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The Sustainability of Industrial Hemp: A Literature Review of Its Economic, Environmental, and Social Sustainability

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Review

The Sustainability of Industrial Hemp: A Literature Review of Its Economic, Environmental, and Social Sustainability

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Abstract: Industrial hemp is a versatile, sustainable plant with several applications of its various forms, including fiber obtained from hemp stalks, food obtained from hemp seeds, and oil obtained from hemp flowers and seeds. Industrial hemp has the potential to offer a solution to the crisis of climate change, since it is a viable energy source that satisfies the three pillars of sustainability, namely economy, environment, and society. Although industrial hemp has been growing as an agricultural commodity in different parts of the world for decades, its production was banned until recently in the U.S. because of its association with marijuana. We conducted a literature review to explore some of the reasons why the U.S. production of industrial hemp has increased significantly since the ban was lifted. Our findings revealed that hemp's rapidly increasing popularity in the U.S. since 2018 can be attributed, in part, to its sustainability potential (defined as the potential to positively impact the sustainability of products, using hemp as a renewable raw material). This study fills a gap in the knowledge regarding hemp's potential as a sustainable crop.

Keywords: industrial hemp; economic sustainability; environmental sustainability; social sustainability

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1. Introduction

The recent climate changes on Earth, which are a significant result of human activities, are causing global environmental problems. Overpopulation, global warming, and biodiversity destruction are some of the impacts of these problems. The literature supports that these processes are the result of natural resources being used in an unsustainable way [1–4]. To sustain the environment, sustainable agriculture, economy, and ecology are critical and must cooperate [5]. Recently, sustainable agricultural opportunities have been of considerable interest to United States (U.S.) farmers. One crop that has gained attention for its sustainability potential is industrial hemp. In the U.S., hemp production has been virtually nonexistent since the 1950s. Previously, the U.S. was a prominent producer of hemp [6], and it played an important role in U.S. history. However, because of its association with marijuana, hemp was banned in the U.S. after the passage of the Marijuana Tax Act of 1937 [7,8]. Along with other varieties of cannabis, it fell under the Controlled Substances Act's (CSA) Schedule I classification [9].

Under U.S. law, hemp and marijuana have different legal definitions. Congress defined industrial hemp as "the plant *Cannabis sativa* L. and any part of such plant, whether growing or not, with a delta-9 tetrahydrocannabinol concentration of not more than 0.3 percent on a dry weight basis" as part of a 2014 farm bill [9]. Prior to this bill, the U.S. hemp market could not meet demand and was heavily dependent on imports [9]. Under a federal action after the bill was passed, state agriculture departments were authorized to cultivate hemp as a pilot project [10]. In a 2018 amendment to the farm bill, Congress expanded the definition to "the plant *Cannabis sativa* L. and any part of that plant, including the seeds thereof and all derivatives, extracts, cannabinoids, isomers, acids, salts, and salts of isomers, whether growing or not, with a delta-9 tetrahydrocannabinol (THC) concentration of not more than 0.3 percent on a dry weight basis" [9].

In the past ten years, the U.S. business community, including state governments, private researchers, and companies, has shown great interest in industrial hemp. According to advocates supporting its legalization, hemp is a viable alternative cash crop for U.S. farmers due to its sustainability potential, including its environmental benefits, its versatile adaptability to various agronomical conditions, and its manifold applications. Studies have claimed that if industrial hemp is allowed to develop in the same manner as other commercial agricultural enterprises, it could be lucrative [11].

Much of the current literature on hemp's sustainability potential is based on assumptions that are either untested or outdated due to limited industrial hemp production in the U.S. This paper reviews the current literature on industrial hemp's sustainability from the perspectives of three elements of sustainability—environmental, economic, and social sustainability—to address these gaps in the literature.

2. Methodology

We searched the literature related to industrial hemp, its parts, uses, and sustainability using Google Scholar to identify and source both academic and gray literature. Various publications are consulted, from 1970 to 2022, to review the historical perspective of industrial hemp issues, with the most recent reports being used for quantitative data (acreage, pricing, etc.). We reviewed journals from around the world, without limiting ourselves to the U.S. or any specific region. Examples of some of the search strings we used for our literature review are: "industrial hemp *", "*Cannabis sativa* L.", "industrial hemp plant fiber *, "hempseed OR hemp oil *", "parts of hemp plant *, "uses of industrial hemp * OR *Cannabis sativa* L.", "pillars of sustainability", "social OR economic OR environmental sustainability *", and "hemp global production *". The symbol (*) indicates variations of the search term.

The search on Google Scholar produced more than 200 matches. A second search was performed to filter and include academic, peer-reviewed journals, as well as reports from government agencies and international organizations. Next, we assessed the relevance of the search results by analyzing their titles, keywords, and abstracts. For example, sources were not included if industrial hemp was not discussed in the source in terms of its modern uses, or if the sustainability of hemp was not emphasized in the source. As a result of this scan, 70 papers ultimately matched the purpose of the research project.

3. Results

Our results are organized into three sections, the first describing the industrial hemp plant, the second describing its parts and uses, and the third describing the various dimensions of sustainability as covered in the current literature.

