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REVIEW ARTICLE

A review of the industrial use and global sustainability of *Cannabis sativa*

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Abstract
The Cannabis plant (*Cannabis sativa* L.), also known as hemp, is a sustainable and multipurpose plant that may be used for a wide range of purposes, from the fiber in its stalks to the food in its seeds to the oil in its flowers and seeds. Since the Cannabis plant has been recognized to be an outstanding carbon trap and environmentally friendly biofuel that supports all three aspects of sustainability—the economy, the environment, and society—it may provide a solution to the climate change dilemma. The cultivation of the Cannabis plant has been practiced as a dietary staple in numerous places across the globe for an extended period. However, its production has been prohibited in several countries mostly owing to its relationship with illicit drug consumption. The illegality of the plant has impeded research efforts for an extended period of time on a global scale. As a result, people's ability to assess the whole range of beneficial effects and dangers shrank. However, the global trend toward Cannabis legalization and decriminalization has accelerated in recent years. This has stimulated more investigation into the botanical, ecological, and practical aspects of the plant. This study reviewed the available literature to understand more about the Cannabis plant's global sustainability. The results demonstrated the potential of Cannabis plants to affect product sustainability and the use of hemp as a renewable raw material. Furthermore, this review outlines the connections between the Cannabis plant and the Sustainable Development Goals (SDGs) of the United Nations. This research fills a gap in our understanding of the Cannabis plant's sustainability as a highly promising multi-purpose crop for the future.

Keywords: Cannabis; Hemp; Fiber; Industry; Environment; Sustainability

Introduction

Global environmental issues are being exacerbated by the current climate changes on the planet, which are mostly the result of human activity (Raihan et al., 2022a; Abbas et al., 2023). Some of the results of these issues are overpopulation, climate change, and the loss of biodiversity. The literature confirms that these phenomena arise from the irresponsible consumption of natural resources (Jaafar et al., 2020; Begum et al., 2020; Voumik et al., 2022; Raihan, 2023a). Ecological, economic, and agricultural sustainability are interdependent and necessary for environmental protection (Agrawal et al., 2022; Ibarra et al., 2023; Raihan, 2023b). Sustainable farming options have recently garnered a lot of attention from farmers all around the world (Raihan et al., 2023a; Sharma et al., 2023). Hemp, often known as the Cannabis plant, is attracting interest as a sustainable crop with great potential (Rivas-Aybar et al., 2023). Cannabis is thought to have originated in East and Central Asia before spreading throughout the rest of Asia and, eventually, to Europe (Wani et al., 2023). Industrial hemp, also known as *Cannabis sativa* L., is cultivated for its fiber, oilseed, medicinal, and recreational uses (Visković et al., 2023).

The Cannabis plant is an annual herb that can reach heights of 1 to 6 meters and is dioecious in nature (Agate et al., 2020). Hemp, one of the world's fastest-growing plants, is an annual with a complex leaf structure (Kaur & Kander, 2023). Besides improving air quality, thermal balance, and environmental impact, Cannabis plants can remove up to 10 metric tons of carbon dioxide from the air in a single vegetation cycle (Zimniewska, 2022).

The Cannabis plant has a high yield when it comes to fiber production; on the same amount of land, it may generate 250% more fiber than cotton and 600% more fiber than flax (Rupasinghe et al., 2020). Figure 1 presents the benefits of the hemp apparel industry. Cannabis plants can be produced without the use of herbicides because their dense canopies shade out weeds and reduce the number of soil-dwelling fungi and nematodes (Adesina et al., 2020). Because of how firmly it anchors its roots in the ground, the Cannabis plant helps preserve soil quality by preventing erosion and nutrient leaching. It also aids in phytoremediation by removing pollutants such as heavy metals from the soil and preserving them inside the plant (Cleophas et al., 2022). Throughout the growing season, leaves fall to the ground, providing a steady supply of wet organic matter (Rupasinghe et al., 2020). The Cannabis plant is an excellent option for use in crop rotation plans to enhance the production of the primary crop because of its role in enhancing the soil quality. If Cannabis cultivation is handled correctly, the plant is predicted to be a sustainable and environmentally benign crop (Adesina et al., 2020). Farmers who cultivate the Cannabis plant have the option of using fewer herbicides, rotating crops, and eventually becoming certified as organic (Visković et al., 2023). The agricultural sector is interested in cultivating Cannabis due to its environmental benefits and the expanding market for hemp products (Quaicoe et al., 2023). Growing, processing, using, recycling, reusing, bio-refining, and waste management—the entire value chain of the Cannabis plant—satisfies the principles of sustainability tactics and can aid in combating climate change (Kaur & Kander, 2023).

