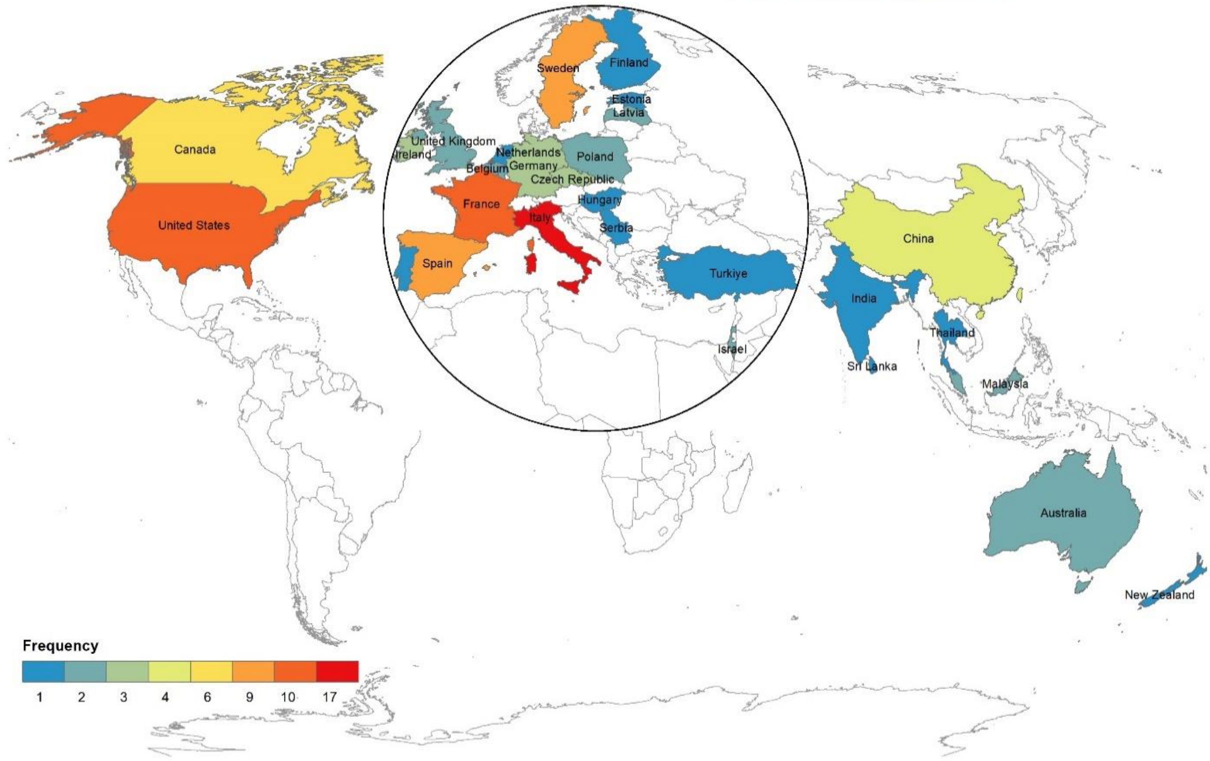

FIGURE 5 Map of the world showing the number of publications by countries.

classification framework (see Figure 9): LCA ($n=40$), VC ($n=30$) and feasibility analysis ($n=28$). Collectively, the thematic content of VC articles was found to be product unspecific or multi-product, while the LCA and feasibility articles dealt with specific hemp products. Notably, only two articles, one each under the LCA and feasibility analysis categories, were related to "Phytoremediation," indicating that very few articles built upon the narrative of industrial hemp performing well under marginal land conditions.

3.2.1 | Life cycle analysis

Articles under the LCA category assessed the environmental burden of industrial hemp products, mostly considering cradle-to-gate boundaries across environmental indices. As shown in Annex 1, these included global warming potential, eutrophication, acidification, and ecotoxicity. Under the LCA category, hempcrete has been studied the most (20% or 50% of the total), followed by bio-composites (7) with four articles belonging to pulp and three articles related to solid/biofuels, three for fibers, one each related to phytoremediation, hemp oil and green protein respectively. The five hempcrete and three bio-composite related articles co-studied LCC, which estimates costs incurred by actors of respective (product) VCs. In all, LCA has been the most comprehensively studied among the three deductive categories. As such, consideration of a wide range of close comparators, distinct boundaries, and units of analysis have attributed to the analytical rigor of LCA studies (Annexes 2 and 3).

3.2.2 | VC analysis

Under the VC category, the 10 initial articles studied economic VC actors and their roles within the chain. In other articles from the most recent decade, eight identified critical intervention areas and explored intervening techniques, while nine articles simultaneously recognized the value-adding opportunities to convert raw hemp components into high-value products. Two articles studied the prospects of novel blockchain technology to solve issues in the hemp VC. Finally, one article explored competitive hemp products for marginal land through multiple European nations' stakeholders' social-VCA.

3.2.3 | Feasibility analysis

Industrial hemp as an energy crop for producing biofuels (bioethanol, biodiesel, and methane) and solid biofuels

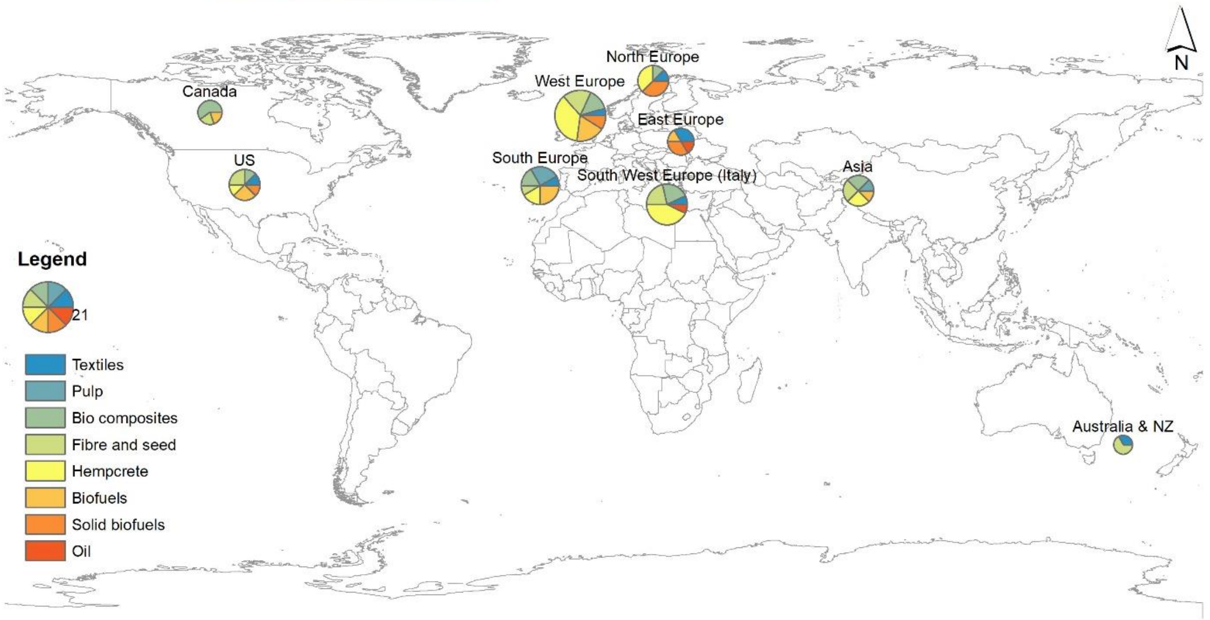

FIGURE 6 Map of the world showing regional distribution of hemp products as emphasized by the selected articles' country of origin.

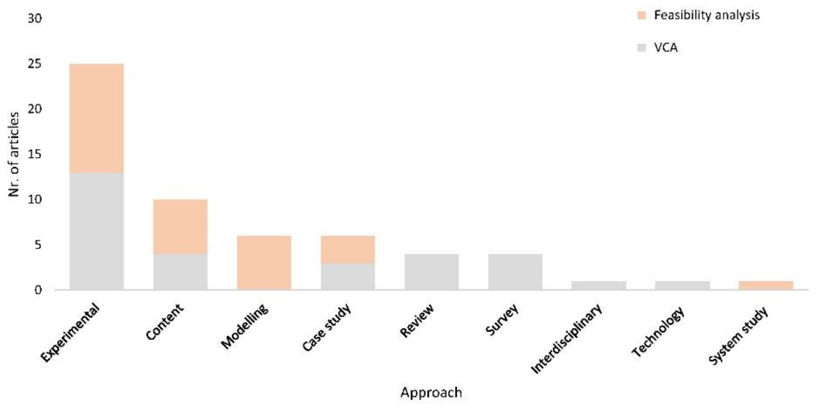

FIGURE 7 Approach-wise distribution of articles.

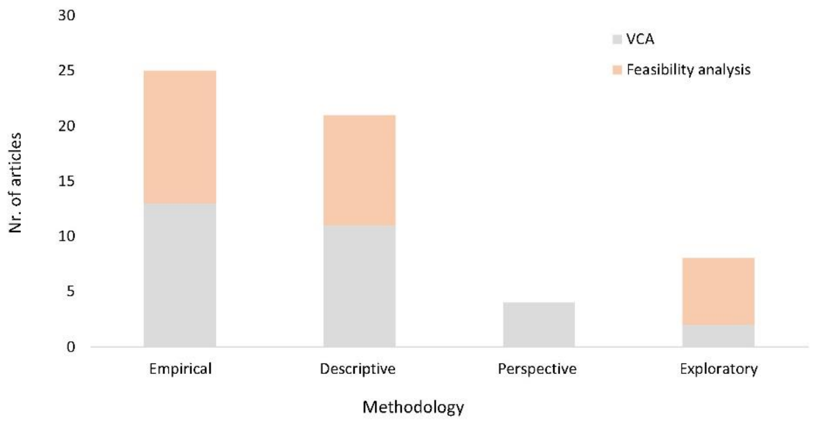

FIGURE 8 Methodology-wise distribution of articles.

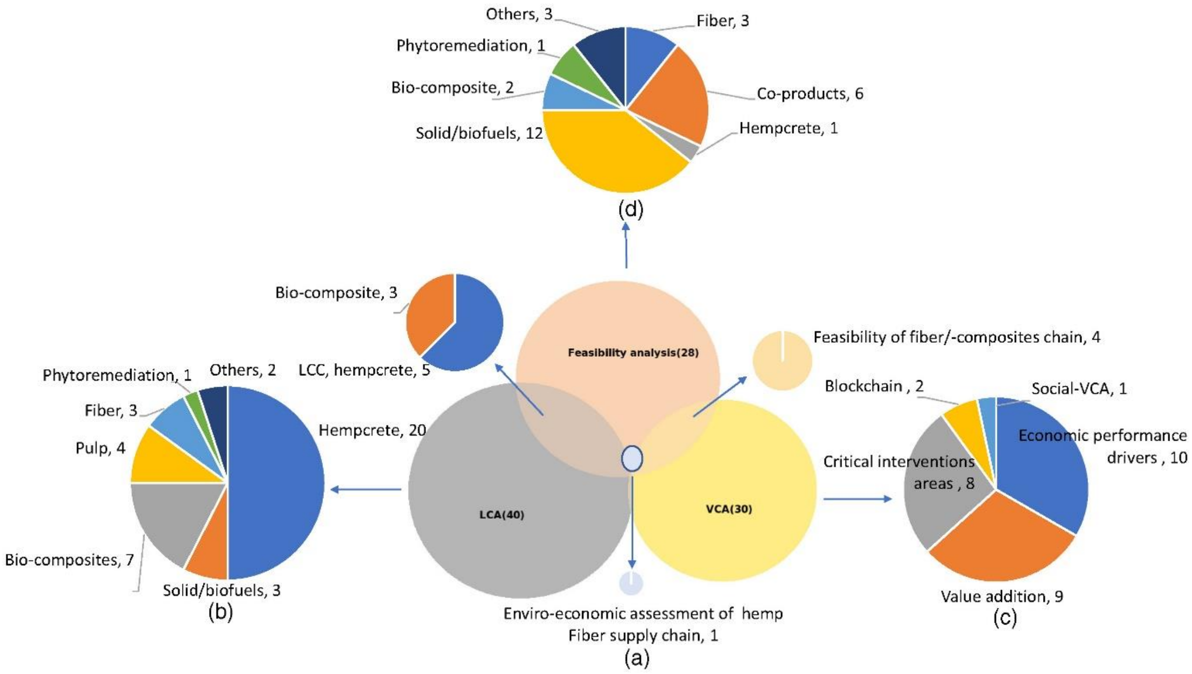

FIGURE 9 Emerging themes of included research articles. The center bubbles (a) indicate broad (deductive) categories and three pie charts around the bubbles show the number of articles with inductively derived themes across each category. (b, d) corresponding to the respective LCA and feasibility bubbles show product-specific themes, while (c) which corresponds to VCA contains themes related to different VC dynamics. The numerals indicate number of articles. $N > 98$ due to overlapping themes.

(briquettes and pellets) were the most extensively studied products under the feasibility analysis category ($n = 13$). Next, concurrent products (i.e., fibers and biofuel, and fiber and seed) ($n = 6$), fiber ($n = 3$), bio-composites ($n = 2$), phytoremediation ($n = 1$) and hempcrete ($n = 1$), and two others (hemp oil and seed) were prioritized hemp products studied from a feasibility perspective. Half of the studies undertaking feasibility analysis solely considered the "cost" of industrial hemp products from manufacturers and the user perspective, while the other half studied factors like benefits and profit margins. This leaves a gap in literature regarding the profitability of some hemp products.

Finally, one of the articles encompassed all three categories, comparing GHG emission and economic feasibility (yield/cost/price) from industrial hemp tailored to bioenergy production, against those of wheat and poplar.

4 | DISCUSSION

4.1 | Revisiting the bibliometric overview

The spatiotemporal trend of selected articles reveals that over 90% of studies that consider the enviro-economic and feasibility assessments of industrial hemp are conducted in Europe or North America. More than half of them were published in the past 5 years. This can be attributed to the recent lenient and lucid EU regulations for industrial hemp (Sorrentino, 2021), which has enabled an environment for conducting research. The surge of US interest in hemp research followed the authorization of the Farm Bill 2018 that also led to a substantial rise in publications (Abernethy, 2019). Moreover, the increasing interest in the topic of the environmental and economic sustainability of industrial hemp among scholars of the Western world can be explained by the EC's extended commitment toward the circular economy 2015 (EC, 2024). This envisages and encourages a harmony between economic development and environmental protection (Domenech & Bahn-Walkowiak, 2019). However, there is a clear dearth of research on industrial hemp in related facets in other parts such as vast areas of the Global South.