3.1. Industrial Hemp Plant

A cannabis plant (species *Cannabis sativa* L.) grown for fiber, hurd, and oilseed/grain, is known as industrial hemp [12]. *Cannabis sativa* L., including industrial hemp, is an upright, yearly plant that grows up to 1–6 m tall and is primarily a dioecious herb [13,14].

The *Cannabis sativa* L. species produces many plants, including hemp and marijuana. It has more than 100 recognized cannabinoids, which are chemical compounds that have different physiological effects on humans [15,16]. The two most notable and researched cannabinoids of the *Cannabis sativa* L. plant are cannabidiol (CBD), a safe, non-addictive, and non-hallucinogenic compound known for its therapeutic profile, and tetrahydrocannabinol (THC), the psychoactive element causing the "high" with which cannabis is commonly associated [9,15,17]. CBD is marketed and sold in bud, oil, and tinctures to soothe swelling and promote relaxation [17]. THC is frequently used for medicinal purposes and for recreational use; because of its psychoactive effects, it is illegal in many countries [18].

The primary difference between industrial hemp and marijuana is the concentration of THC. Industrial hemp typically has less than 1% of THC on a dry-weight basis, while marijuana has 3% to 15% [19,20]. The perceived legitimacy of industrial hemp varies between countries. To discourage its recreational use, the European Union (EU) and countries around the globe only allow production of hemp with low THC, thereby reducing or eliminating its psychoactive effects [18,21]. The EU limits THC content to 0.2%, the strictest regulation in the world, while Mexico limits it to 1.0%; Malaysia to 0.5%; and the U.S., Canada, and East Asia to 0.3% [22]. In the U.S., industrial hemp cannot legally have more than 0.3% of THC in any part of the plant in any condition or growth stage [23].

3.2. Parts and Uses for the Industrial Hemp Plant

Cannabis plant parts include seeds, stem/stalk, inflorescence, leaves, and roots (Figure 1) [16].

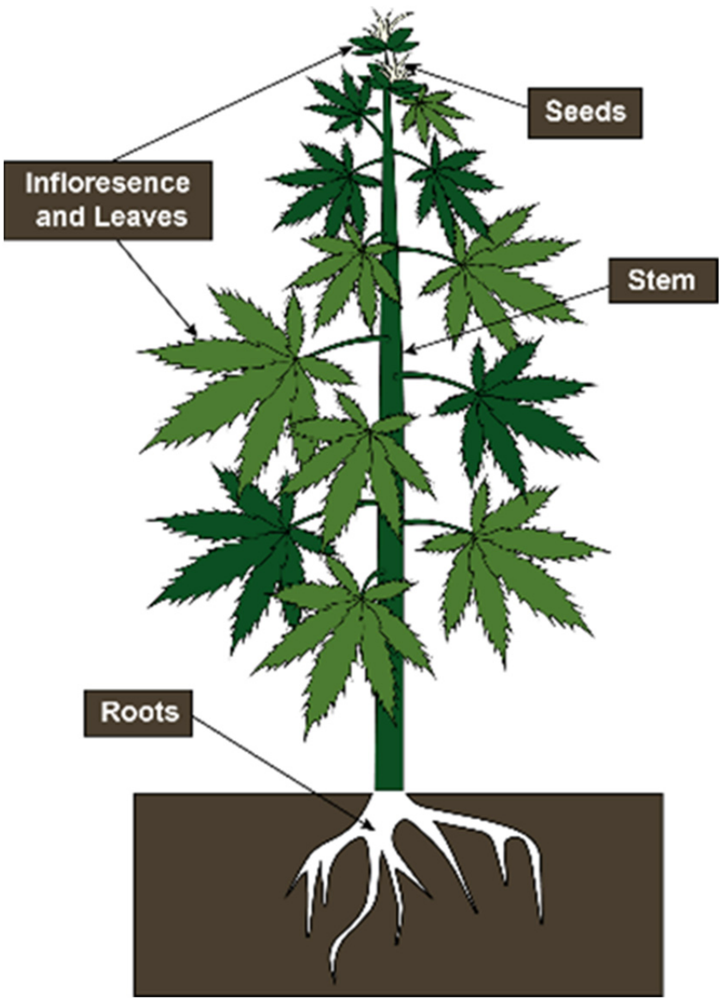

Figure 1. Various parts of the cannabis plant; derived from, (CC BY 4.0) [16].

Industrial hemp plants harvested for their stem/stalk provide hemp fiber. To produce hemp fiber, branching and flowering of the plant is discouraged. The plant is planted densely, averaging 35 to 50 plants per square foot. The harvest height of plants for fiber is 10 to 15 feet [9]. A hemp stem/stalk is composed of two sublayers, the outer layer consists of more valuable bundles of fiber, called bast fiber, and the inner layer consists of a less valuable woody (xylem core body) component, called hurd or shive fiber (Figure 2) [24–27]. A hemp stem's xylem core/hurd constitutes 85% of its biomass compared to bast fiber's 15% contribution [28]. To produce fiber, core fibers are mechanically separated from bark (using a decorticator) or by retting, or by a combination of the two. After being separated, dried and baled hemp fibers can be further processed by additional mechanical separation (such as cottonizing, shredding into smaller lengths, and spinning into yarn).