Figure 1. The benefits of the hemp apparel industry.

Many different plants, notably hemp and marijuana, are produced by the Cannabis genus. Cannabinoids, which are found in high concentrations in Cannabis, each have their own unique physiological effects in humans, numbering over a hundred (Simiyu et al., 2022). The two most studied cannabinoids are tetrahydrocannabinol (THC), the psychoactive component responsible for the "high" associated with Cannabis, and cannabidiol (CBD), a safe, non-addictive, and non-hallucinogenic substance known for its medicinal properties. profile (Johnson, 2019). Bud, oil, and tinctures containing CBD are on the market for the purpose of reducing inflammation and stress (Iseger & Bossong, 2015; Hameed et al., 2023). Because of its intoxicating effects, THC is prohibited in many countries despite its widespread medical and recreational usage (Bridgeman & Abazia, 2017). Hence, it is imperative to differentiate between the several classifications of *Cannabis sativa* L., namely marijuana and industrial hemp, in order to engage in lawful cultivation practices. The determination of the THC concentration threshold on a dry weight basis is commonly employed as the primary criterion for distinguishing between the two unique types. On a dry weight basis, THC concentrations in industrial hemp are typically below 1%, but in marijuana can range from 3% to 15% (Rupasinghe et al., 2020). Industrial hemp's validity varies across different locations and countries. Producing hemp with high concentrations of psychoactive cannabinoids is illegal in most countries, including the European Union (EU), in order to deter its usage for recreational purposes (Sgrò et al., 2021). The EU regulations impose the most stringent limitation on THC concentration, capping it at 0.2%. In comparison, Mexico allows up to 1.0% THC, Malaysia permits 0.5% THC, and the majority of countries, including America, Canada, China, and East Asian countries, set the maximum at 0.3% THC (Zhao et al., 2021). Research into Cannabis has been hampered for decades by the plant's widespread prohibition, slowing the development of policies and agricultural extension guidelines needed to minimize adverse environmental outcomes (Wartenberg et al., 2021; Clarke & Fitzcharles, 2023). As a result, people's ability to assess the whole range of beneficial effects and dangers shrank. However, the global trend toward legalizing and decriminalizing *Cannabis sativa* has accelerated in recent years (Yousufzai et al., 2023). Because of this, researchers have begun to focus more on the plant and its many potential applications (Simiyu et al., 2022). Governments, individual researchers, and corporations from all around the world have recently expressed an intense curiosity about industrial hemp (Kaur & Kander, 2023). Proponents of Cannabis legalization point to the plant's environmental benefits, adaptability to different agronomic circumstances, and myriad uses to argue that it should be legalized as a cash crop for farmers (Taylor et al., 2023). It has been suggested in research that the cultivation of the Cannabis plant could be financially rewarding if treated like any other commercial agricultural entrepreneurship (Kaur & Kander, 2023). However, due to global limitations and restrictions on industrial hemp production, much of the existing research on the sustainability potential of the Cannabis plant is based on notions that have not been validated or are already out of date (Visković et al., 2023). Therefore, this study seeks to fill these gaps by reviewing the existing literature on industrial uses of the Cannabis plant and its sustainability from multiple points of view of economic, environmental, and social sustainability. In addition, this study portrays how the Cannabis plant contributes to achieving the United Nations' Sustainable Development Goals (SDGs). This research has the potential to contribute to the development and implementation of appropriate policies aimed at the global legalization of the Cannabis plant, as well as the promotion of industrial hemp, with the ultimate aim of accomplishing the SDGs.