Hemp products prioritized by the studies tended to have regional prioritization. In general, hempcrete with environmental amicability was the most highly sought product in the European research papers. Indeed, the use of hempcrete for insulation purposes is one of its main applications in Europe (Carus & Sarmento, 2016). Of particular significance, our results emphasize regional specificity, with papers from Southern European countries (i.e., Spain and Portugal) mostly highlighting hemp-for-pulp and East European countries favoring textile fibers. The specific product focus across these country-specific studies can be explained by regional factor; for instances, the Spanish climate that limit the application of industrial hemp to only pulp paper and the East European condition suitable for textile quality yarn production (Gorchs & Lloveras, 2003).

4.2 | Environmental assessment of industrial hemp

The selected 40 articles conducted LCAs of major hemp products with main focus on the global ecological index such as carbon emissions (CO_2) associated with global warming, as well as local/regional eutrophication and acidification indices. Some of the identified carbon hotspot are the yarn production phase during textile manufacturing (Turunen & Van Der Werf, 2007), the functionalization phase for use as composite fiber, and use of lime binder during hempcrete formation (Pretot et al., 2014). However, hempcrete related emissions are counterbalanced to carbon-negative values because of photosynthetic CO_2 fixation during the growth phase and CO_2 absorption (via. carbonation) during the use phase (Arehart et al., 2020). Estimated net carbon storage potential of (m^2) unit hempcrete insulation wall (of varying thickness) ranges from 4.28 kg CO_2 eq (Zampori et al., 2013) to 36.08 kg CO_2 eq (Ip & Miller, 2012). Shortening the supply chain phase of resource extraction (Di Capua et al., 2021) and the use of unfired binders alternatives (Florentin et al., 2017) instead of lime binder (Pretot et al., 2014) can further reduce hempcrete-associated emissions.

The application of (nitrogenous) fertilizer and pesticides during cultivation of industrial hemp has been the subject of ecological concern, leading to regional consequences such as eutrophication, (Bernas et al., 2021), acidification (Casas, 2005), and ecotoxicity (Seile et al., 2022). Owing to these environmental constraints on input use, hemp as a pulp for paper remains less sustainable than flax (González-García, Hospido, et al., 2010; González-García, Teresa Moreira, et al., 2010), eucalyptus (Da Silva Vieira et al., 2010), and woody perennials (Sun et al., 2018). Regarding the ecological footprint associated with hemp hurds derived biofuels (e.g. bioethanol), the pros of reduced fossil fuel demand and photooxidation (González-García, Moreira, et al., 2010) can be counterbalanced by reallocating the environmental burdens of by-products such as glycerine, cakes, and straw. Other energy crops like triticale, wheat, sugar beet, and maize were considered more carbon and energy-efficient than hemp for biofuels, as illustrated by Börjesson et al. (2015).

Moreover, above discussions are based on the research findings of industrial hemp grown in the dedicated agricultural land under input intensive production system. The performance of industrial hemp with minimal inputs and in marginal landscapes could be a good discussion topic in future studies. To this end, a pioneering study by Todde et al. (2022) showed the relative energy saving of 36.8 GJ and emission reduction by 641 CO_2 eq/ha from industrial hemp under contaminated soil and a low-input scenario, when tailored to bioenergy production. More empirical studies are needed to widen our understanding of how hemp will perform and what hemp products can be produced with low environmental trade-offs, under given unconducive scenarios in particular regions.

4.3 | VCA of industrial hemp

Based on the analysis of included VC articles, the stakeholder rendezvous at the Canada AgFibe 2002 conference can be considered a significant milestone for industrial hemp VC studies. Back then, the linkage between VC actors (e.g., producers, processors, and buyers) in the fiber supply chain was critical in the Canadian fiber VC (Hanks, 2003). The French system also demonstrated how linkages between VC actors were crucial (Alex et al., 2005). The study recognized the need of network consortium among farmers and primary processors to ensure the continuous supply of high-quality textile fibers. Over the course of time, expanding industrial applications demanded increasingly economical production of high-quality diversified raw material components, including fiber, hurds, and seed. Consequently, the thematic focus of the most recent decade on VC research shifted towards the identification and workings of technical or production process-oriented issues, with a strong focus on extracting raw materials for market competitive diverse hemp products in more economical ways.

4.4 | Potential areas for improving economic performance

In general, hemp harvesting (Pari et al., 2015) and fiber processing (Vandepitte et al., 2020) have been identified as key intervention areas for global hemp VC development (Müssig et al., 2020). Due to a slow harvesting and components extraction process, the traditional manual hemp harvesting method is no longer feasible, especially in parts of the industrialized world with expensive labor charges. So, these exigent circumstances drive the need for mechanization. Various researchers have conducted trials using currently available harvesters. For instance, Vandepitte et al. (2020) adapted agronomic practices to acquire the desired size of hemp stalks that fit within the arc of automated flax harvesters. Meanwhile, Assirelli et al. (2020) reduced the rotary cutter of self-propelled forage harvesters to separate fibers right from standing. These harvesting techniques excelled in speed of operation alongside reduced labor with enhanced quality of component fiber (tow and long fibers) and shives yields. The sunflower head assembled combined harvester is one recently tested technique that enables the acquisition of valuable threshing residues during seed harvesting (Assirelli et al., 2022).

At the fiber processing stage, decortication (Gratton & Chen, 2004) and spinning steps (Zimniewska, 2022) have been a recurring concern (Wang et al., 2018). Fibernova D7 type decorticator was proposed previously, but with high moisture retention (70.5%) in hurds, it is economically unviable at the farmers' level (Riddlestone et al., 2006). Similarly, a linen spinning technology can be adjusted for hemp yarn production, but this system demands a specialized implementation configuration that is inaccessible in most markets (Zimniewska, 2022). Other identified issues in the hemp VC include funding sources and traceability, with one potential solution being the proposed adoption of novel blockchain technology (Ferrández-Pastor et al., 2022; Liu et al., 2023).

4.5 | Value addition

Researchers have explored various opportunities within the industrial hemp VC that showcase ways to add value to the products. For example, the blend of hemp fibers during composite knitting step can create UV-resistant high-value apparels (Kocić et al., 2019; Müssig et al., 2020). Similarly, hemp seed is valued for human food fortification, to both enhance protein content and stabilize the physico-bio-chemical properties of food products (Burton et al., 2022).

Valorization is one such technique that can convert low-value biomass into value-added bioproducts and chemicals (Loow et al., 2016). Moreover, various biophysical pretreatment and accompanying recovery procedures (Murthy & Madhava Naidu, 2012) have been the basis of several experiments (Figure 10) to produce high-value commercial products with a range of applications. Hemp hurd, a by-product of the textile industry (Dang & Nguyen, 2006), can be valorized into textile fibers and nanocellulose through a route called Organosolv pulping (Muangmeesri et al., 2021). Sonication–microwave–alkali treatment procedure is another way to convert fibers into nanocrystalline cellulose suitable for bio-composite reinforcement (Xu et al., 2013). Similarly, volatile fatty acids (e.g., single-cell proteins and polyhydroxy butyrates) are high-end market products obtained through the acidogenic fermentation of hurds, leaves, and inflorescence (Moscariello et al., 2022). Furthermore, mercerization and subsequent enzymatic treatment (George et al., 2015) or tall oil application (George et al., 2016) are demonstratable techniques for removing the hydrophilic hemicellulose content of hemp fibers to enhance its thermal properties. Capitalising on valorization opportunities will enhance the economic value of industrial hemp products. The development and scaling-up of laboratory-demonstrated techniques to an industrial level will ensure extra income generation.

4.6 | Economic feasibility of hemp-based products

Hemp as a feedstock for bioenergy generation entailing biofuels (e.g., bioethanol, biodiesel, and biogas), briquettes, and pellets were the most studied products among articles included under the feasibility analysis category. However, industrial hemp for bioenergy production in Northern Europe did not look economically sanguine under the current levels of feedstock productivity, input cost, and energy price. In the Irish context, Rice (2008) calculated a negative gross margin of energy hemp at the prevailing energy price of US$4.06/Gj (peat as fuel). Highly optimistic scenarios including 14 t/ha DM yield, organic fertilizer input, and start-up grant availability may provide a profit margin of US$1123/ha (Finnan & Styles, 2013). But the maximum yield potential of European hemp cultivars' is 10.7 t/ha (Kolarikova et al., 2015). In Estonia, financially remunerative hemp briquette necessitated a surge in price from 130.63 US$/t to at least 199.47 US$/t (Alaru et al., 2013). The prospect of hemp pellets production is also disarming, with an estimated input (tillage and seed fertilizer) cost of 432 US$/t DM, which is at least 52.9 US$/t DM higher than other energy crops like reed canary grass and other crop by-products such as shavings and straw (Nilsson et al., 2011). Additionally, methane production from hemp biomass in Europe is not fortuitous (Gissén et al., 2014). The estimated hemp feedstock yield of 80 Gj methane/hac is only half of sugar beet (including tops) yield and, with a feedstock production cost of 15.12 US$/Gj, profit realization cannot be expected.

Nonetheless, due to a relatively low-input demand and high productivity, the use of hemp fibers can be more cost-effective than cotton for textile industries (Duque Schumacher et al., 2020). Similarly, the application of hemp fiber composites such as in automobiles (Hagnell et al., 2020), in bioplastic production (La Rosa et al., 2013), and in manufacturing conduits and fittings (Haylock & Rosentrater, 2018) have shown considerable cost reductions when compared to petrochemical-derived glass

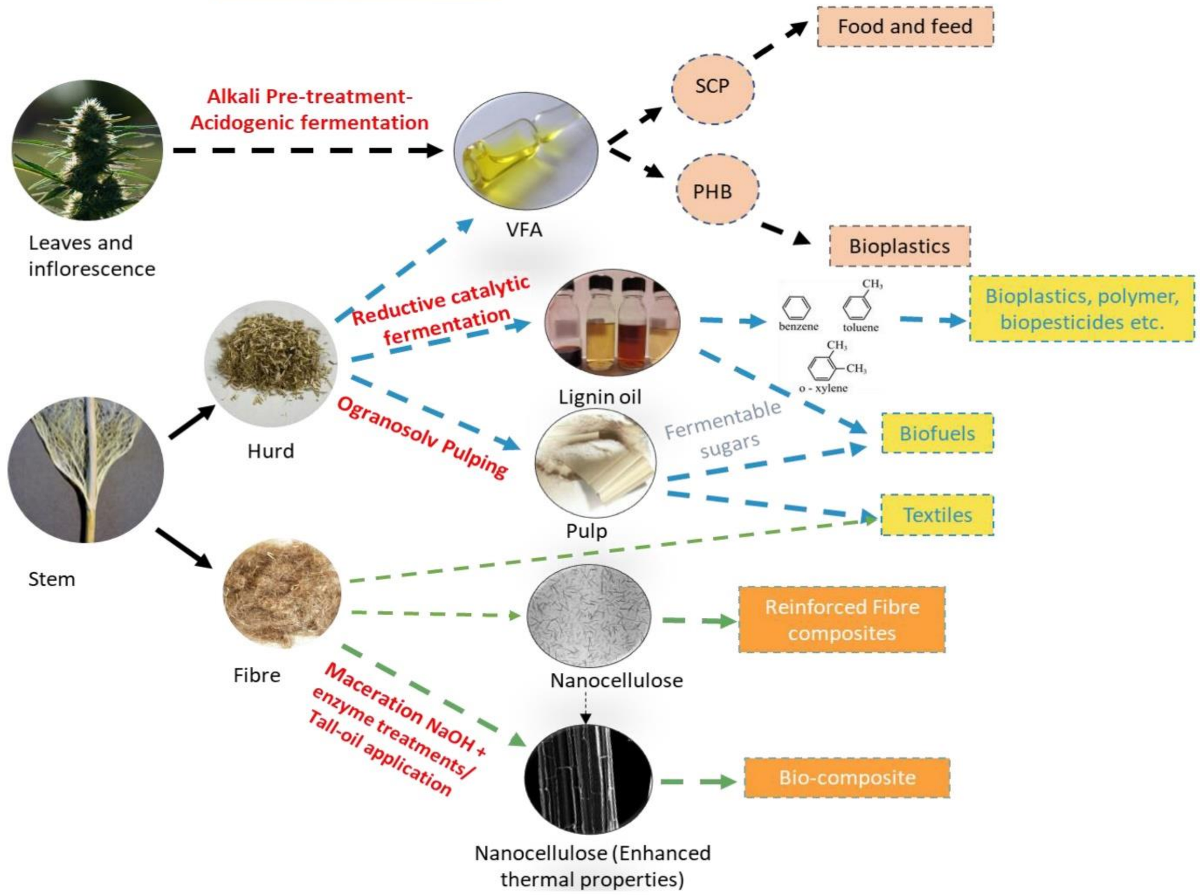

FIGURE 10 Illustration of different routes of valorization proposed by different authors.

fiber and non-renewable talc. However, bio-composites sourced from flax fiber and date palms were cheaper than hemp bio-composites for the automobile industries (Al-Oqla et al., 2015).

The cost competitiveness of hempcrete for housing insulation can vary with region. In Italy, Annibaldi et al. (2020) estimated installation costs for the inner surface (wall) was 22.88 US$/m^2, which was 24.24 US$/m^2 cheaper than alternative insulation materials like aerogel, cork, calcium silicate, and polystyrene. It also had a low life cycle NPV costing (3024.9 US$/m^3) compared to either synthetic polyurethane (3217.34 US$/m^3) and mineral rock wool (3122.5 US$/m^3; Rocchi et al., 2018). In France, insulation solutions like glass wool, cellulose fiber, rigid foam polyurethane expanded-polystyrene (XPS), and extruded-polystyrene (EPS) were more economical (Colli et al., 2020). Moreover, the economic viability of hemp fibers for various applications depends on the cost-effective acquisition of fiber material, influenced by fluctuations in the fiber process (Seile et al., 2022). In fact, high cultivation (particularly N fertilization) and manufacturing costs has led to relative cost inefficiencies at the upstream level as compared to alternative bio-based solutions such as miscanthus (Schulte et al., 2021). From the producer's perspective, high input costs may infer low relative profitability, regardless of the ultimate use.