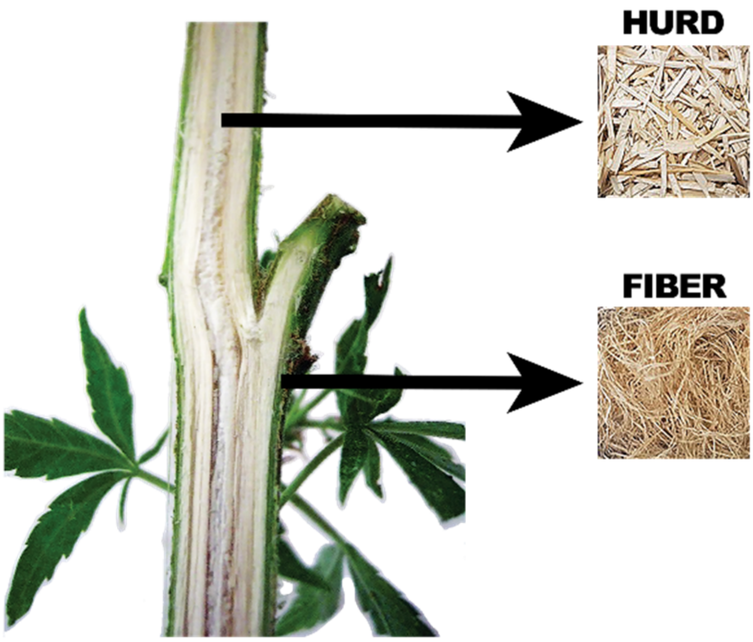

Figure 2. Raw materials obtained from hemp stems/stalks.

Industrial hemp plants harvested for seeds provide oilseeds. The process of growing plants to produce hemp seeds is similar to that of growing plants to produce hemp fiber. The harvest height of plants for seed/grains is 6 to 9 feet [9]. A hemp seed/grain measures approximately one-eighth to one-fourth of an inch in length and has a smooth surface [29]. In seed processing, the shell is removed from the hulled seed kernels [30].

Industrial hemp plants are harvested for their flower buds and floral materials, which provide CBD and other oils. To produce flower buds and floral materials, wide branches and leaves are encouraged. The hemp is planted more sparsely, approximately three to five feet apart, so the plant can branch more widely [9]. The harvest height of industrial hemp plants grown for flowers is four to eight feet. To produce oil, an assortment of extraction methods is required, including lipid infusion, CO_2 extraction, and solvent-free extraction [9].

According to a Congressional Research Service report [9], hemp grown for fiber yields 2000 to 11,000 pounds of whole dry stems per acre, while hemp grown for seeds and grain yields 800 to 1000 pounds per acre. Hemp grown for flowers yields about one pound of dried flower buds per plant [9].

Almost all parts of the industrial hemp plant can be used [16]. Industrial hemp is not only one of the fastest growing plants [31], but is also a versatile, sustainable plant with several applications, including the use of the fiber, seeds, and oil [32]. As shown in Figure 3, the seeds, dehulled or whole, can be utilized as a food source, as feed for animals, and in cosmetics, or they can be made into oil through a cold press process. Shives (hurd) and fiber that are obtained from the stem can be used for animal bedding, building materials, paper, or textiles. The hemp flower can be used to produce cosmetic and pharmaceutical products, including essential oils (Figure 3) [33]. Recently, the global industrial hemp market has been growing [34], resulting in the production of more than 25,000 products across the globe in various subsectors: paper, construction and insulation materials, fabrics and textiles, yarns and spun fibers, biocomposites, carpeting, and home furnishings (Figure 4) [29,30,32].