Methodology

The present study employed the systematic literature review methodology as suggested by Tawfik et al. (2019). According to Benita (2021) and Raihan (2023c), the systematic literature review framework is considered to be a reliable approach. A preliminary review of the literature was conducted to identify pertinent articles, validate the proposed idea, avoid redundancy with previously covered issues, and ensure the availability of sufficient articles for conducting a comprehensive analysis of the subject matter. Both scholarly and gray literature were identified and sourced using a global Google Scholar search of the literature on industrial hemp, its applications, and its sustainability. The industrial application and long-term viability of the Cannabis plant are examined by reviewing a variety of publications covering the time span from 2000 to 2023. "Cannabis sativa," "industrial hemp," "parts of the hemp plant," "hemp fiber," "hemp seed," "hemp oil," "uses of industrial hemp," "hemp global production," "pillars of sustainability," and "hemp and sustainability" are only some of the search keywords used in this literature study. The Google Scholar search returned almost a thousand results. Peer-reviewed publications, book chapters, and government and international agency reports were filtered into a second search. The study then analyzed the titles, keywords, and abstracts of the search results to determine how relevant they were. For instance, documents were omitted if they failed to address the present applications of industrial hemp or the sustainability of hemp. Figure 2 illustrates the development of review criteria employed for the selection of suitable documents for review analysis.

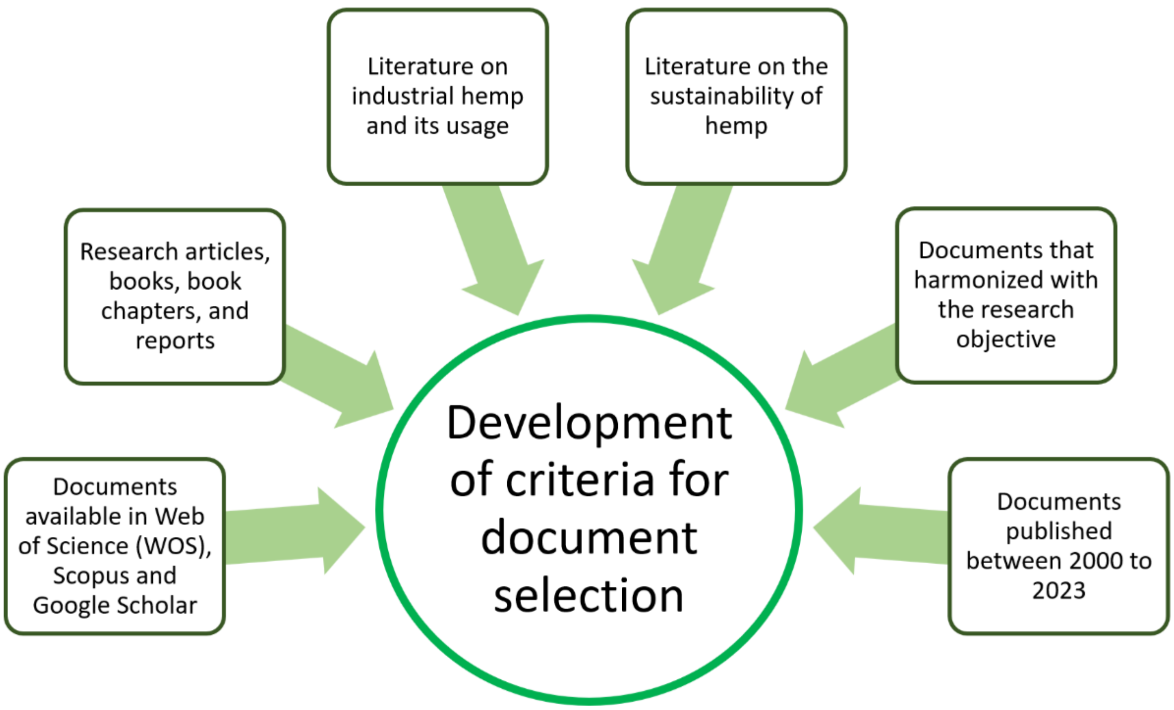


Figure 2. The development of criteria for the selection of documents.

The comprehensive literature review encompassed a total of 86 distinct scholarly documents. The present study implemented a data verification process, wherein each included article was cross-checked with its corresponding entry in an extract sheet using visual evidence. It is noteworthy to mention that of the 86 documents subjected to qualitative synthesis, only those publications containing relevant material were cited in the reference list contained in the manuscript. This implies that certain articles were not included in the reference list. Figure 3 illustrates the systematic review procedure utilized in the current study. After the research topic was chosen, this study conducted a systematic search for relevant publications, analyzed and synthesized information from diverse literature sources, and prepared written materials for article review. The synthesis phase encompassed the collection of a wide range of publications, which were subsequently amalgamated into conceptual or empirical analyses that were relevant to the finalized research.