4.6.1 | Co-production scheme

Profitability of industrial hemp can be assured through a production scheme that considers multiple co-products. Figure 11 presents pooled data indicating positive returns from bioethanol and grain co-products, with a range of 640 US$/ha to 2632 US$/ha across hemp varieties and geographical location, while there is a profit loss under a bioethanol-only production scheme. This was observed directly in several regional localities. For example, a dual production scheme of fiber and seed in Turkey (Ceyhan et al., 2022) or a combination of concurrent products of biodiesel, fiber, or seed in Malaysia (Szulczyk & Badeeb, 2022), were seen as profitable. However, hemp fiber production only in

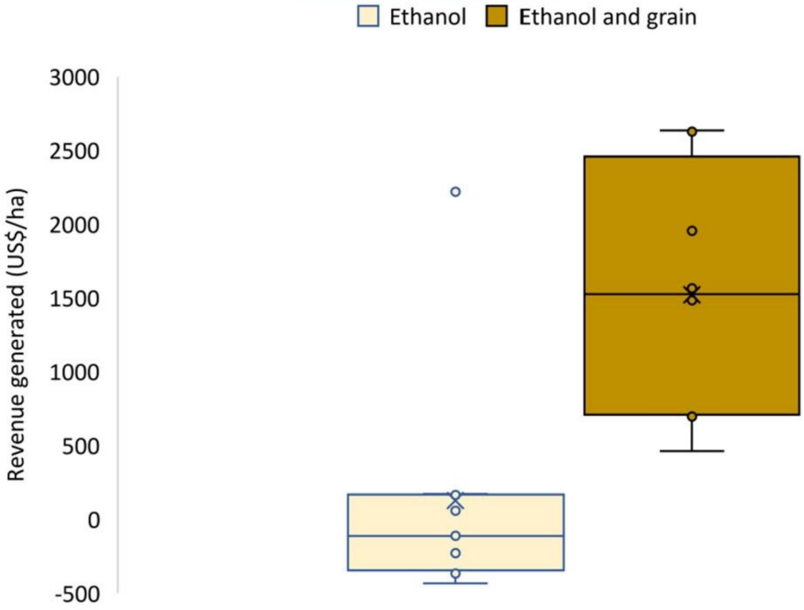

FIGURE 11 Comparison between revenue generation from ethanol and co-product ethanol and grain. Based on the pooled revenue figures of different nations estimated by Parvez et al. (2021), Das et al. (2017, 2020) and Buck and Senn (2016).

both the Turkish (Ceyhan et al., 2022) and the Malaysian edapho-climatic scenarios (Wimalasiri et al., 2021, 2022) resulted in a monetary loss of −555 US$/ha and −2000 US$/ha to −1800 US$/ha, respectively. Other findings indicate that in a co-production scheme profitability could be further enhanced through biotechnological advancements that increase the amount of products with highest price, such as increasing hemp plant lipid content to enhance high-priced biodiesel production processes over ethanol production (Viswanathan et al., 2021).

The current body of evidence suggests positive returns on concurrent hemp products. However, hemp as a dedicated crop in the arable landscape should also be financially competitive with other conventional crops. Future studies should therefore investigate the relative profitability of industrial hemp as compared to established arable crops. Furthermore, current findings are region-specific, with most observed in developed nations and cannot be generalized to other parts of the world. The Global South, for example, is home to the vast majority of smallholder farmers, who are characterized by low-input farming systems and cheap labor forces (La Rosa & Grammatikos, 2019). These regions can potentially host more economically viable industrial hemp production systems; however, countries in the Global South producing industrial hemp from this aspect are yet to be studied.

4.7 | Enviro-economic linkages

Overall, it may be surmised that the arable landscape of the Global North cannot have environmentally sustainable industrial hemp vis-à-vis profitability. To illustrate this, in France, Institut Technique du Chanvre (2007) recommended a nitrogen (N) fertilizer rate of 120 kg/ha (Abernethy, 2019) for achieving optimum economic returns from industrial hemp (Alaru et al., 2013). Thus, the environmental consequences of field nitrogen application are evident. A study by Finnan and Styles (2013) suggested that organic fertilizers such as low or no-cost sludge applications are both environmentally friendly and economical, and therefore make profitable yield alternatives. However, their findings indicated lucrative hemp biomass yield from organically grown hemp is more likely case or context sensitive and cannot be generalized. Rather, a premium price received by the producers for delivering eco-friendly (organic) products can be a key profitability factor. Therefore, understanding consumers' perceptions toward hemp bioproducts and their willingness to pay premium prices should drive future research. Additionally, the price competitiveness of all the economic actors involved in the industrial hemp VC could be another important aspect for further analysis. For this, a feasibility study should be conducted from the vantage of the VC, aiming to quantify the monetary flow across all the actors along the entire chain.

5 | CONCLUSION

To recapitulate the major findings of our bibliometric analysis, above 90% of the studies were conducted in the regions of Europe and North America. The results revealed regionally prioritized hemp products, such as hempcrete in Southwest Europe (Italy), biofuel in Northern European states, and textile fiber and bio-composites in Eastern Europe, Asia, and North America. These findings emphasize the large concentration of studies on hemp products in the Global North, with insights from the Global South remaining uncaptured.

LCA studies show that industrial hemp can provide environmentally benign products for transportation to the construction sectors as compared to fossil fuel alternatives. In particular, hempcrete is an equivocally touted climate-friendly construction solution, with net carbon storage from at least 4.28 CO_2 eq/m^2 to 36.08 kg CO_2 eq/m^2 due to carbon assimilation during growth phase and carbon absorption during use phase. However, alternative bio-based solutions from flax, palm, or eucalyptus can be more ecologically amicable. Moreover, the application of fertilizers and pesticides during the biomass production stage of industrial hemp can incur an environmental risk.

The most recent decade on VC research recognized the urgent need for mechanization at both the harvesting and fiber processing nodes within the chain. This can reduce manual labor costs and enable the acquisition of plant components of various application. Research also divulged value-adding steps and valorization pathways from laboratory experiments to convert hemp residual biomass into high-value products such as VFAs and nanocellulose. To monetize these valorized products effectively, future studies should focus on scaling at the industrial level.

The research outcomes in the feasibility analysis category show that co-production schemes in combinations, like biofuel and grain or fiber and grain, are financially remunerative, while sole production schemes for biofuels (pellets and briquettes) and fiber remain unfeasible. The feasibility of bio-composites and hempcrete are elusive since most literature to date investigates the cost effectiveness of industrial hemp at the upstream user level and the price competitiveness at the downstream producers or manufacturer level is still largely unknown.

AUTHOR CONTRIBUTIONS

Rajan Budhathoki: Conceptualization; data curation; formal analysis; methodology; writing – original draft. **Tek Maraseni:** Conceptualization; supervision; writing – review and editing. **Armando Apan:** Supervision; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

Data will be made available upon request.

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ANNEX 1 Summary of LCA of different hemp products, methodology, unit of analysis, span, and considered environmental indicators.

			LCA methodology				Considered (major) environmental impacts								
Reference	Products	Country	Study approach	Comparators	Unit	Span (years)	GW	E	A	T	OD	FD	PM	LU	O
	Direct plant products														
Van Der Werf (2004)	Fiber	France	Cradle-to-farm gate	Fiber hemp versus arable crops			×	×	×	×				×	×
Turunen and Van Der Werf (2007)	Fiber	Hungary	Seeding-to-spinning of yarn	Fiber hemp versus Flax fiber across different rating scenarios	100 kg yarn		×	×	×			×		×	×
Bernas et al. (2021)	Edible oil	Czech Republic	Cradle-to-gate	Hemp oil versus traditional oilseed crops	1 m^3 edible oil and parcel of land required for this production volume	-	×	×	×	×		×			
Campiglia et al. (2020)	Seed	Italy	Cradle-to-gate	Different hemp genotypes	1 kg seed		×	×	×	×	×	×	×	×	×
	Fiber composites														
Recupido et al. (2023)		Italy	Cradle-to-gate (factory)	Among different types of hemp-based fillers	5.9 gm filler	—	×	×	×	×	×	×			×
Seile et al. (2022)		Latvia	Cradle-to-gate (factory)	Among hemp/– and flax/PLA and between non-renewable polyamide composite	1000×500 mm dimension composite	—	×	×	×	×	×	×			
Ead et al. (2021)															
Haylock and Rosentrater (2018)		US	Cradle-to-grave	Hemp fiber (PLA composite) filler versus other renewable non-renewable fillers	10, 100 and 1000 gm fillers		×	×	×	×	×				×
La Rosa et al. (2014)		Italy	Cradle-to-gate (factory)	Sandwich panel manufactured with hemp/ bio-epoxy resin versus conventional epoxy/glass fiber	0.4×0.4×0.02 m dimension sandwich panel	—	×	×	×	×	×	×			×
Ramesh et al. (2022)		India	—	Review	—	—	×	×	×	×	×	×			×
	Building materials														
Haik et al. (2023)	Hempcrete	Israel	Attributional or consequential	Lime hempcrete versus hempcrete with unfired binders as a substitute	1-storey building	50	×								
Mouton et al. (2023)		Belgium	Cradle-to-grave	Bio-based dwelling components	1 m^2 of purposed building elements	60	×						×	×	
Vilaboa Díaz et al. (2022)		Portugal	—	Materials from agricultural waste	1 kg of bio-based materials		×								
Colli et al. (2020)		France		Hempcrete versus bio-based and synthetic insulation solutions	1 m^2 of insulating materials		×			×		×	×		
Ip and Miller (2012)		UK	Attributional	Exploratory study	1 m^2, 0.3 m thick hempcrete wall	100	×								
Di Capua et al. (2021)		Italy	Cradle-to-gate	Hempcrete vs conventional construction materials	1 m^3 wall	-	×			×		×			

Continued

ANNEX 1 (Contiuned)

			LCA methodology				Considered (major) environmental impacts								
Reference	Products	Country	Study approach	Comparators	Unit	Span (years)	GW	E	A	T	OD	FD	PM	LU	O
Pittau et al. (2020)		Italy		Hempcrete blocks as a surface insulator versus another insulation choice with refurbishment and reconstruction case	Historical industrial building		×	×	×	×	×	×	×	×	×
Scrucca et al. (2020)		France	Cradle-to-gate	Exploratory study (hurds for building sector)	1 kg hemp hurds		×					×			
Arehart et al. (2020)		US	Cradle-to-gate	Exploratory study (hempcrete for insulation material)	1 m^2 wall		×	×							
Heidari et al. (2019)		France	—	Treated hemp hurd versus untreated hurd and reference wall materials	1 kg hemp hurd and sol–gel (coating)/1 m^2 insulation wall	60–120			×	×				×	×
Sinka et al. (2018)		Latvia	Cradle-to-gate	Lime hempcrete versus hempcrete with magnesium binder as lime substitute	1 m^2 wall		×	×	×	×	×				×
Mungkung et al. (2016)		Thailand	Cradle-to-gate	Hempstone versus artificial stone	Hempstone sheet (3.04 L × 0.82B × 0.012H m^3)		×	×		×					
Pretot et al. (2014)		France	Cradle -to-grave	Hempcrete walls with different coating compositions	1 m^2 hempcrete wall having 27 cm thickness (incl. 2 cm and 1 cm external and internal coating)	100	×	×	×		×	×			×
Hult and Karlsmo (2022)	Insulation	Sweden	—	Hemp fiber versus conventional insulation solution	Nuclear family home	50	×								
Dickson and Pavia (2021)		Ireland	—	Hemp versus conventional insulation	1 m^2 insulation materials		×	×	×		×	×			×
Schulte et al. (2021)		Germany	Cradle -to-grave	Among materials of biological (incl. hemp) origin and between non-renewables	1 m^2 external wall	70	×	×	×	×	×	×	×	×	×
Florentin et al. (2017)		Israel		Hemp-lime insulation versus conventional insulation solution	110 m^2 Residential building apartment	50	×								
Zampori et al. (2013)		Italy	Cradle-to-gate	Hemp fiber insulation versus rockwool insulation	1 m^2 insulation panel	—	×		×	×	×	×		×	×
Rocchi et al. (2018)		Italy		Among renewables (hemp and kenaf) and between non-renewables	1 m^2 insulation panel	25	×				×				×
Kiesse et al. (2017)		Germany		Environmental impacts resulting from various potential actions	1 m^2 insulation panel and wall	50/100	×	×	×	×					×
	Pulp and paper														
González-García, Hospido, et al. (2010)		Spain	Cradle-to-gate	Hemp versus flax fiber	1-ton fiber	—	×	×	×			×			×

ANNEX 1 (Contiued)

Reference	Products	Country	LCA methodology: Study approach	Comparators	Unit	Span (years)	Considered (major) environmental impacts: GW	E	A	T	OD	FD	PM	LU	O
González-García, Teresa Moreira, et al. (2010)		Spain	Cradle-to-gate	Hemp versus flax fiber			×	×	×	×					×
Da Silva Vieira et al. (2010)		Portugal	Cradle-to-pulp	Hemp versus eucalyptus paper	1-ton paper manufactured	-	×	×	×					×	
Sun et al. (2018)		China	Cradle-to-gate	Hemp and flax pulping versus straw-based pulping	1 ton of wheat straw pulp	—	×	×	×	×	×	×			×
	Bioenergy														
González-García, Moreira, et al. (2010)	Ethanol	Spain	—	Hemp hurd feedstock versus alternative lignocellulosic feedstocks	1 km distance travelled by flexi fuel vehicle	—	×	×	×			×			×
González-García et al. (2012)		Spain	—	Hemp hurd feedstock-based bioethanol at varying blends	1 km distance travelled by flexi fuel vehicle	—	×	×	×			×			×
Börjesson et al. (2015)	Methane	Sweden	Field to tank	Biogas production from hemp versus different crop biomass	1 GJ of biogas produced		×								
Todde et al. (2022)	Electricity	Italy	Cradle-grave	Electricity generation using hemp biomass versus traditional sources	1 kg dry biomass and 1 ha phytoremediation area										
Casas (2005)	Biodiesel	Spain	Cultivation to fuel manufacturing	Biodiesel versus diesel			×	×	×		×	×			×

Abbreviations: A, acidification; E, eutrophication; FFD, fossil fuel depletion; GW, global warming potential; LU, land use; O, others; OD, ozone depletion; PM, particulate matter; T, toxicity.

ANNEX 2 Summary of the studies on value chain analysis of industrial hemp, approach, methodology used, their applications, and country.