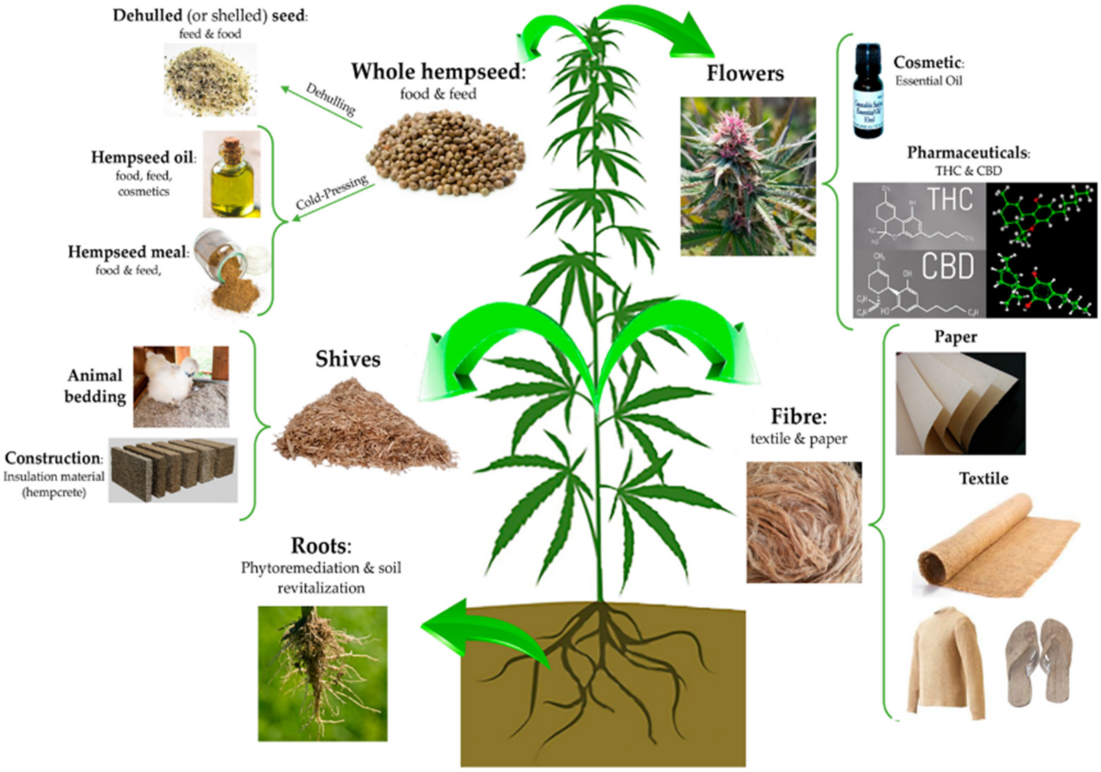

Figure 3. The many applications of the industrial hemp plant, (CC BY 4.0) [33].

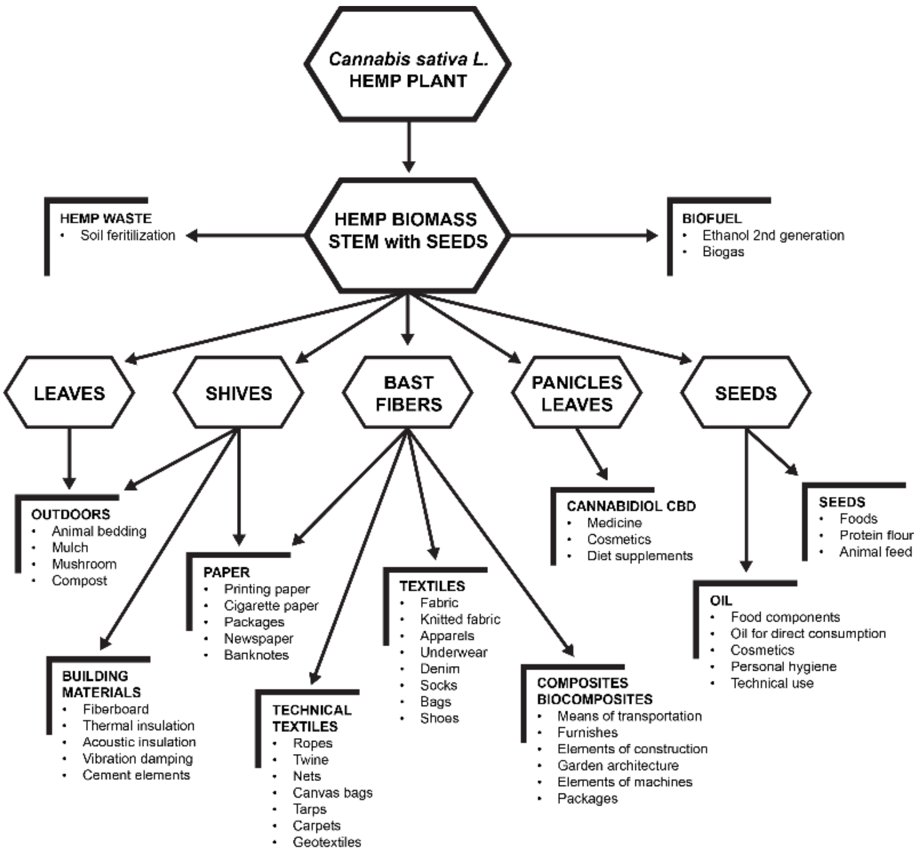

Figure 4. Modern uses of industrial hemp plant raw material, (CC BY 4.0) [35].

Each of the *Cannabis sativa* L. categories, (a) fiber and hurd, (b) seed or grain, (c) products for medicinal markets, and (d) products for recreational markets, has many modern uses.