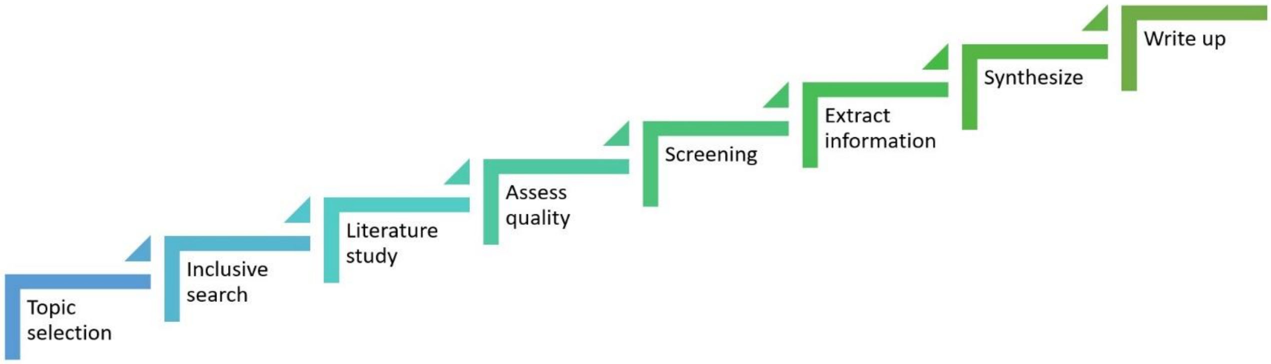


Figure 3. The procedure of systematic review conducted by the study.

Usage of Cannabis plant

Seeds, stems, flowers, leaves, and roots are all components of the Cannabis plant. Figure 4 depicts various components of the Cannabis plant. Hemp fiber is the stem and stalk of the industrial hemp plant. Hemp fiber production requires preventing the plant from spreading out and flowering. Plants are spaced at a density of 35-50 per square foot. Ten to fifteen feet is the optimal height at which to harvest Cannabis plants for fiber (Johnson, 2019). The outside layer of a hemp stem is made up of bast fiber bundles, which are more valued than the inner layer, which is made up of hurd or shive fiber bundles, which are less expensive woody components (John, 2019; Kaur & Kander, 2023). Figure 5 shows the hemp stem separated into fiber and hurd.