References	Objective	Approach	Methodology	Application/ products	Country
Liu et al. (2023)	To study the applicability of blockchain technology in supply chain management	Content	Descriptive	Unspecific	China
Moscariello et al. (2022)	Investigating valorization procedure on hemp biomass to achieve high-value bioproducts	Experimental	Empirical	Multipurpose (unspecific)	Italy
Ceyhan et al. (2022)	To conduct a value chain analysis of industrial hemp from an economic perspective in Turkey	Survey	Descriptive	Fibers and seed	Turkey
Ferrández-Pastor et al. (2022)	To suggest a model that parallelly integrates experts' knowledge and technology, that is, blockchain and internet of things approach for enhancing traceability of industrial hemp chain	Content	Descriptive	Unspecific	Spain
Burton et al. (2022)	To review the studies about the applicability of hemp seed as a value-added human dietary ingredient	Review	Descriptive	Seed	Australia
Zimniewska (2022)	To review literature on fiber properties and processing identifying their intervention nodes	Review	Descriptive	Textile	Poland
Assirelli et al. (2022)	To investigate a novel hemp seed supply chain through manipulation of sowing time and harvesting practices	Experimental	Empirical	Propagating seed	Italy
Panoutsou et al. (2022)	To conduct social perspective VCA of industrial hemp in marginal agricultural land	Survey	Descriptive	Unspecific	Europe
Zhao et al. (2021)	SWOT analysis of industrial hemp among different regions of China	Survey	Perspective	Unspecific	China
Muangmeesri et al. (2021)	To demonstrate the valorization techniques converting low-value hemp stalks into high-value compounds	Experimental	Empirical	Multipurpose (unspecific)	Sweden
Vandepitte et al. (2020)	To evaluate the fiber characteristics of hemp varieties and their feasibility to get processed into flex scutching line	Experimental	Empirical	Textile	Belgium
Rupasinghe et al. (2020)	To provide an analytical review of industrial hemp about its potential usage as a value-added dietary ingredient and physical well-being	Review	Descriptive	Seed and seed oil	US
Colombo et al. (2020)	Value chain analysis of organically grown hemp for oil purposes in Sicily, Italy	Case study	Exploratory	Seed oil	Italy
Assirelli et al. (2020)	To evaluate the efficiency of a mechanical harvester in separating different hemp biomass components	Experimental	Empirical	Multipurpose (unspecific)	Italy
Giupponi et al. (2020)	To examine the Italian hemp production chain and overall usage	Survey	Descriptive	Multipurpose (unspecific)	Italy
Grégoire et al. (2020)	To investigate alternative fiber extraction processes and their effects on fiber morpho-mechanical characteristics	Experimental	Empirical	Geotextiles/ Bio-composite	France

ANNEX 2 (Continued)

References	Objective	Approach	Methodology	Application/ products	Country
Alonso-Montemayor et al. (2020)	To explore the fate of polyamide 6 in enhancing the mechanical strength of hemp fiber composites	Experimental	Exploratory	Bio-composite	Spain
Kocić et al. (2019)	To compare the properties of hemp fibers with other natural and synthetic fibers concerning UV protection	Experimental	Empirical	Textile	Serbia
Gusovius et al. (2019)	To compare the outcomes of various retting procedures enabling value-added chain and products	Experimental	Empirical	Bio-composite	Germany
Wang et al. (2018)	To compare the decortication efficacy of hemp varieties at a laboratory scale	Experimental	Empirical	Unspecific	Italy
George et al. (2016)	To analyze the effect of physical and enzymatic treatment on the physical and morphological properties of hemp	Experimental	Empirical	Bio-composite	Canada
Bono et al. (2015)	To explore areas for the development competitive industrial hemp value chain	Content	Perspective	Multipurpose (Unspecific)	France
Pari et al. (2015)	To provide a review on hemp (and other blast fibers) harvesting strategies adopted in China and Europe and to provide a way forward to enhance its product value	Review	Perspective	Multipurpose (Unspecific)	China
George et al. (2015)	To study the effect of physicochemical treatment on enhancing fiber for high-value application	Experimental	Empirical	Bio-composite	Canada
Xu et al. (2013)	To demonstrate the fate of enzymatic treatment in producing value-added products	Experimental	Empirical	Bio-composite	Canada
Garnier et al. (2007)	To analyze the marketing and economic forces within the French hemp chain	Content	Descriptive	Multipurpose (unspecific)	France
Riddlestone et al. (2006)	To evaluate a technology aimed at addressing a nodal point	Technology	Descriptive	Textile	UK and Australia
Alex et al. (2005)	To develop an economically resilient hemp value chain	Case study	Prescriptive	Textile	France
Hanks (2003)	To identify underlying problems of the hemp value chain	Case study	Descriptive	Textile	Canada
Amaducci (2003)	To develop a support system ensuring high-quality fibers	Interdisciplinary	Empirical	Textile	Italy

ANNEX 3 Summary of the studies on economic feasibility assessment of different hemp products, approach, methodology used, their applications, and country.

References	Approach	Methodology	Factor	Products	Application	Country
Wimalasiri et al. (2022), Wimalasiri et al. (2021)	Modeling	Descriptive	Profit (NPVB)	Fiber (and seed)	Unspecific	Malaysia
Duque Schumacher et al. (2020)	Content	Exploratory	Cost		Textile	US
Pecenka et al. (2009)	Content	Descriptive	Cost		Unspecific	Germany
Eerens (2003)	Content	Exploratory	Cost/benefit analysis		Unspecific	New Zealand
Salami et al. (2021)	Experimental	Empirical	Cost	VFAs	Agro-biochemicals, stimulants	Finland
Muneer et al. (2021)	Experimental	Empirical	Cost/benefit analysis	Green protein	Food and Feed	Sweden
Devi and Khanam (2019)	Experimental	Empirical	Cost	Oilseed	Edible Oil	India
Gorchs and Lloveras (2003)	Case study	Descriptive	Gross margin	Fiber	Paper	Spain
Seile et al. (2022)	Content	Descriptive	Price	Reinforced composite	Automotive	Latvia
Hagnell et al. (2020)	Case study	Descriptive	Cost		Automotive	Sweden
Haylock and Rosentrater (2018)	Modeling	Descriptive	Cost		Pipes and fittings	US
AL-Oqla et al. (2015)	Modeling	Descriptive	Ranking		Automotive	Malaysia
La Rosa et al. (2013)	Case study	Descriptive	LCC		Pipes and fittings	Italy
Schulte et al. (2021)	Content	Descriptive	LCC	Insulation materials	Building	Germany
Colli et al. (2020)	Case study	Descriptive	WLC (NPV)		Building (hempcrete)	France
Annibaldi et al. (2020)	Case study	Descriptive	Cost		Building (inner wall)	Italy
Rocchi et al. (2018)	Case study	Descriptive	LCC (NPV)		Building (roof)	Italy
				Bioenergy products		
Rheay et al. (2021)	Content	Descriptive	Cost	Bioenergy	Unspecific	US
Finnan and Styles (2013)	Experimental	Exploratory	Cost	Fuel	Unspecific	Ireland
Prade et al. (2012)	Experimental and modeling	Descriptive and exploratory	Economic efficiency	Fuel	Unspecific	Sweden
Dornburg et al. (2005)	Case study	Descriptive	Cost	Fuel	Unspecific	Poland and Netherland
Das et al. (2020)	Experimental	Empirical	Revenue	Ethanol (and co-products)		US
Das et al. (2017)	Experimental	Empirical	Revenue and cost	Ethanol (and co-products)		US
Buck and Senn (2016)	Experimental	Empirical	Revenue	Ethanol (and co-products)	Fuel (vehicles)	Germany
Szulczyk and Badeeb (2022)	Modeling	Empirical	Price			Malaysia
Viswanathan et al. (2021)	Modeling	Descriptive	Cost	Diesel	Fuel (vehicles)	US

ANNEX 3 (Contiued)

References	Approach	Methodology	Factor	Products	Application	Country
Vávrová et al. (2022)	Experimental	Empirical	Cost	Briquettes and/or pellets		CZ
Kolarikova et al. (2015)	Experimental	Empirical	Cost/revenue/profit			CZ
Gissén et al. (2014)	Experimental	Empirical	Cost	Methane	Heating	Sweden
Alaru et al. (2013)	Experimental	Empirical	Price			Estonia
Nilsson et al. (2011)	System study	Descriptive/Exploratory	Cost		Heating	Sweden
Rice (2008)	Content	Descriptive/Exploratory	Feasibility/profitability	Biofuels	Heating/power generation	Ireland

3.3. Links and implications

Although this systematic review paper took quite a while to publish due to the lengthy publication processes, the synthesis of global literature on the industrial hemp value chain aids in identifying research gaps. The subsequent chapter i.e., paper 2 addresses the identified research gap that includes industrial hemp-based value chain study in the developing nations, from a smallholder perspective and under low input production scenario.

CHAPTER 4: PAPER 2: A CONTESTED INDUSTRIAL HEMP VALUE CHAIN STEMMING FROM THE RURAL MOUNTAIN LANDSCAPE OF NEPAL

4.1. Introduction

This chapter quantitively explores the social construct regarding hemp cultivation and illustrates how the operational activities are being carried out despite the legal ambiguity (objective 2). The qualitative approach follows a quantitative exploration of industrial hemp in light of providing substantial evidence of its contribution to the income of pro-poor households. The study further implemented a structure-conduct-performance paradigm to analyse the industrial hemp value chain from farmers to manufacturers (objective 3). These two objectives are studied conjointly because risk and adaptation are the key elements inherent to the value chain of legally contested products, without a comprehensive understanding of which overall value chain dynamics cannot be studied. This posits the rationale behind merging two objectives to formidably analyse the case in a paper, thereby enhancing publishability in the prestigious Q1 journal.

4.2. Submitted paper

A contested industrial hemp value chain stemming from the rural mountain landscape of western Nepal

Abstract

The cultivation and production of hemp has been regaining its momentum after a long period of deadlock due to its widespread prohibition since the early 20th century. Along with the mounting interest among wider nations and communities because of its eco-friendly production and profitability, there has been much-increased attention towards the contested issues of its value chain, especially from the farmers and production communities. In this context, using the case of rural farmers in the Nepalese mountains and employing a mixed-method approach, we aim to uncover the tapestry of the illegal hemp value chain, evaluate the contribution of industrial hemp to pro-poor households, and analyse the structure, conduct, and performance of the industrial hemp value chain. Based on our findings around illegality, we conceptualised 'dark,' 'opaque,' and 'clear' visions, which respectively explicate the sympathetic ground for production allowance, deliberately created opacity for outbound operations and unconcealed distribution activities. Results suggest, albeit with a negative gross margin for farmers when the opportunity cost of labour was considered, hemp has been a compulsion due to a lack of other options, but it has strongly contributed to (food) poverty alleviation for them while also it is a profit-making opportunity for downstream actors. The relationships between value chain actors are not trustworthy and co-innovative, partly due to the illegal nature of the production system. Legalizing hemp, improving marketing information, implementing consortium marketing strategies, and building strong partnerships among vertical and horizontal value chain actors, with a formal code of conduct, could be beneficial to all actors and the nation as well.

Keywords: Industrial hemp, value chain, illicitness, pro-poor, tapestry

Introduction

Industrial hemp (*Cannabis sativa L.*), synonymously called 'cannabis' or only 'hemp' (Small, 2015) is an unconventional crop historically valued for sturdy fibres and oilseed (Small, 2016). The popularity of industrial hemp was so high between the 16th and 18th centuries that it was considered "the king of fibre-bearing plants" and a yardstick for measuring other natural fibres (Boyance, 1900). However, production waned at the outset of the 20th century due to concerns raised by the Western world over the presence of intoxicating agent Δ^9-tetrahydrocannabinol (THC) in hemp, leading to legal production ban (Cherney & Small, 2016; Frontberry and Mick 2014) across countries, including Nepal. The aftermath of that legal sanction in Nepal meant annual national revenue shrink of the then US$100,00, an appalling consequence was the impact on the livelihood of poor far western mountain communities (Fisher, 1975) who were marginalized due to fragile rugged landscape and low human and natural resource base (Nepal & Chipeniuk, 2005).

After the hiatus, the interest in this historically iconic crop is renewed again in the global arena due to the consideration of a diverse range of eco-friendly products and profitability (Dhondt & Muthu, 2021). So far, countries including most European nations (Simiyu et al., 2022), Canada in 1998 (Baker et al., 2010), Australia in 2017 (The Farmer magazine, 2020), the US in 2018 (Farm Bill, 2018) and elsewhere allowed licit production; caveat applies, narcotically active THC under 0.2%-0.3% threshold (Adhikary et al., 2021). This international regulation change bodes some positivity for hemp in Nepal as well (Shakya et al., 2021) but no formal amendments to the pre-existing Narcotic Drug (control) Act 1976 have been reported. Albeit the poor farmers of western (mountain) Nepal continued to cultivate cannabis (or harvest naturally) for seed and fibre production from which they support their livelihood (Clarke, 2007).

Regardless of the legal prohibition and (reportedly) recurring disruption due to the destruction of the cannabis field by the police authority, hemp goods appear as one of the very few products that have gained relative success in both national and international markets. Indeed, it has been the national source of earning foreign currency (DOC, 2023) and is also touted for enhancing the mountain's livelihood. However, the study of the social and economic position concerning illegal industrial hemp production and the operational activities partaken by the actors remain elusive.

The estimates suggest that the global market volume of the hemp industry reached US$4.9 billion in 2019 with the increased forecasted figure of a staggering US$18.6 billion by 2027 (Chouhan et al., 2020). Most importantly, countries of Asia-Pacific regions are key market actors. As Nepal shares the Asia-Pacific territory, the country is poised for a huge regional market, and this has piqued the interest of (hemp) entrepreneurs as proven by the scores of lately flourishing hemp-based businesses around the capital city. Indeed, this sector has prospered significantly beyond the farm gate although the smallholder farmers' level of production is still futile. This advancement has subsequently garnered the interest and involvement of various actors like manufacturers, traders, logistics, wholesalers and, retailers (Ceyhan et al., 2022). To this end, it becomes imperative to orient the realm of the study towards the value chain aspect. So far, the study to date is limited to perfunctory narratives of successful hemp entrepreneurs covered by mainstream and fringe media and in unofficial reports; the current research is an attempt to fill those research crevasses.

Moreover, research on industrial hemp is polarised across the countries in the global North, where most value chain (VC) activities are licit and the focus is on farm-level profitability and there is a lack of understanding of industrial hemp in the Global South and across various VC actors (Budhathoki et al., 2024). The overarching goal of this study is to address this gap by estimating the contribution and reward from the industrial hemp VC among the VC actors and understanding overall VC activities in contexts where legality may be uncertain. In particular, the objectives of this study are: (1) To uncover the tapestry of the illegal hemp value chain, in terms of its production and operational mechanisms, (2) to evaluate the contribution of industrial hemp for the pro-poor households, and (3) to map the structure and analyse the conducts and performance of the industrial hemp value chain. Based on our study, we have proposed some key intervention strategies for industrial hemp value chain development in Nepal.