a. Fiber products: Numerous industrial applications use hemp fiber as a natural source of bast fiber [36]. Known for their strength, durability, and length (fiber bundles can reach 1–5 m), hemp fibers have long been valued for serving many purposes including making rope, paper, and textiles [37–39]. The life cycle assessment (LCA) of hemp fibers, from cradle to grave, reveals that hemp fibers perform better than glass fiber by weight [40]. LCA assesses the environmental impact and resource usage of a product, including its raw material acquisition, manufacturing, and disposal phases [41–44]. The increased global demand for eco-friendly natural products and sustainable systems has increased the market share for textiles, fabrics, and clothing made from hemp fiber [12,45]. Hemp fiber is also used to make biodegradable mulch, horticultural planting materials, pressed fiber products, paper and pulp products, building-construction materials, insulation materials, animal bedding made of hurd, plastic bio composites, and compressed cellulose plastics [12].
b. Seed or grain products: Hemp seed has historically served as a vital food source [46,47]. It consists of 20 to 30% edible oil, 20 to 30% protein, 20 to 25% fiber, 20 to 30% carbohydrates, and many other important nutrients and vitamins recommended for humans [12]. Hemp seed oil and grain products include whole and dehulled hemp seeds, hemp seed oil, hemp seed flour, hemp seed cake (a byproduct of mechanical oil pressing), hemp seed meal, hulls of hemp, and hemp protein isolates and concentrates (Figure 5) [48]. Hemp seeds are used to produce olive oil and salad dressing, and seeds of hemp contain omega 3 fats and proteins. In addition to being used in cosmetics, hemp seed oil can be used as a substitute for industrial oils [12].

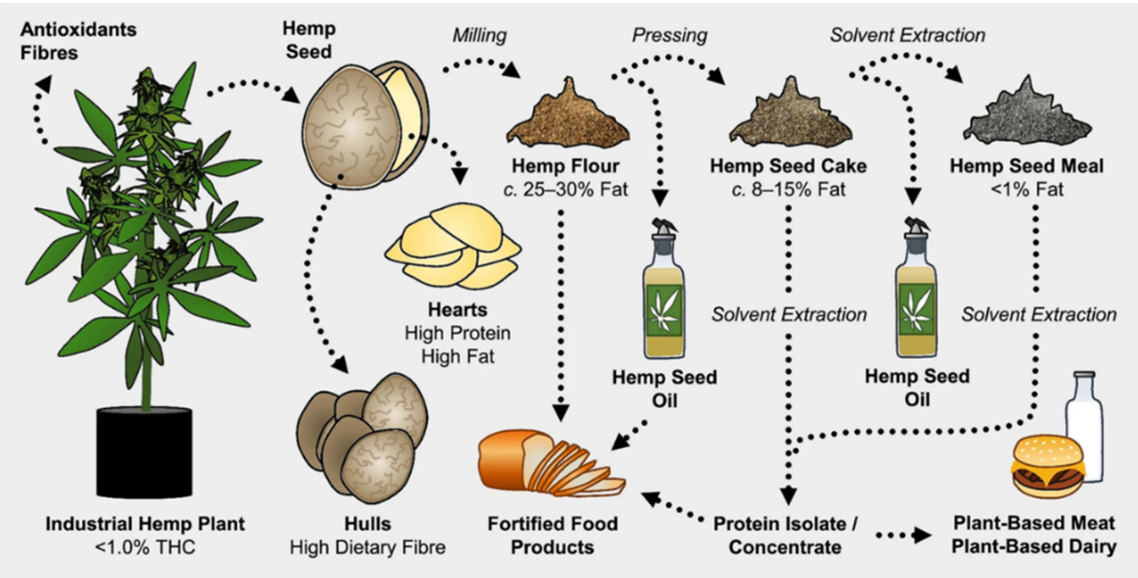

Figure 5. Processing to generate the main types of hemp seed-based food ingredients (CC BY 4.0) [48].

c. Products for the medicinal market: CBD oil is a nonintoxicating cannabinoid compound produced using industrial hemp; unlike THC, it is not addictive. Because it is non-addictive and may offer health benefits, many states have recently made CBD oil legal [49]. Although CBD is used in various products, such as sparkling water, lotions, and pharmacological substances, its purported health benefits have not been scientifically verified. These areas offer an exciting opportunity for further research [12]. Medicinal market applications, while important, are not the focus of our review.

d. Products for the recreational market: Because industrial hemp does not include high THC, it is not used for recreational purposes, and this application was not included in our review.

3.3. Sustainability of Industrial Hemp

Traditionally, sustainability has included three pillars: the economy, the environment, and society [50]. Even today, this framework remains relevant [51,52]. Hemp, as a sustainable plant, aligns with all three pillars.

3.3.1. Hemp Economic Sustainability

Economic sustainability refers to maintaining capital [53], for which sustainable business practices are critical [52].

As is the case for many other industrial plant species, hemp economics is complex. Although hemp has been sold for centuries [54], currently, there are many economic uncertainties facing the hemp industry and its supply chain actors (hemp producers, processors, manufacturers, retailers, input suppliers, and consumers) [55]. While hemp is a rapidly evolving industry, three things are certain about its economics [56]:

1. A wide range of products can be made with hemp.
2. Hemp products account for a small percentage of food, textiles, personal care products, pharmaceuticals, and nutraceuticals sales in the U.S. and worldwide, but sales are growing quickly.
3. Despite the falling production of hemp worldwide, due to its association with marijuana since the 1950s, business and policy changes, infrastructure investment, and improved production methods have led to a rebound in hemp production over the past decade.