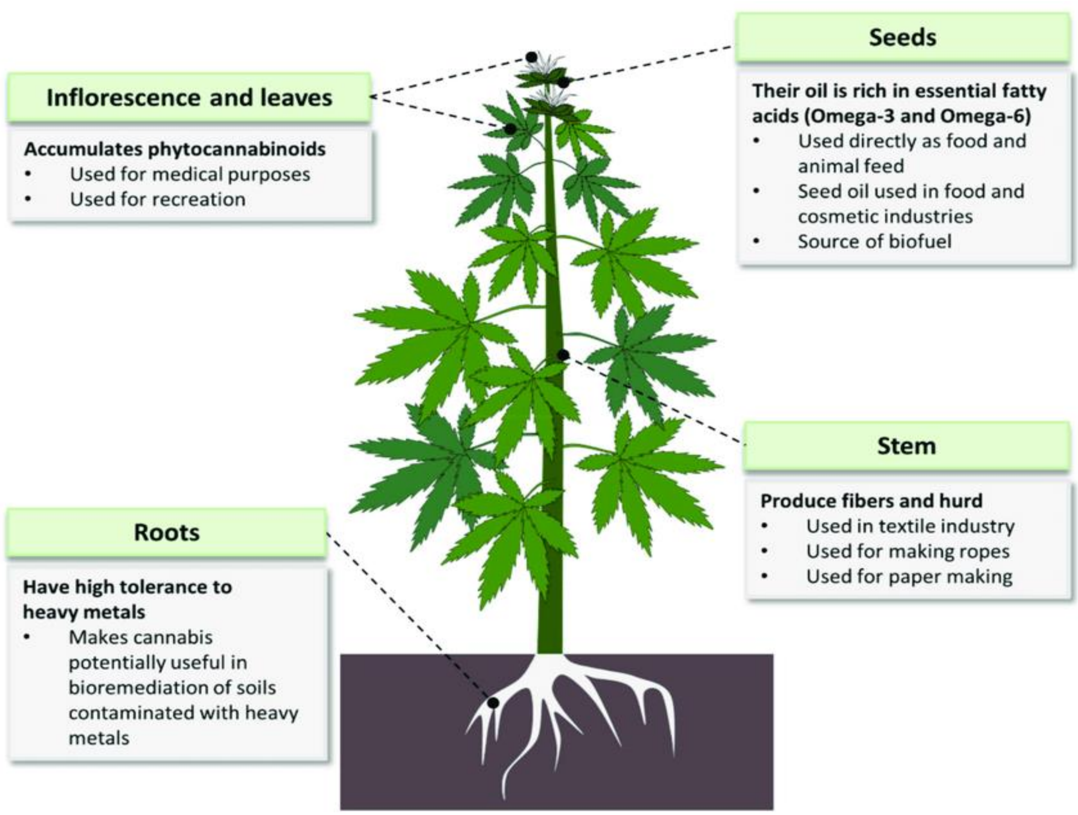


Figure 4. Various components of the Cannabis plant (Simiyu et al., 2022).

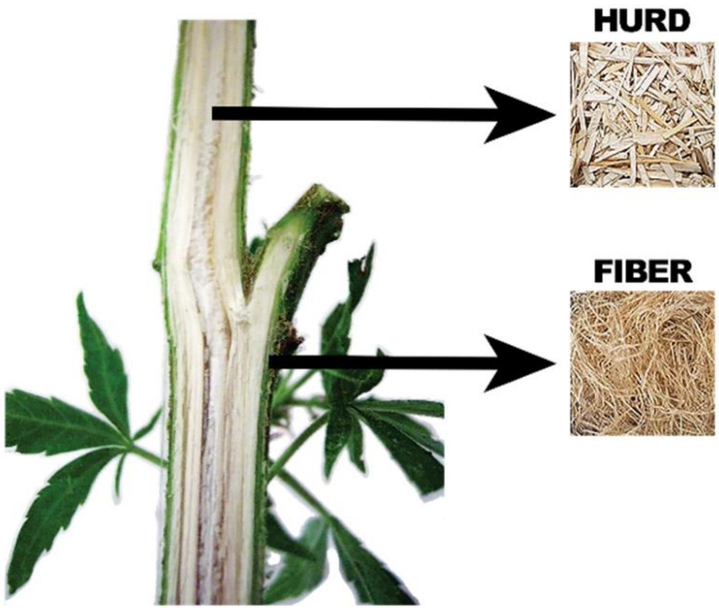


Figure 5. The stem fibers and hurd derived from the Cannabis plant (Kaur & Kander, 2023).

The hurd of a hemp stem accounts for 85% of its biomass (Li et al., 2018), while the bast fiber only accounts for 15%. Using a decorticator, retting, or both, the core fibers are mechanically removed from the bark to create fiber. After being cleaned, dried, and bale, hemp fibers can undergo further mechanical separation to undergo processes including cottonizing, shredding, and spinning into yarn. Oilseeds are obtained from the seeds of industrial hemp plants (Kaur & Kander, 2023). Growing hemp plants for their seeds is quite similar to growing hemp plants for their fiber. Seeds and grains from Cannabis plants can be harvested when they reach a height of 6 to 9 feet (Johnson, 2019). Hemp seeds range in size from about 1/8 to 1/4 inch and have a smooth exterior. Figure 6 is a cross-sectional view of a hemp seed from the side. During seed processing, the seed kernels are separated from their hulls (Kaur & Kander, 2023).