Methodology

Study area

The study was conducted in Rukum East, a hilly mountainous district of western Nepal. It was selected because previous studies have highlighted it as one of the major hemp cultivation areas in Nepal (Clarke, 2007). It extends over a 272.34 km^2 area, has an elevation rising from 754 to 6072 m above mean sea level, having a sub-tropical to sub-alpine climate (CBS, 2021). The district has three rural municipalities (RM) namely, Putha Uttarganga, Sisne and Bhume, among which Bhume RM was purposively selected for study, where subsistence farming is the major livelihood option (Rai et al., 2023). As such, crops, livestock, and woody-perennial tree species are integral components of farming systems in this area. Inhabitants conduct a farming operation in two vertically disjunct land masses. One is in close proximity to their settlement area, while the other is an elevated highland area called *Goth*. They follow a mandatory pastoral migration to pre-defined highlands in the summer months. During this migration, they perform a range of activities including livestock grazing, and field crop cultivation alongside hemp cultivation that generates cash income (Rai & Dangal, 2022).

Major hemp-producing villages in the selected municipality were identified through one-on-one consultations with local government officials, progressive farmers, and social groups. Based on their input, the Kakri, Khabang, and Sakim villages of Bhume RM were chosen for the study (Fig 1.).

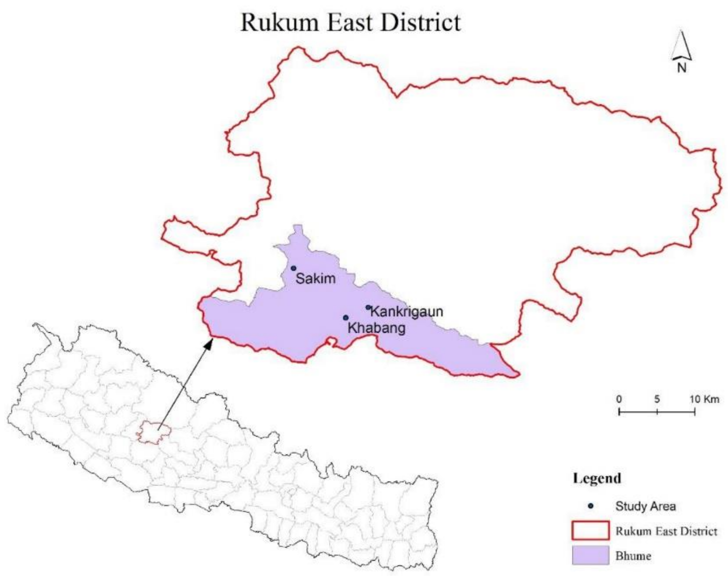

Figure 1: Map of Nepal showing the location of study areas.

Research approach and sampling

In the context of the dearth of prior information, a mixed-method approach to data collection is most appropriate (Chouvy & Afsahi, 2014). Thus, we applied a combination of qualitative and quantitative methods to dig deeper into the less explored industrial hemp value chain dynamics. Before conducting the field survey, we obtained human ethical clearance from the University of Southern Queensland Research Ethics Committee (Approval No. ETH2023-0320). This involved submitting several documents, including risk and benefits assessments, questionnaires, participant information sheets (PIS), and consent forms (CF). Each participant was given a CF to sign, indicating their agreement to participate in interviews. Participants were informed that their participation was voluntary, all information would be kept confidential, and they could withdraw from the study at any time. To make the respondent feel safe and secure in providing the information, the whole interviews, the household survey in particular, were conducted in a friendly environment following an emic approach (Sánchez-Pérez et al., 2023).

At first, we conducted key informants' interviews (KIIs) (n=10) that included representatives of local government, progressive farmers, agriculture extension officers, researchers working in the study area and others including officials of line agencies like Hemp Association Nepal (HAN) and Federation of Handicraft Association (FHAN). The KIIs were guided by open-ended structured questionnaires that consisted of (i) the contribution of industrial hemp to local and national economy (ii) types and quantity of input used; (iii) identification of major hemp VCs actors/ stakeholders, their profile, and functions; (iv) value chain mapping, focusing on products flow and interactions with other stakeholders; (v) institutional and financial settings of the regions; and (vi) institutions related to hemp and marketing activities. Also, during KIIs sessions, questionnaires prepared for household surveys and VC participant interviews were adjusted. After the response from the key informants and subsequent pre-testing of the household survey questionnaire, farm-level production inputs cost calculation was deemed irrelevant. This is because of the involvement of family labour and land with almost zero opportunity cost. Similarly, other inputs including manures were prepared in situ, while excess labours requirement was arranged through a traditional '*parma*' setting, a need-based reciprocal farm labour exchange system. However, we also included foregone labour opportunity cost in the result and discussion section.

For the household (HHs) survey, we acquired the settlement and household lists from the ward offices of respective villages. The three villages i.e. Kankri, Khabang and Shakim were comprised of 670 HHs in total, where we randomly selected 87 using the sample size estimation equation proposed by Yamane, (1973). Of the 87 HHs, only 60 responded (response rate 68.96%) to the survey. The response rate was deemed adequate as those randomly selected villages have demographic and socioeconomic homogeneity alongside similar topographic, edaphic, and climatic attributes. The household (and village-level actors) survey questionnaires entailed both unstructured open-ended and structured close-ended questions. The former explored emerging themes about various social realities and manifestations of illegal production and operational processes while the latter captured process-associated variable costs and returns.

Other industrial hemp value chain actors were identified by using the chain referral sampling (snowball sampling) technique. During the household interview, farmers were requested to provide a referral list of village-level traders. Interviews were then conducted with village traders who ultimately referred to the national traders and this way we tracked and interviewed all the actors down to the manufacturers. During the chain referral, the information provided by subsequent actors of VC was also validated. Accordingly, three local traders, two local retailers, one wholesaler/ cooperative, two national traders, two Suppliers, and five (weavers) national manufacturers were identified and interviewed. Based on snowball sampling, our selected value chain actors were related to fabric manufacturers and seed cooperatives.

Data analysis

At first, we performed a descriptive analysis to provide a snapshot of the socio-economic characteristics of the study area. Next, we used a qualitative approach to understand the reasons for production regardless of its illicitness, and its overall operational mechanisms. The qualitative part of the data generated during the interviews was analysed following the standard analytical steps in the study to categorize, code and identify the dominant perspective themes (Creswell & Poth, 2016). This involved recognition of constructed realities that distinguished farmers' participation in industrial hemp production from non-participation and the undergoing settings that enabled hemp seed and fibre supply chain activities. We conducted within-case analysis and then cross-case analysis to respectively identify similarities and discrepancies from the common patterns as described by Tobin et al., (2016). This process was crucial in understanding why production is happening and how it's being operated.

Further, we quantified the household cash income contribution of industrial hemp by calculating the percentage of incomes from hemp fibres and seeds out of total annual incomes from collective sources. Then, we divided the gross income of 60 households into income quartiles to statistically analyse the cash dependency of each quartile group on industrial hemp cultivation. Hemp products exchanged for rice through barter are conceptualized as cash income because the farmers can interchangeably exchange hemp products for cash in the study site of their own volition.

Finally, based on the information provided by the actors and stakeholders, we prepared an industrial hemp value chain map that illustrated the structural components, connections and exchanges depicting the flow of products, money, information, and relationships among them.

We analysed market conducts of the industrial hemp value chain on different categories explained by De Figueirêdo Junior et al., (2014). As such, there is no specific rule that governs the analysis of conduct (Wosene & Gobie, 2022). So based on the available information we analysed the conduct elements entailing marketing channel, marketing strategy, price, linkages, and agglomeration. Further, based on the structure-conduct-performance, a strategic map was established in the reference value chain map to highlight the possible intervention strategies for industrial hemp value chain development in Nepal.

The financial performance analysis across different industrial hemp value chain actors involved the average gross margin calculation by subtracting variable costs from gross income (Abbott & Makeham, 1990). The labour profile was created based on the average (monthly) labour requirement in detail from (hemp) farming to harvesting (seeds and fibres) and post-harvest operation and tabulated per hectare basis. Multiplying total workdays per hectare with the average wage rate (i.e., US$ 4.49/ day) of the study area gives the estimation for average total labour cost. We also calculated the gross margin of hemp farmers from the sales of hemp seeds and yarn with and without considering the opportunity cost of labour. To derive the manufacturer's cost, we modified the equation proposed by Utkun & Özdemir, (2015) to develop a calculation method that estimates the variable cost of fabrics in handloom. For this, we exhaustively captured every procedural step involved and associated variable cost incurred in manufacturing fabrics from processed fibres (yarn) of unit weight. Also considering the shrinkage rate and density of prepared fabrics we devise an equation (1).

Equations:

Variable manufacturing costs, $C_T = C_M + C_L + C_E$ *(1)*

C_T total cost

C_M materials cost (yarn & dye)

C_L labour cost (weaving & dyeing)

C_E energy cost,

Calculation for material cost,

$C_M = C_Y + C_D$ *(2)*

C_Y yarn cost

C_D dye cost

Calculation for labour cost,

$C_L = C_{LD} + C_{LW}$ *(3)*

C_{LD} labour cost of dyeing

C_{LW} weaving cost

In the case of weaving costs,

$$C_{WL} = L_F\ (m) \times C_{UL}\ (\frac{\text{US\$}}{\text{m}})$$ *(4)*

Where:

L_F length of fabric manufactured

$C_{UL} the\ the$ unit labour cost of fabric manufactured

$where,$

$$L_F = \frac{Q_Y(\text{kg}) \times 1000}{W_F\ (m) \times \rho_F\ (GSM)} \times (1 - R_{SP})$$

Q_F quantity of yarn consumed

W_F width of fabric manufactured

ρ_F fabric density (gram per square meter)

R_{SP} shrinkage rate (%) of product

Results

Socio-economic characteristics of the sample population

Among the 60 sampled households, 82% were male and 18% were female with an average age of 41. About 23% were illiterate and the average schooling time of less than 5 years. The sample was mostly homogenous in ethnicity, with about 83% identifying as indigenous "Kham Magar" and 17% Dalits (oppressed social groups) and an average household size of 5.08, slightly higher (4.37) than the overall RM average (CBS, 2021).

The 83% of the respondents were primarily engaged in agriculture and other performed economic activities such as tailoring, petty trade and hotel business along highway corridors. Wheat, millet, rapeseed, potatoes, and beans were pre-dominant field crops for subsistence while hemp fibres were the source of hard cash income and hempseed both exchanged for rice through barter or cash. Of the average land holding of 0.3 ha, one-third of the land was temporarily (May to December) devoted to hemp farming. Seasonal labour as a construction worker inside the district and neighbouring country India is among the prime off-farm activities being conducted during the lean farming season. 61.6% of households were food insufficient.

*The tapestry of illegal hemp **Value chain***

As noted in (Fig. 2), the industrial hemp value chain begins with fibre and seed cultivation by smallholder farmers. However, hemp production and supply remain illegal in Nepal, raising questions about why and how the industrial hemp value chain operates in the country, and how we can track the activities of all value chain (VC) actors. We found that hemp cultivation acts as a main stray of livelihood, in particular, the earning strategy of smallholder farmers in the study area. One key informant explained: *"Provided the favourable [referring to legal] condition of growing hemp, it has potential to sustain the livelihood for six months a year…this is indeed the source of income from which households arrange the delicacy to feed chelibeti [married daughters and sisters] during the maternal reunion and celebrate festivals"*. The verbatim elucidated the economic significance of industrial hemp cultivation in pro-poor households alongside the cultural values the rural indigenous family upholds. We also found that there was no distinct high or low-THC content cultivar. As such, farmers grow native hemp varieties with potentially enriched with THC. To illustrate, in a different context a local imminent recounted: *"During the meetings I often used to say to them [law enforcement authority], if you caught anybody off guarded rubbing [the resin], promptly initiate your legal procedure, nobody will intervene you but let them grow cannabis for seeds and fibres.* This indicates that some are involved in the intoxicating resin production, which is beyond the realms of our exploration.

The explanations for how hemp cultivation is going on despite of the disruptive activities from the law enforcement authorities varied, but in common, farmers were allowed to cultivate hemp on the sympathetic ground. One anonymous respondent off record said: *"Police turn a blind eye most often, but they sometimes do visit hemp farm during patrolling and destroy some plants; they also need to present some sort of progress report to the headquarters,"* Another said: "*It happens in mutual agreement"*. We understood how hemp production took place, we symbolised the activities with blind 'dark' vision and attempted no further exploration.

During the household survey, we noticed a clear distinction between non-participation in hemp cultivation and withdrawal from the survey. There were various reasons for non-participation, including households with better-off farm employment, old-aged households and some households who abandoned cultivating hemp. Among the households that no longer cultivate hemp, the majority were from Sakim village. Village leaders recounted: "*Six years ago, police destroyed our ready-to-harvest hemp stand, and we left helplessly watching uphill inferno engulfing the entire hemp field. In the aftermath of that incident, many villagers relinquished hemp cultivation while some still cultivate. Police do sometimes come even these days, but I haven't noticed any damages done*".

After national traders collect bulk hemp yarn through village traders, the physical movement of hemp yarn takes place through *opacity*. As confirmed by the traders, they pay levies and local taxes and prepare road permits under the guise of *Allo* fibres (Himalayan nettle yarn) to bypass potential legal impediments posed by the police check posts along the highway. Soon after it reaches the (Kathmandu) city-based suppliers, a 'grey' outbound channel turns white, where they sell to the manufacturer with 'clear' differentiation between hemp yarn and *Allo* yarn.

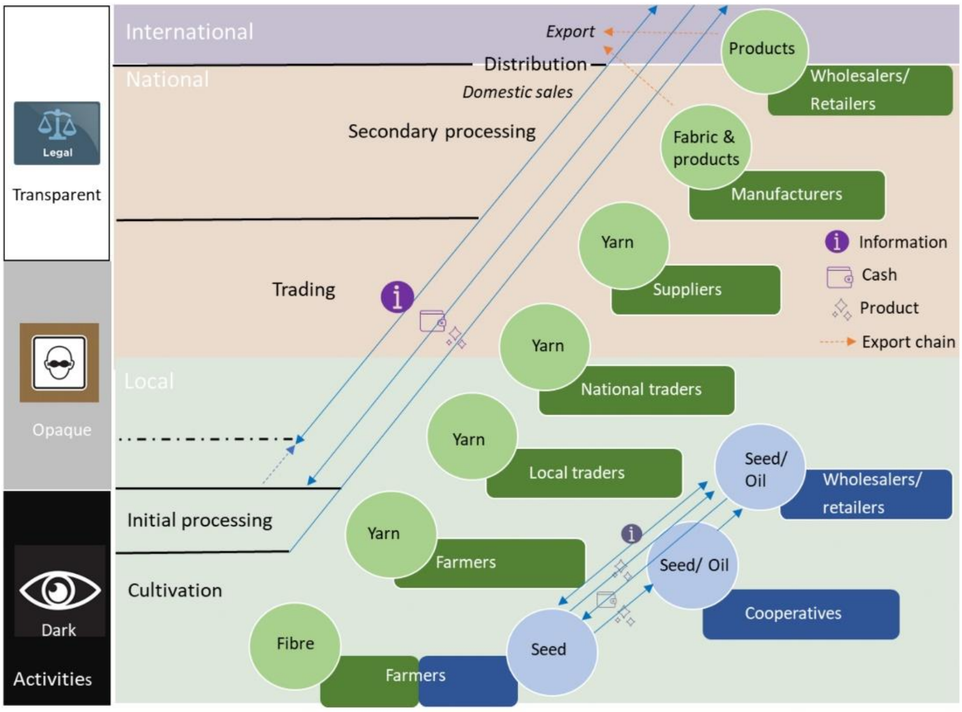

Figure 2: Industrial hemp value chain map relating to the constrained landscape of Nepal.