Considering the various uses of different parts of the plant, policy and regulatory uncertainty in the U.S., and limited data at the farm and market level, economic evaluation of the crop is challenging for economists [56]. Presently, in addition to regulatory hurdles, two main issues impacting the economic sustainability of industrial hemp growth exist. First, hemp crops can "go hot" (exceeding the authorized THC limit), requiring their destruction [57]. This creates an economic risk when growing hemp. Second, the procurement of robust and readily available planting and harvesting equipment is challenging. For example, sickle-bar mowers and hay swathers, which are currently used in hemp harvesting, often clog, and the blades become blunt due to frequent use [58]. This adds expenses for equipment maintenance and repair. In addition, more robust harvesting equipment designed specifically for hemp is typically manufactured overseas and is expensive and time consuming to import.

For economically sustainable hemp cultivation, an important and progressive direction is the convergence of agriculture and energy in "agrivoltaics", where solar modules are located above hemp crops, which has positive economic and environmental impacts on agricultural systems [59].

Per a report published by Expert Market Research [60], the market value for industrial hemp worldwide in 2020 was valued at USD 4.7 billion. Aided by increased product awareness, the sector is predicted to achieve an annual compound growth rate (CAGR) of 22.5% from 2023–2028, with revenues of USD 14.6 billion by 2026. According to the report, rising textile industry demand and favorable government policies are driving the market. There is a rapid growth in the Asia Pacific region for hemp production due to easier access to raw materials and increasing global demand. The region is expected to continue to grow between 2023–2028 [60]. Due to its rise, research institutes and manufacturers are investing resources to develop new innovative products. One key area of research is medical uses, specifically for the potential treatment of chronic diseases such as diabetes; another key area is biofuel and bioplastics. These possible uses for hemp are projected to drive its growth in the coming years [61].

However, the global industrial hemp market size estimates vary greatly. For example, the global market size (Asia-Pacific, Africa, North America, Latin America, Europe, and the Middle East) was estimated by Market Data Forecast to be as high as USD 18.87 billion by 2027 [62], whereas a report published by Impactful Insights estimated a more conservative market size of USD 10.0 billion by 2027 [63]. Three key factors play a role in these varied estimates. First, to date, there are no official global estimates of hemp under cultivation, which severely hinders forecasting. In addition, a massive oversupply of CBD oil caused 60% of U.S. growers in this sector of the business to struggle due to a crash in wholesale prices during the third and fourth quarters of 2019 [64]. This period saw a drop of 18% in the price of hemp seeds and a decline of 68% in the price of crude hemp oil [64]. Moreover, hemp's three largest markets are beverage and food, fiber (paper and textiles), and beauty and personal care items [65]. Since each of these markets represents a billion-USD global market, with an estimated 2019 market sizes for packaged beverage and food valued at USD 4,837 billion [66], textiles valued at USD 1,587 billion [67], and beauty and personal care items valued at USD 503 billion [68], even a slight fluctuation in calculated market size can result in substantial differences in market size estimates [48].

Industrial hemp's global market has radically changed over time due to fluctuating demand driven by war, prohibition, taxation, and more recently, competition with other fibers. Although some have claimed that industrial hemp's global economy may change slowly, its legalization in a large region often causes significant and dramatic economic shifts [69].

Globally, around 30 European, Asian, North American, and South American countries legally produce hemp. Canada, China, and the European Union are the top three global markets producing hemp [70]. According to the FAO, industrial hemp is also produced in Pakistan, Chile, Japan, Iran, South and North Korea, Syria, Turkey, and Russia. Countries producing and/or trading industrial hemp that are excluded from the FAO's reports are Egypt, South Africa, Malawi, India, Thailand, Russia, Uruguay, Switzerland, New Zealand, and Ukraine [29].

Canada is the world's top producer and exporter of hemp-based foods, including hemp seeds, hemp oil, and hemp protein powder [70]. Growing industrial hemp on a research basis was first authorized by the Canadian government in 1994 [71]. Its legal commercial hemp industry started in 1998 and is therefore, relatively new [29]. Canada's federal government controls hemp production, and farmers may only produce plant varieties that are legally approved. According to new 2018 Canadian regulations on hemp, farmers are also allowed to grow hemp flowers, leaves, and branches [70].

China is reportedly the world's leading producer of hemp fiber, accounting for almost 50% of the world's supply [72]. A total of 70% of China's hemp products are textiles; the remaining 30% includes cosmetics, CBD products, food, and supplements [70]. China is known as a global pioneer in hemp and consumer textile production [73]. There is no official data for China's hemp cultivation and production. Most of the hemp production in China is concentrated in the far northeast Heilongjiang and far southwest Yunnan provinces [72]. Even though hemp fiber and seed have been grown in China for thousands of years, its production was banned between 1985 and 2010. In recent years, its production has grown rapidly and is expected to continue to grow [72].

Hemp is produced across Europe, and its production has grown significantly in recent years. France is the top producer, accounting for 70% of the EU's total production, followed by the Netherlands with 10% and Austria with 4% [74]. France is the third-largest industrial hemp producer in the world [75]. In the EU, hemp is mostly produced for hurds, organic seeds for food, hemp fiber for automobile composites, pharmaceuticals, and CBD, which has gained popularity in recent years [56,76].