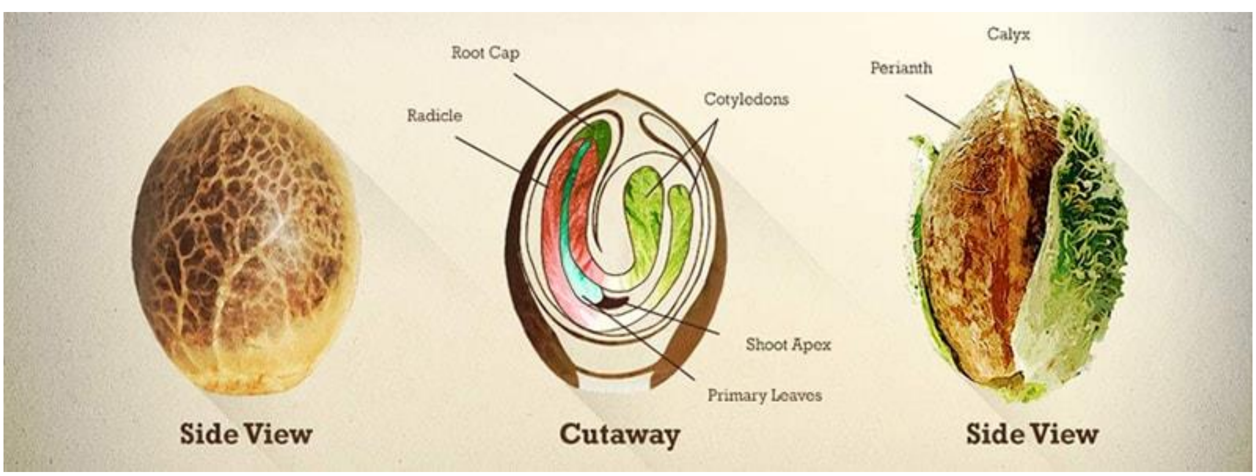


Figure 6. A side view and cross-section of a hemp kernel.

Flower buds and other floral components on Cannabis plants are collected for extraction of CBD and other oils. Flower buds and other floral materials can be cultivated by encouraging the development of wider branches and leaves. Hemp is spaced out more, typically between three and five feet, so that the plant has room to spread its

roots and shoots (Johnson, 2019). Flowers on industrial hemp plants can be harvested when they are between four and eight feet tall. Lipid infusion, carbon dioxide extraction process, and solvent-free extraction are all necessary for oil production (Johnson, 2019). While hemp produced for seeds and grain produces 800 to 1000 pounds per acre, hemp farmed for fiber produces 2,000 to 11,400 pounds of entire dry stems per acre. According to Kaur and Kander (2023), each hemp plant may produce roughly one pound of dry flower buds.
Cannabis is a versatile plant in that nearly every part of it can be utilized (Simiyu et al., 2022). Hemp is one of the most rapidly reproducing plant species, and its fiber, seeds, and oil can be used in a variety of ways (Kaur & Kander, 2023). Multiple commercial applications for the Cannabis plant are shown in Figure 7. The dehulled or unhulled seeds can be used in cooking, as animal feed, in cosmetics, or pressed into oil using a cold process (Montero et al., 2023). The stem can be harvested for its shives (hurd), which can be used as animal bedding, as well as its fiber, which can be made into paper or textiles (Naeem et al., 2023). Essential oils, among other things, can be extracted from the hemp flower for application in cosmetics and medicines (Farinon et al., 2020; Arif et al., 2023). More than 25,000 products are made from industrial hemp around the world in various industries such as paper, fabrics and textiles, construction and insulation materials, home furnishings, yarns and spun fibers, carpeting, and bio-composites owing to the expanding global industrial hemp market (Kaur & Kander, 2023).