Livelihood contribution of hemp farming

The data suggested that the estimated average income from hemp is US$0.89 per person per day which is enough to cover the daily per capita cash requirement of (adjusted figure based on the official regional poverty line data) US$0.67 (CBS, 2023) to buy non-food commodities and services and (US$0.57) food expenditure during average 1.8 month of food insufficiency (US$0.10) in the study area. However, most of the household (73.33%) falls under the lowest income quartile (Q1) with an average income of US$0.39 per capita per day depicting severe poverty.

Although the cash income contribution from the sales of hemp fibres and seed was 29.89%, Q1 households derive 44.7% of income from hemp (Fig. 3). Analysis of variation on ranks through Kruskul-Wallis test confirms (Statistic= 47.05 p-value: <0.05) significantly high share of hemp income on the total for first quartile. It is worth noting that both quartile population and percentage cash income contribution of hemp decreases sharply for the second, third and fourth quartiles with no contribution for the highest (Q4) income quartile.

The majority of pro-poor (Q1) households did not have income enough to meet non-food ends (Fig. 3). However, over 81% of pro-poor households fulfil their average monthly food deficit through the income from the sale of yarn and/or seeds. Seeds are usually exchanged for rice to feed all family members during the period of insufficiency. On top of it, rice has profound cultural significance on the part of indigenous 'Kham Magar'.

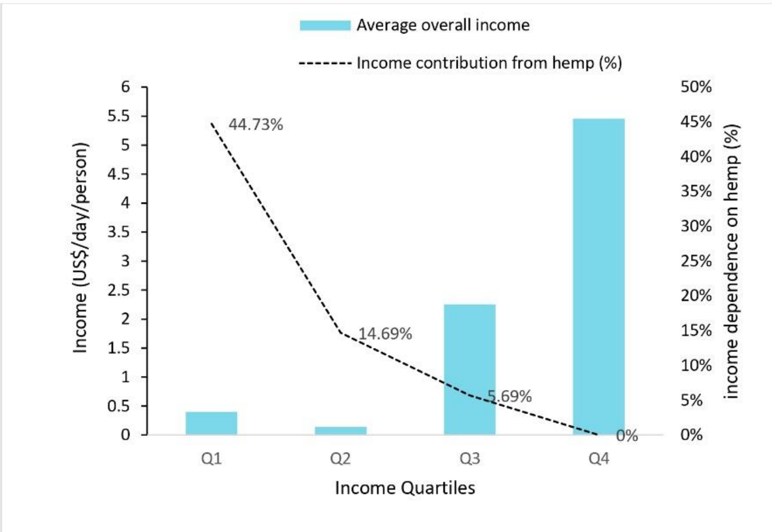

Figure 3: Shares of income from the industrial hemp to the total income along different quartiles.

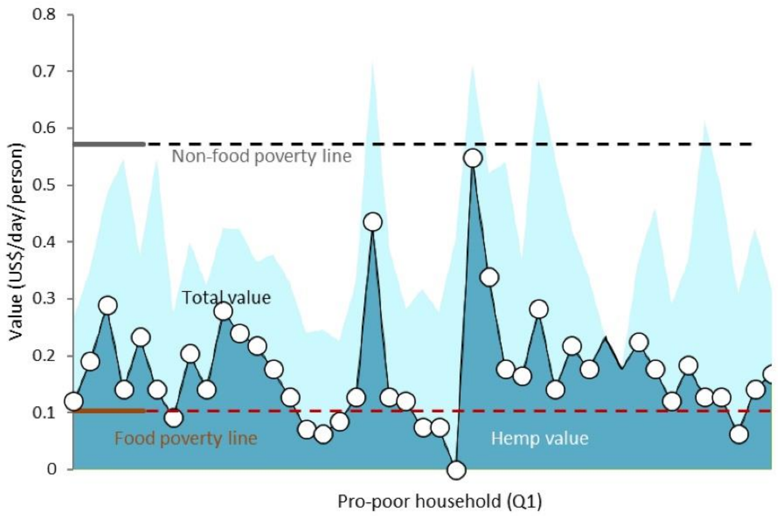

Figure 4: Income contribution of hemp for the lowest quartile pro-poor house household in relevance to regional poverty line estimates.

Industrial hemp value chain structure

Based on the information collected from KIIs, hemp value chain actors and stakeholders, we prepared a Nepalese industrial hemp value chain map (Fig. 2) showing major actors and the flow of products, money, and information across the chain. As illustrated in Fig 3, the Nepalese hemp value chain can constitute up to seven and just three main actors dealing respectively with two concurrent products i.e., fibre and seeds. They flow through specific channels. Fibre-for-textile channel is spatially long, begins with production in rural mountains and culminates in national and international consumer markets. After smallholder farmers sell spun yarn fibres to the village traders from their doorsteps, they sell it to the national traders which is then sold to the city-based suppliers. The significance of national traders is that they hold an authorized trading licence that enables them to outbound inter-regional transportation of goods. The manufacturers buy hemp yarn from the traders to manufacture varieties of hemp-based goods from woven fabrics. They directly sell manufactured hemp goods to national and international consumers or through retailers/wholesalers. Major exporting countries are France, Chile, America, and Germany. On the other side, the seed-value chain is very short and more traditional. Farmers can sell hempseeds to retailers placed along the road corridors while the major purchasers of hempseed are cooperatives who purchase in bulk and sell locally or to distant markets at times. Additionally, the local cooperative is also involved in value-adding activity through the extraction of hemp oil from hempseed and bottling.

Major value-adding activities that entail weaving yarn into fabrics and manufacturing hemp-based textile products were performed by the manufacturers and considered key actors of the hemp fibre-for-textile chain. They also hold a rich source of information regarding national and international markets and consumers' preferences for hemp products. The (international) consumers' information is limited to the country of export and has no further information that enables them to trace the origin of hemp fibres. Based on the market situation, manufacturers set the price of hemp yarn which flows horizontally and vertically downward up to the village traders. While some level of horizontal flow of information occurred among farmers, vertical information flow related to yarn market price was limited. For farmers, traders set the price in a way to reap the fixed amount of profit unaffected by the change in fibre price. However, farmers in the seed supply channel have comparatively better access to market information.

Market conduct of the industrial hemp value chain

Although farmers obtain a higher gross margin (and value share) by utilizing cooperative channels for seed marketing, cooperatives have limited purchasing capacity due to market limitations. Moreover, cooperatives usually sell hemp seeds to nearby wholesale/ retail markets of the district headquarters and only occasionally to the big provincial-level suppliers. Due to a short distribution channel and limited market, the hemp seed market of cooperatives is at risk of market surplus. In response, the cooperative has initiated value additional options such as extracting hemp oil from hemp seed and bottling but these may be insufficient without market expansion.

The main issue of the fibre-for-textile market is the fluctuating demand for hemp goods in the international market. As revealed in Fig. 5. the revenue generation from the export (2012-2023) of hemp goods experienced intermittent rise and fall beyond and sharp decline following the outset of the global COVID-19 pandemic. However, despite of low export level, hemp yarn fetched a record (US$ 4.87/ kg) high price during the peak COVID period (2021/2022) when compared to pre-covid (US 1.49/kg) and current price of US$2.62/kg, as confirmed by the respondents. This correlates with the case of volatile global natural fibre market prices (Mornement, 2021). Also, despite the concentration of hemp goods manufacturers in the same location, they do not benefit from physical agglomeration, especially in case of high demand. Indeed, they operate individually and have limited capacity in terms of product output and sales volume.

A manufacturer recounted: *"Recently we received a demand for 1000 hemp bags from one of our international clients to be dispatched in a matter of less than a month. We unwillingly turned down the order as we could not manufacture in such colossal quantity in that timeframe.*

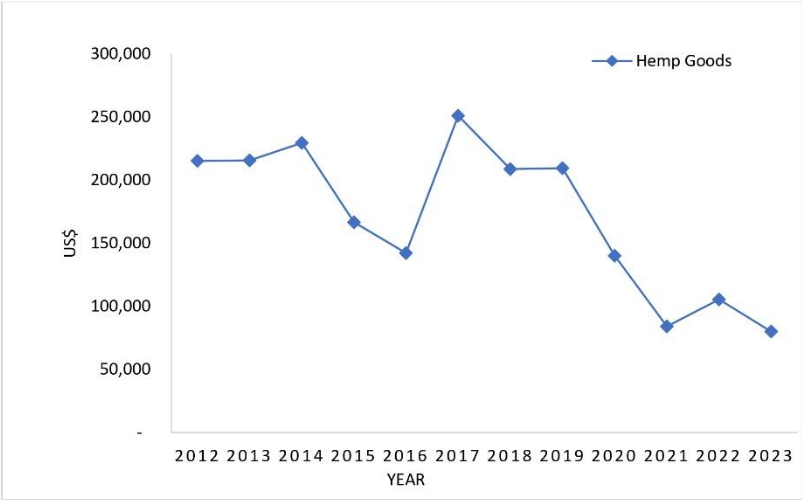

Figure 5: Revenue earns from the export of hemp goods. (FHAN, 2023)

Performance analysis of industrial hemp value chain

In Table 2, for clear comparison across the industrial hemp value chain actors, we estimated gross margin based on average household seed and yarn production. Gross margin analysis shows a negative gross margin for farmers when the opportunity cost of labour was considered. The cooperative and village-level traders in respective seed and fibre value chains savour the gross margins with no apparent cost other than the price paid to the farmers for the purchase of hemp yarn. Apart from yarn price (US$ 3.194/kg), local tax (US$0.037/kg) for transporting the products across the local administrative boundary and the transport cost (US$ 0.194/kg), the traders also bear unnecessary transaction cost i.e. royalty charge of US$ 0.152/kg paid to the district forest office to obtain a "Release Order". To the national traders, the cost of unwinding yarn was reported to be US$ 0.219/kg. The costs incurred in manufacturing fabrics from unit hemp yarn are estimated to be US$ 8.087/kg hemp yarn consumed. That included material costs, labour costs and energy costs. Therefore, the value share (Fig. 6) of gross margin in the fibre-for-textile chain for manufacturers, suppliers, national traders, village traders and farmers were 39%, 14%, 9%, 6% and 32%, respectively. Regarding seed marketing through cooperative channels, farmers obtained a value share of 74% and for cooperatives, the value share may increase to 62% when involved in value addition through milling to extract hemp oil and bottling. Overall, the value share across the actors seems reasonable when the opportunity cost of labour is not considered.

Table 1: Average monthly labour requirement to perform hemp farming activities (workdays/ha)

Labour activity	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
In-situ manure preparation											25	
Land preparation, manure & sowing	50											
Weeding and harvesting (male plant)						80						
Harvesting (seed & female stalk)							120					
Seed winnowing & drying								40				
water retting								100				
Fibre extraction									80			
Spinning							600					

Table 2: Cost and gross margin for actors involved in converting yarn to fabrics.

Variables	Actual average household hemp area 880 m^2		
	Seed	Fibre	Yarn
Average yield (kg/area)	117.26	88.53	52.08
Average marketed yield (kg/area)	106.60	-	45.29
Average price ($/kg)	1.30	-	2.62
Average revenue ($)	138.58	-	118.66

Actors	Cost ($)		Revenue ($)			Gross margin ($)		
Farmers	Seed	Yarn	Seed	Yarn	Total	Seed	Yarn	Total
Production cost ($)								
With the opportunity cost of labour	435.25		138.58	118.66	257.24	-296.67	-316.59	-178.01
Without opportunity cost of labour	2.08					136.5	116.57	255.16
Cooperative								
The price paid to the farmer.	135.35		183.38	-	-	48.03	-	-
Village traders								
Yarn price paid to the farmer.	-	118.65	-	142.66	-	-	24.00	-
National traders								
The price paid to village trader.	-	142.66		193.38			33.51	
Transaction cost (i.e., royalty)	-	6.91						
Local tax	-	1.69						
Transportation	-	8.60						
Suppliers								
The price paid to village trader.	-	193.38		254.52			51.17	
Unwinding cost	-	9.96						
Manufacturer								
Material cost	-			509.05			141.78	
Yarn price paid to the supplier.		254.52						
Dyeing chemical	-	2.71						
Labour cost								
Dyeing	-	15.39						
Weaving preparation &weaving	-	86.50						
Energy cost	-	8.15						

Note: Fabric produced from per kg yarn was 2.5 × 1.02 m^2. Selling price US$4.95/m^2 fabric, wastage rate 20%, shrinkage rate 15% & fabric density 333.33 gsm.

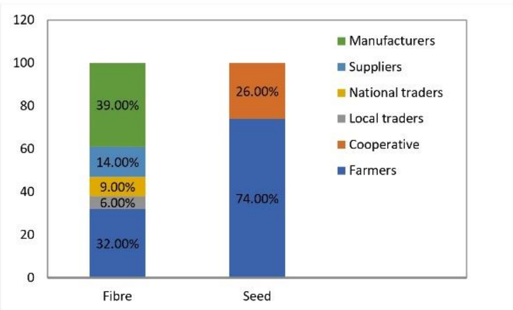

Figure 6: Proportion of gross profit distributed among industrial hemp value chain actors.

Discussions

The tapestry of illegal hemp value chain

Through a qualitative inquiry, the study explored the reason for farmers' participation in illegal hemp production. Indeed, with no other reliable source of income, poor households (in the study area) were compelled to engage in illegal hemp cultivation. Odd disruption by the police authority, resilience, withdrawal from participation and continuation with legal trepidation summed up illicit hemp production in the study area. Analysing the tapestry on how illicit production and operational activities are being conducted, we uncovered and conceptualised with terms 'dark', 'opaque' and 'transparent' vision that respectively elucidated law enforcement authority turning a compassionate (or at times negotiating) blind eye for allowance of production and trader's created opacity (disguised under Allo fibre) to negate the outbound legal barrier and practically clear distribution channel. The main implication of this tapestry is that it imposes significant legal barriers for the entry of industrial hemp value chain enablers beyond the line of 'clear' vision. From a value chain development perspective, the *darkness* and *opacity* leave a very narrow intervention window. Also, the symbolized 'opaque' vision implies an operational inefficiency at the trader's node.