U.S. hemp production data are followed and maintained by the United States Department of Agriculture (USDA). Data accumulated by the USDA in 2021 showed that the total planted area for industrial hemp was 54,152 acres [77], the area harvested was 33,480 acres [77], and the value of hemp production was USD 824 million [77]. In 2021, the top six states ranked according to the cultivated acreage were Colorado, Montana, Oklahoma, Texas, California, and Minnesota [77]. According to the National Hemp Report in 2022, the prices for fiber, seed/grains, and flowers in the U.S. varied on average from USD 0.14–3.47, 0.65–15, and 2.33–503, respectively, in 2021 [77].

The legalization of industrial hemp does not come without its economic challenges and uncertainties. Following the implementation of the 2018 farm bill, some of these uncertainties were addressed. Hemp farmers can now apply for crop insurance, and researchers can apply for federal grants. The Drug Enforcement Administration (DEA) and the FDA still face regulatory uncertainties, despite legislative approval [56].

For profit-maximizing firms, hemp must be cost competitive with similar oils, fibers, therapeutic compounds, and health supplements. For hemp to be lucrative, farmers must compare it with other crops and compete against hemp imports from other countries.

3.3.2. Hemp Environmental Sustainability

Environmental sustainability is essential and seeks to preserve natural resources for social and economic purposes [53]. Hemp contributes to environmental sustainability because it benefits biodiversity, captures a high amount of carbon (which helps mitigate climate change), and does not require significant amounts of herbicides or pesticides [78].

The ecological effect of hemp hinges on the methods by which it is grown and refined; it can be a carbon neutral or carbon negative plant, depending on these methods. In one study, hemp straw grown on a 2.47-acre field stored 3.06 tons of carbon [79]. Carbon stored by hemp is also unlikely to return to the environment for several years, since the products produced with hemp have a long shelf life. Hempcrete, particularly, has a life span of over 30 years [79]. For bioremediation objectives, hemp has also been used to remove heavy metals from soil. When grown in a multi-crop system, the lengthy taproot and comprehensive origin system of hemp have additionally been revealed to avoid soil disintegration and enhance topsoil quality [80]. Hemp also requires much less water and less chemical input than cotton and other natural fiber plants. Environmentally conscious farmers must focus on fertilizer usage, water usage, distance to refineries, and power consumption while harvesting and processing crops [81].

Although it is not ecologically impact free, hemp exhibits reduced ecological effects compared to many other plants or competing raw materials. Using hemp as a renewable raw material can reduce the strain on diminishing, non-renewable sources. Agronomically, hemp can decrease fertilizer, as well as chemical usage, and boost soil oxygenation because of its substantial root system [71]. It is also an excellent rotational crop [82]. Overall, hemp reduces demand on the surrounding environment more than many comparable plants; this benefit will increase with future harvesting innovations. Furthermore, hemp generates eco-friendly materials, including heat-insulating materials, carbon-sequestering polymers, and sustainable, lightweight concrete substitutes [83].

Historically, the agricultural sector has been dominated by monocrops, and scant attention was given to ecological friendliness. Information comparing the ecological virtues of crops is limited. In a report titled "Evaluating the Ecological Friendliness and Biodiversity of the Hemp Crop" [84], 25 parameters are analyzed to determine the ecological friendliness of *Cannabis sativa* L. as a fiber and an oilseed crop. The author of the report stated that despite various studies comparing monocrop sustainability, the focus has been on economic success, rather than biodiversity conservation. In addition, the report mentioned that recent studies concluded that hemp shows exceptional biodiversity compatibility. Using crop characteristics related to biodiversity, the report compared hemp with major monocrops. The report evaluated hemp using a scoring system in which -1 represented relatively undesirable impacts on biodiversity, 0 represented average impacts, and +1 represented relatively desirable impacts. The mean score was calculated using simple averaging, with a higher positive score representing a more ecologically friendly crop. The study compared hemp fiber and oilseed with food and fiber crops that dominate world agriculture and significantly impact biodiversity [84].

The report compared the biodiversity friendliness of 21 of the world's most significant agricultural crops with hemp oilseed and hemp fibers [84]. Hemp oilseed ranked marginally higher compared to hemp fibers. The author's evaluation revealed that alfalfa was the most biodiversity-friendly, followed by timber trees. Several important global crops, including potatoes, cereals, cotton, sugar cane, sunflowers, rapeseed, soybeans, and tobacco, ranked low regarding these environmental factors. Details of the parameters used in the comparison can be seen in their original publication [84].

The author of the above study concluded that hemp was superior to most major monocrops in its impact on biodiversity. The author also concluded that hemp could play an increasingly pivotal role in addressing future global needs. However, the author acknowledged the limitations of their methodology, explaining that their rankings of the crops should not be interpreted as precise because:

1. The criteria were set based on the author's familiarity with the topic.
2. There is a limitation to the author's knowledge of a wide range of crops and criteria.
3. There may be some criteria that deserve to be heavily weighted, depending on location (e.g., irrigation may be more critical in areas with low water availability).

3.3.3. Hemp Social Sustainability

Social sustainability refers to maintaining investments and necessary services for society. It can be promoted within a community and benefit that community through interconnectedness, discipline, and ethics [53]. Human sustainability, related to social sustainability, refers to nurturing values, relationships, and socialization [85].