Income contribution of industrial hemp for pro-poor households

The study confirmed that the income from the industrial hemp fibre and seed serves a significant (44.73%) contribution to the total income of pro-poor (Q1) households. However, the contribution of hemp income for higher income quartiles was insignificant and may indicate that households would not have engaged in hemp farming if they had reliable alternative sources of income.

Although the income from hemp farming was not sufficient for the upliftment of the pro-poor households of sampled villages beyond the regional poverty line, it ensures food safety for the majority during food deficit periods. Apart from the economic value (food security), rice obtained through barter transactions with hempseeds has socio-cultural importance for the indigenous "Kham" community. They are the devotees of deities, where in almost every religious festival rice is the main offering to god and rice-based cuisines are treated during social, religious and cultural gatherings (Rana Magar, 2020).

Industrial hemp value chain in Nepal: structure, conduct and performance

We found (a) structurally short and limited markets for hemp seeds while fibre price volatility and fluctuating international demand for hemp goods constrained the hemp fibre-for-textile chain; and (b) reasonably justifiable value share distribution across the industrial hemp value chain actors but negative gross margin for farmers.

Even though the seed supply channel is entrusted and collaborative, both the distribution channel and consumer base are very narrow. So, the sustainability of the hemp seed market necessitates a concrete market expansion strategy. Importantly, in the backdrop of illicitness, the strategy needs to be explored within the limited opportunity window. Regarding hemp fibre, the issue of price volatility seen in the current study correlates with fluctuating global market prices for natural fibre (Mornement, 2021). Moreover, according to the VC actors, the yarn fibre price doubled during the COVID-19 pandemic. Since the national market is relatively constant, this high price may surmise a rise in global demand due to the low or interrupted supply from major actors like China. Drawing upon this may raise questions on whether or not Nepalese hemp fibre goods (or VC actors) have the capacity to compete and meet the demand of bulk (international) buyers. Subsequently, market competitiveness can be achieved through improved value chain efficiency and enhanced production capacity.

Financial performance analysis of the industrial hemp value chain showed a negative gross margin for farmers when the opportunity cost of labour was considered. This is attributed to the labour-intensive nature (Senkondo et al., 2004) of hemp cultivation and production and may infer limited alternative cash-earning opportunities in the study area. Gross margins for other value chain actors are positive at current prices and (variable) costs, while seed cooperatives (26%) and fabric manufacturers (39%) had high-value shares. Since cooperatives bear the risk of market surplus and manufacturers are key value-adding (and market) actors, their high share of gross margins seems justifiable. Moreover, village traders can be regarded as rent-seeking actors as also considered by Perdana & Roshetko (2015). They reap margin with risk-free (inter-village) collection at substantially less cost by exploiting farmers' limited access to market and market information. However, the role of national traders is crucial in transferring hemp yarn from secluded rural villages to the city. Therefore, the created opacity should not be viewed as a ploy by traders. Indeed, with no dramatic increase in gross margin, they have to bear royalty costs (unnecessary for non-forest products) to the Divisional Forest Offices, while some amount of risk of police seizure still prevails along the highway.

Strategic and Structural Interventions for industrial Hemp value chain Development

Based on the results and within the limited intervention window due to illegality, we explored certain areas that may generate additional revenue for the actors and ensure money to reach poor farmers' end (Fig. 7).

As such, the development of Intervention strategies to enhance both value and distributable income for VC actors necessitates cohesiveness to the context and coherence to the operational need on the considered chain (Hainzer et al., 2019). The process also demands an overarching knowledge of typology, the enabling environment and constraints (McKague & Siddiquee, 2014). In light of this, we developed integration, cooperation, expansion, and consortium (formation) strategies at different industrial hemp VC nodes (Fig 7). Integration in the agriculture value chain is an established concept destined to provide avenues for smallholder farmers to gain access to the market by the virtue of which they accrue more benefits (Kissoly et al., 2017). A well-integrated market has the potential to channel a luxury supply of inputs to distant markets (Barrett, 2010). Inconsistent, albeit in our context, we envisaged a vertical integration of surplus hemp seed into a pre-established fibre supply chain. Similarly, government agencies and relevant non-government organisations are the enablers of conventional agriculture value chain development and take the onus of coordinating market linkages (Kumari et al., 2021; Mangla et al., 2018). In context to this unconventional crop, as being only known chain enabler, we conceptualize a cooperative to coordinate the vertical chain integration. Moreover, a switch in governance power from members to management can bolster vertical coordination in the value chain (Bijman et al., 2012). Thus, the executive body of the cooperative was chosen as a coordinating entity. This study proposed a 'consortium marketing' strategy to meet the fluctuating international demand for hemp products. Consortium marketing is one such case of integrated marketing that embodies a planned interfirm collaboration/cooperation in innovation and manufacturing to handle the customer's demand that exceeds the capacity of individual manufacturing firm (Albino et al., 2007). This inter-firm market cluster and networking strategy can also be instrumental for smaller firms to compete global market (Felzensztein & Gimmon, 2007). Moreover, the localized small firms up against mighty international buyers is a challenging phenomenon in the global fashion industry, as can be seen in the Italian leather industry sector (Guercini & Woodside, 2012). This seems pertinent to the Nepalese industrial hemp (fibre) products manufacturing sector. The consortium built on cooperative instinct can help out-compete the challenge. We also envisioned Hemp Association Nepal (HAN) as an entrusted executive body that takes the onus of establishing links with global markets and business customers. So far, HAN is the invisible (not officially registered) enabler identified during the study which encompasses members including manufacturers. Further, regarding the fluctuating export market and price of hemp-based products, we call out a 'fair-trade' initiative aimed at fostering financial benefit to marginalized farmers in the global south (Jaffee, 2010). As such, this initiative delves into strengthening impoverished producers through the provision of price equity and stable mainstream market links while also promoting socially and environmentally amicable products (Raynolds, 2012). If the consumers of the developed north endorsed this fair-trade movement, this could aid in the development of which co-innovative, collaborative, and trustworthy industrial hemp value chain.

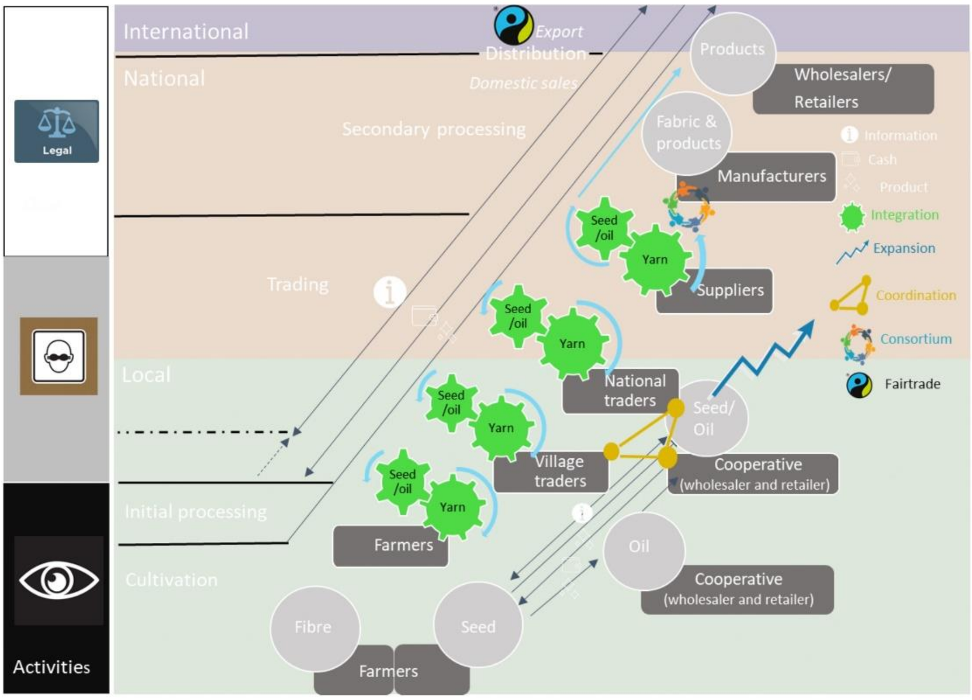

Figure 7: Proposed intervention to enhance the profitability of industrial hemp value chain actors in Nepal.

Policy implication for the regulation of the hemp value chain

Although the recreational aspect of hemp is beyond the realm of our exploration, we cannot ignore the reality that hemp farmers grow native varieties with potentially high inflorescence THC content. So, considering the pitfall of the actor's involvement in recreational hemp production and supply chain, this study does not suggest outright hemp legalization. However, the onus is on the government to either provide alternative income opportunities for poor hemp farmers or implement effective control mechanisms to strictly regulate recreational intent cannabis production and legalize industrial hemp.

Moreover, illegality in the supply chain lacks transparency and traceability (Schöneich et al., 2023). Therefore, establishing greater transparency through the legalization of industrial hemp may enhance operational efficiency through reduced cost (e.g., unnecessary transaction cost) and better market information flow (Deimel et al., 2008), owing to which the entire value chain can be substantially improved. Similarly, traceability related to the origin of products (Konstantinov, 2021) may ensure fair pay for poor farmers due to the recognition of their contributions (Shafi, 2022). Further, legalization also provides access to the formal entry of industrial hemp value chain enablers.

Limitations

As an exploratory (and prescriptive) case study related to the small population fractions of Rukum East district, the findings may be generalized to the industrial hemp farmer of western (mountainous) Nepal and some Indian rural states and not global commercial industrial hemp farmers. This limits the regional and global applicability of the findings. However, these findings are enough to develop hypotheses for more comprehensive research covering wider geographical areas. Next, due to the occluded production and illicitness in transactions, we had a paucity of secondary data including intra-country market share of hemp products, that could provide a solid foundation for the study. Further, in light of the non-existent established equation to calculate the unit costs of manufacturing woven fabrics in handlooms, we devised an equation by comprehensively capturing detailed process-associated costs. This also entails the adjustment in the equation for wastage, shrinkage, and fabric density, yet needs further validation.

Conclusion

The study showed a significant contribution of industrial hemp to the livelihood of pro-poor farmers in rural communities in Nepal. Investigating the value chain activities revealed a compassionate ground of approval for cultivation, a created opacity for channelization and downstream (beyond then national suppliers) legal clarity. From the market analysis, we found an overly short seed market channel and fluctuating fibre price and export demand for hemp goods. Vertical Integration of hemp seed/oil into existing fibre supply channel, formation of consortium networks and the strong commitment of international buyers for fair trade movement may solve the market-related constraints.

Due to uncertainties in government policy, fear among VC actors, and vested interests in personal profit over overall VC success, the horizontal and vertical linkages among different VC actors are non-interdependent, non-innovative, and non-collaborative. Regulating hemp production, building partnerships between VC actors, adopting a flexible code of conduct, and sharing marketing information could help overcome these challenges. Although we do not claim to generalize our findings to the global scale, we argue that our research findings are sufficient to set hypotheses for broader research.

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4.2. Links and implications

The current study entails components disaggregated by two distinct yet linked objectives. The first objective i.e., the systematic review provides a snapshot of the industrial hemp value chain from the environment and economic perspectives in the global north. The second objective of this study consummates the research gap in the global south as it provides an understanding of the industrial hemp value chain in the context of Nepal where the legality of hemp production and operational activities are relatively unknown. The review study identifies environmentally amicable hemp products and deciphers environmental hotspots of various hemp-based products. The findings of the review study have practical implications suggesting hemp value chain actors, stakeholders, and researchers to streamline technical efficiency through innovative harvesting and processing strategies and the development of value-added products on a commercial scale. The results of the second objective provide implications for policymakers to realize a legislative measure destined to improve economic and operational efficiencies by eliminating compliance and risk-associated costs and providing better access to information and protection to entire hemp value chain actors.

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1. Discussion and concluding remarks

Building on past literature describing spatial dynamics of the industrial hemp value chain research, we found that 90% of the studies are conducted across Europe, the US and Canada. Hence, the systematic review's findings (first objective) reflect the context of the global north, leaving significant research gaps in the global south. This paucity of research on industrial hemp is often due to the legal prohibition on performing hemp-related activities in the southern hemisphere (Anem, 2020 cited by Wimalasiri et al., 2021), which deter researcher concern about safe and reliable data collection (Minten et al., 2023). Nevertheless, it is important to know the value chain of illicit products as they possess social, economic and regulatory relevance (Sánchez-Pérez et al., 2023). Also, since industrial hemp goods have niche markets (Roach et al., 2019), the products, processes, and market dynamics are unique so the global studies may not capture these unique features. In this regard, the content, and the context of the case study component of this thesis have a particular relevance.

As opposed to the blanket ban on all hemp-related activities imposed by the Narcotic Drugs Control Act of 1976, the study revealed that, although the production and trading activities are scrutinised, manufacturing and distribution of hemp goods do not face legal scrutiny. Therefore, Nepal's industrial hemp value chain is situated in a 'gray zone'. A 'Gray area' status refers to the legal-illegal ambiguity (Dickinson, 2022). Based on the findings on how hemp cultivation and operational activities are being carried out, we conceptualised with terms 'blind', 'opaque' and 'transparent' vision that respectively elucidate compassionate ground for production approval, opacity (disguised under allo fibre) to elude outbound legal barriers and practically clear distribution channel.

These unique terminologies assigned across production, supply and distribution nodes should not just be viewed in terms of the desperation of poor farmers, the strategy of traders and the ultimate success of product flow within the market. Undoubtedly, the compassionate ground of approval by authorities signifies the compulsion of pro-poor farmers for cash income from hemp. However, the paradoxical aspect is that the economic importance of industrial hemp is more for other value chain actors than farmers. The assertion is bolstered by the empirical findings of the current study that showed negative gross margins for farmers and profit-earning opportunities for other actors. Similarly, falsified documentation prepared by the traders to disguise hemp as *allo* fibres for channelization across the nodes is more than a ‘cleaning process’ described by (ibid, p.82 cited by Dickinson, 2022). Indeed, the role of traders in marketing hemp fibres from secluded rural villages to the city should not be undermined and the unnecessary transaction cost bear by them should not also be devalued. Moreover, industrial hemp fibres beyond the trader’s node have no legal issue, hence, it is reconfigured into their original form and transacted as ‘hemp fibres’. This reconfiguration may well imply that hemp fibres have more value in national and international markets than *allo* fibres. Therefore, industrial hemp is important not only for the value chain actors but also for nations as it contributes by earning foreign currency through exports. But, ironically, for major value chain actors i.e., at the farmer's level industrial hemp is not remunerative.