The social sustainability of hemp is indicated by its economic and ecological impacts. Its popularity and economic success across various countries reflect that it is fulfilling a necessary service through its various uses.

The value of industrial hemp as a raw material in terms of social sustainability is derived in part from the ability to build local and regional supply chains. These localized supply chains are encouraged by two primary factors. First, the expense of shipping harvested hemp stalks is high due to the low density of stalk bales. Second, the optimal varieties of hemp grown in each region depend on local climates and soil conditions. These two factors make it economically advantageous to grow, process, and manufacture hemp-derived products locally, providing an incentive to process and manufacture hemp near its source farms. While trading on a national or international scale, regional production gains economic value that benefits the local community. Producing more valuable goods and materials from local raw materials results in greater economic gain to the farming community and to local manufacturers compared with exporting raw materials for manufacturing at remote sites [69]. These driving forces tend to maintain profit in the local communities, encouraging social sustainability.

Despite these benefits, hemp does come with some production hazards and workplace health and safety concerns, which are common in the textile industry and impact social sustainability [78].

Large-scale raw hemp handling may lead to persistent breathing problems and symptoms [81]. Workers may be exposed to hemp dust when working with fiber processing machines. Hemp dust may carry plant particles, glucans, viruses, bacteria and endotoxins, pollen, insects, and compost, all of which can lead to serious diseases upon exposure, such as respiratory infections or irritation, allergies, and/or inflammation [78,86]. Studies have shown that inhaling the dust particles produced by raw hemp can cause a lung disease called byssinosis [87–90], which can include chest tightness, fever, headache, or muscle aches [78,86,91]. Byssinosis is most common in the textile industry, and people who are sensitive to dust are more prone to this disease [91].

Although hemp production does not require significant amounts of pesticides or herbicides, some farmers still prefer to use some of these chemicals, which exposes them to various health risks and chronic diseases, including acute and chronic neurotoxicity [92,93]. Studies have also linked certain pesticides to cancer [94]. Organically grown hemp is not subject to these chemical hazards [95], but when cultivated indoors, it is sometimes treated with carbon dioxide to encourage its growth, which causes oxygen deficiencies in the atmosphere, posing health risk to workers [96]. The textile industry exposes its workers to a wide range of chemicals, specifically while dyeing, printing, and finishing the materials. Occupational hazards associated with chemical use include skin irritation, lung edema, burns, and DNA mutation. Chemical exposure poses a hazard to textile workers based on how they are exposed [97]. Water contaminated with these chemicals can also impact local populations [93].

Additionally, industrial hemp production poses health risks, such as allergies and breathing problems [98]. Several studies have shown that hemp pollen in the atmosphere during summer and autumn can cause allergic skin reactions, often with asthma-like symptoms [99–102]. Decorticating hemp and organic dust have also been found to cause allergic reactions [103]. Decortication is the mechanical separation of bast fibers from shives and is an integral part of the production process for natural fibers [35,104].

Processing hemp is traditionally labor-intensive, and only Eastern European and Asian countries with low labor costs practice it [105]. Labor-intensive work can cause musculoskeletal disorders [106]. Improper posture, noise, and unsafe working environments contribute to physical risk and can cause injury [107]. These risks can be reduced through proper training and education [108].

Despite the importance of workers' rights, human rights concerns are inherent in the textile industry. These concerns include insufficient or dangerous working conditions, discrimination, and child and/or forced labor [109,110]. Wages for female workers are often low [111], and work is unstable or unpredictable [109,112]. Many textile workers are therefore living in poverty and cannot properly support their families [109]. This can lead to workers taking on a greater workload and/or working overtime [106].

While the results of initial studies are promising, quantifying the social sustainability of hemp as a renewable industrial raw material is in its infancy, and additional research will need to be conducted in order to better measure and assess the impact of growing and processing industrial hemp and manufacturing hemp-derived products from this versatile raw material [78].

4. Conclusions

After reviewing the literature, we found that hemp's rapidly increasing popularity in the U.S. since 2018 can be attributed, in part, to its sustainability potential (defined as the potential to positively impact the sustainability of products, using hemp as a renewable raw material). The hemp plant is lauded for its countless uses, its harmony with the environment, its use as an alternative cover crop for small farmers, and its potential as a value-added enterprise for local entrepreneurs and businesses. Our study also found that most sustainability information on hemp pertained to environmental impact, followed by economic impact. Very little information is available on social impacts and social sustainability. This could be because the study of the social impact regarding sustainability and LCA is still evolving. However, while not reviewed here, the emerging study of circular economies is starting to incorporate social impact with environmental and economic impact [113,114]. Further, consumers' perceptions of health and environmental benefits from hemp products will determine the future demand for hemp, which will further depend upon the price of hemp products. As no global organization or federal government currently collects global data on hemp production or its impact, these areas offer an exciting opportunity for further research. Despite the present gaps, hemp exhibits significant sustainability potential because it naturally aligns with all three pillars of sustainability. It therefore fills a need as a sustainable raw material option and offers one solution to address the urgent climate crisis.

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