As such, the profitability of industrial hemp to the upstream actors is not assured globally as confirmed by the global literature review components of this study. Moreover, existing harvesting systems and fibre processing technology are key impediments, potentially rendering hemp economically unviable for upstream actors, particularly in developed nations. In this regard, several studies have explored value-adding opportunities such as hemp fibre knitting for creating UV-protected apparel (Mišković et al., 2021) and hemp seed fortification in human goods (Sciacca et al., 2023), alongside valorisation techniques for physiochemical conversion of low-value hemp biomass into high-value products (Tripathi et al., 2023; Fiorini et al., 2019; Moliterni et al., 2022). Capitalizing on these opportunities by scaling up to the commercial level may ensure an economically sustainable hemp value chain. Although due to technological constraints, innovative high-value products hemp cannot be expected but value adding opportunities such as hemp oil from hemp seed and integrated marketing strategy can ensure the economic viability of the industrial hemp value chain in Nepal. Further, legal uncertainty has created hemp value chain inefficiency in Nepal. Legalizing hemp may help reduce unnecessary transaction costs, improve marketing information, and build strong partnerships among value chain actors, owing to which efficient industrial hemp value chain can be developed in Nepal.

This study explicitly points out current issues of unprofitability in using hemp as a feedstock for biofuels such as bioethanol, biodiesel and methane or solid biofuels (pellets and briquettes). So far, the financial attractiveness of hemp for bioenergy production has long been debated among research scholars (Wilbrink, 2021). Regarding the use of hemp for other applications including fibres in the textile industry, bio composite in transportation or hempcrete insulation in construction sectors, it may be more economical than conventional petrochemical-derived parts. However, the availability of cheaper bio composites options from flax fibre or date palms and insulation solutions like cellulose fibre, glass wool etc. may delimit its use, as manufacturers look for cost-effective alternatives. So, the economic viability of industrial hemp for manufacturers depends on the cost of fibre; obviously, the lower fibre price affects the profitability of farmers. Therefore, it may be surmised that a financially viable industrial hemp value chain can only be ascertained through the maximum utilization of plant parts for diverse applications and/or for high-value products. Farmers can afford the delivery of raw materials at cheaper rates while still contributing to profitability through increased sales opportunities.

Concerning the environmental sustainability of industrial hemp-based products, despite its ecological edges of over synthetic products, nitrogenous fertilizer application during the industrial hemp cultivation phase appeared as a common ecological hot spot taking a toll on the climate change index. The result corresponds to some other products of biological origin in similar studies (Canals et al., 2011; Garcia-Velasquez & Van der Meer, 2022; Mousavi-Avval et al., 2023). Some of the identified carbon hotspots include the yarn production phase during textile manufacturing (Turunen & van der Werf, 2007), the functionalization phase for use as composite fibre (Recupido et al., 2023), and lime binder inclusion during hempcrete formation (Pretot et al., 2014). However, hempcrete-related emissions are counterbalanced to carbon-negative values because of photosynthetic CO_2 fixation during the growth phase and CO_2 absorption (via. carbonation) during the use phase (Arehart et al., 2020).

5.2. Contribution of the thesis

- A systematic review component of the thesis provides a scholarly contribution to understanding hemp products individually across environmental and economic domains.

- We proposed hempcrete as a climate-friendly construction solution while economically competitive hemp value in the developed economy necessitates innovation and capitalization of value-adding/valorisation opportunities.
- We believe, the empirical finding of the case study will serve lobbying groups, researchers, and the proponents of hemp to use this information as a basis to institutionalize and commercialize the hemp sector.
- The study can be relevant to other developing nations who are considering hemp value chain development.
- The methodological approach of this study can be replicated in other parts of the world.
- Lastly, the study as a whole can aid in the development of collaborative, co-innovative, and trustworthy hemp VC.

5.3. Recommendation and future research

Drawing upon the synthesis of the literature review, hempcrete is recommended as a climate-friendly product. While various hemp-based products may require careful consideration since environmental hotspots are identified across certain value chain nodes. In the context of the developed world, industrial hemp did not seem profitable and/or economical to all the value chain actors so equipment innovation at harvesting and processing nodes is recommended. This could lower production costs due to the reduction in labour charges owing to which raw/semi-processed products can be delivered at relatively cheap prices. At competitive prices, hemp-based products may likely substitute alternative products.

The findings of the case study reveal a ‘Gray’ zone in the hemp value chain as a major impediment. Therefore, it is recommended that policymakers focus on legalizing all industrial hemp-related activities while enforcing measures to control the risk associated with drug-type cannabis supply chains. Legalization protects farmers' crops, boosts their confidence, promotes transparency, and ensures better information flow. Access to the market information enables farmers to maximize their gross margin, for instance, by selling directly to national traders rather than village traders.

As stated, village traders are rent-seeking actors who make a profit by exploiting farmers' limited information. Similarly, the gross margin of national traders will also increase from the reduced cost of the falsified documentation. Finally, for the manufacturers, it is recommended to organize consortium marketing by which they could address the peak production demand of big international buyers.

We find that research on the industrial hemp value chain has primarily focused on developed nations and certain value chain components—highlighting the need to expand research to encompass regional niches across the globe and the links connecting nodes from production to consumption.

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APPENDIX [A]

Office of District Coordination Committee

Rukum(East)

Rukumkot
Lumbini Province, Nepal

Ref No. 25-2080/81

Office of District Coordination Committee Rukum (East), Rukumkot Lumbini Province, Nepal

Date: Aug 18, 2023

TO WHOM IT MAY CONCERN

Subject: **No objection letter for research**

This is written upon the request of Mr. Rajan Budhathoki, resident of Bharatpur-9, Chitwan, Nepal, who is currently pursuing a Master of Research at the University of Southern Queensland (UniSQ), Australia. His research is titled "An Assessment of Financial Returns for Different Actors in Hemp Value Chains from Three Production Regimes in Nepal".

It is confirmed that Mr. Budhathoki has our permission to conduct the research within the scope and guidelines as outlined in the project proposal. Mr. Budhathoki can interview all hemp value chain actors, including producers, processing companies, shopkeepers and other stakeholders.

We trust that Mr. Budhathoki will adhere to all ethical consideration, maintain the confidentiality of sensitive information and conduct research in a manner that upholds the reputation and values of both UniSQ and our organization.

We expect an electronic copy of the final thesis.

If there is a need of any further information or clarification, please feel free to contact our organization.

With best regards,
Ravindra Budha Chhetri
District Coordination Officer

District Coordination Officer

Phone: +977-088-413086 Mobile: 9843932103, 9840494155 Email: dccrukumeast@gmail.com

APPENDIX [B]

Key informant interview (KII)

Date of interview:

Name of the Respondent:

Position of the respondent:

Institution:

Place of interview:

Contact number:

1. How long have you been working in this organisation?
2. Can you define your roles in your organisation?
3. What does the hemp value chain mean to you or your organisation?
4. As per the existing policies, laws, and regulations (PLR), hemp cultivation and other activities are illegal, then why do you think farmers and other actors are engaged in hemp cultivation and value chain activities despite of illegality?
5. Do you know any recent change in PLR or any caveats that allows cultivation and operational activities?
6. How does hemp value chain occur despite of illegality?
7. Can you describe overall hemp cultivation to final product manufacturing process?
8. What are the key production inputs required for hemp farming and other value chain activities?
9. Can you provide the inputs associated cost of hemp value chain?
10. Have you or your organisation ever conducted research on given industry value chain? If yes, when and what was the key findings? Collect report, if possible.
11. Can you please suggest whether any amendments in these PLR could help to improve the competitive ability of the given value chain industry?
12. How could your organisation influence the operation of the value chain?
13. What are different uses of hemp products/ goods amongst consumers?
14. What are the product features that consumers look for while buying hemp products along with their priorities?

15. Please prepare VC maps of three hemp products depicting flow of products, information, money, and relationships between the actors.
16. Any other suggestions which promote the management and improvement of value chain.

<u>Questionnaire for smallholders' hemp farmers in Rukum East, Nepal</u>

[Express in words, figures, flows, or tick whatever appropriate]

General information of smallholders

1. Name of the respondent and gender: (Anonymous)
2. Relationship to the head of the household (HHH):
3. Age:
4. Education level (years of schooling): ___ respondent ___ HHH
5. Family size: ___ Nuclear ___ Joint
6. Social background of the household

   ___ Brahmin, ___ Chhetri, ___ Indigenous, ___ Dalits, Other (specify ___)
7. Main occupation: ________________ Respondent ________________ HHH
8. Resources and their values:

No.	Items	Number of Unit	Original price	When bought?	Remarks
1	Plough				
2	Tractor				
3	Motorbike				
4	Spade				
6	Other…….				
7	Other…….				

9. Information on landholding, livestock holdings, crop production and food sufficiency

   a) What is the type of land tenure? Secured ___ or insecure ____

   b) Household landholding (hac) ____

Land type		Total area	Cultivated land area	Uncultivated land area	Rented	
					Lend-in	Lend-out
Low land						
Upland						
Others						

c) Livestock holdings

Livestock type	Number
Cattle	
Buffalo	
Sheep	
Others (specify	

d) Food sufficiency ____ months

e) Household income (NRs) per annum from farm and non-farm sources

Income sources	Income amount
Wage labour	
Business	
Non/government services	
Abroad	
Pension	
Others (specify	

<u>Information related to the industrial hemp</u>

10. Do you cultivate hemp?
11. If yes, have you confronted with legal issues for cultivating hemp?
12. Have you or anyone in your village experienced any sort of trouble from police regarding hemp cultivation?
13. If yes, could you please describe the events?
14. Are there any local or regional level provision/regulations that affect cultivation and sales of hemp products?
15. If yes, could you please describe these regulations?
16. How far is that cultivation land from your home? ______
17. How much area do you cultivate hemp? ______
18. What is the average yield of hemp seed and stalk/fibre?

19. Do you process hemp fibre in your household?

20. If yes, what are the activities do you perform while processing?

21. What are the major inputs including manual labour required for entire operation?

Major operation	Activity	Month of activity	Average labour requirement (manual labour per day)
Pre-cultivation	Manure preparation		
	Land preparation		
Cultivation	Manuring & sowing		
	……...		
	Irrigation		
	Weeding		
	……...		
Harvesting			
Post-harvest operation	Winnowing (seed)		
	Drying (seed)		
	Retting		
	Fibre extraction		
	Spinning		

22. What types of hemp products do you sell?

a. Seed ______

b. Raw fibres _______

c. Yarn ________

d. Other (specify) _______

23. Whom do you sell your products?

24. What is the annual price you receive from selling different products?

25. What are the major sales related constraints of the industrial hemp?

26. Marketing:
   a. How do you obtain market information?
   b. How are prices negotiated?
   c. What are your major marketing issues?
   d. Who are the chain actors of your product?
   e. How much control do you have over who you sell your product to?
   f. Who has the most control over the market you sell to and the price you receive?
   g. Why do they have that control? This could be due to position, information, expertise etc.

27. Social capital:
   a. What are the names of the associations (both political and economic) you are associated with?
   b. What are the issues that are usually discussed in your associations?
28. What are the key concerns of your supply chain and how they can be improved?

<u>Semi-Structured Interview Guide: Actors</u>

Interview Guide

General information

1. Name of the respondent:
2. Age:
3. Gender:
4. Name of the organisation/ firm (if registered):
5. Number of employees at the organisation/ firm:
6. Years of involvement in the organisation/firm:
7. Products transacted: Hemp seeds ___, Hemp fibres ___, Yarn ___ Fabric ___ Other (specify) ___
8. Volumes of transaction (kg): Hemp seeds ___, Hemp fibres ___, Yarn ___ Fabric ___ Other (specify) ___

Value chain activities

1. Can you provide a brief overview of major stages of the industrial hemp value chain?

2. What kind of activities do you or your organisation perform within the value chain?
3. Can you describe the overall process you followed during the value chain activities?
4. What are the inputs needed for your activities?
5. Where do you sell your product? Do you know who the final consumers of your product are?

Marketing and sales information

1. Through which marketing channels do you distribute your product?
2. What is the per unit average selling price of your products?
3. What is your average monthly/ yearly sales volume of your products?
4. What are the major markets related constraints?
5. Who and how do you fix price of your products?
6. What are the past and present market trend of your products?
7. How do market trends impact your operation?
8. What strategies do you implement to manage market/ demand fluctuation?
9. What are the challenges and opportunities do you see in the industrial hemp market?

Relationships within and between actors

1. From whom do you purchase raw/ processed hemp materials?
2. Who are major buyers of your products?
3. How is your relationship with these actors?
4. How do you manage the relationship with them?

Legal aspect

1. Are your activities within the value chain legal?
2. Have you experienced issues with law enforcement authorities regarding your activities?
3. If so, how did you handle the issues?

Actors specific cost and revenue information

<table>
<tr><th>Actor</th><th colspan="2">Description of costs</th><th>Cost per unit (m^2 or kg product produced</th><th>Selling price per unit (m^2 or kg product produced)</th></tr>
<tr><td rowspan="6">Traders</td><td colspan="2">Purchase price of yarn/ fibres</td><td></td><td></td></tr>
<tr><td colspan="2">Labour cost</td><td></td><td></td></tr>
<tr><td colspan="2">Tax/ Royalty/ Unofficial costs</td><td></td><td></td></tr>
<tr><td colspan="2">Transportation cost</td><td></td><td></td></tr>
<tr><td colspan="2">Other cost (specify)</td><td></td><td></td></tr>
<tr><td colspan="2">………</td><td></td><td></td></tr>
<tr><td rowspan="5">Suppliers</td><td colspan="2">Purchase price of yarn/ fibres</td><td></td><td></td></tr>
<tr><td colspan="2">Store operation costs</td><td></td><td></td></tr>
<tr><td colspan="2">Labour cost</td><td></td><td></td></tr>
<tr><td colspan="2">Other cost (specify)</td><td></td><td></td></tr>
<tr><td colspan="2">………</td><td></td><td></td></tr>
<tr><td rowspan="8">Manufacturers</td><td colspan="2">Purchase price of raw materials</td><td></td><td></td></tr>
<tr><td rowspan="7">Items and cost associated with converting unit yarn/ fibres into fabrics</td><td>……….</td><td rowspan="7"></td><td rowspan="7"></td></tr>
<tr><td>……….</td></tr>
<tr><td>…………</td></tr>
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At last, do you want to share any additional information with us?