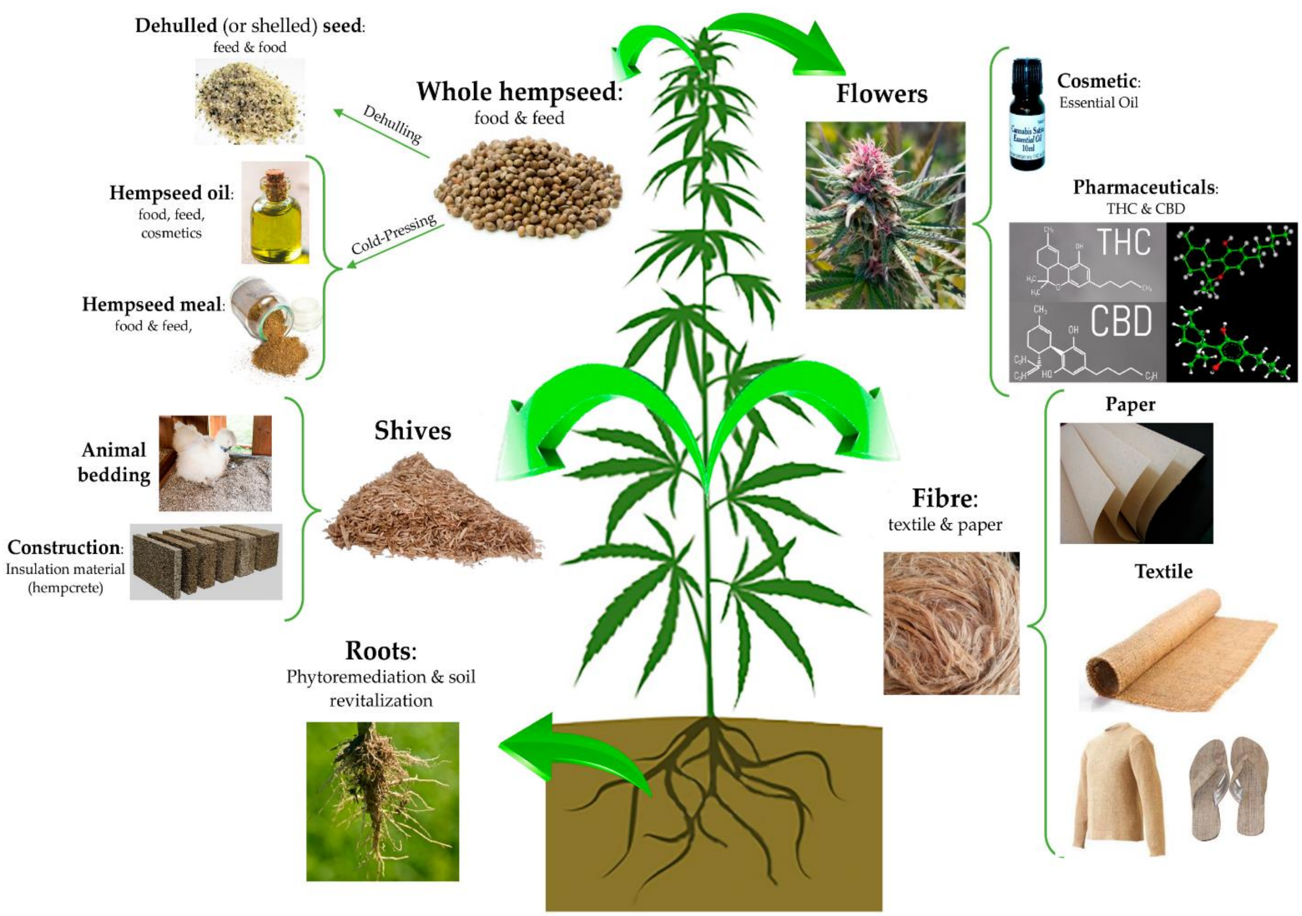


Figure 7. Various industrial applications of the Cannabis plant (Kaur & Kander, 2023).

It's possible to extract useful components from the Cannabis plant, which could be employed in a variety of applications (Martinez et al., 2023). Figure 8 is a schematic illustration of the many possible applications of the Cannabis plant. Hemp fiber is a renewable source of bast fiber and is used in a wide variety of industrial applications (Chaowana et al., 2024). Hemp fibers have been used for a variety of uses, including the production of paper, rope, and textiles (Naeem et al., 2023) due to their strength, resilience, and length (fiber bundles can reach 1-5 m). High-quality fabrics used in the global apparel industry can be woven from the hemp plant's fibers (Kozlowski & Muzyczek, 2023). Hemp fiber production is more sustainable and uses less water than conventional cotton farming (Yano & Fu, 2023). As an alternative to artificial, flammable synthetics, hemp is utilized to reinforce carpets that are resistant to rotting and fire (Filer, 2022). The market share for textiles, fabrics, and garments made from hemp fiber has expanded due to a growing worldwide preference for eco-friendly products from nature and sustainable systems (Gedik & Avinc, 2020; Raihan et al., 2022b).

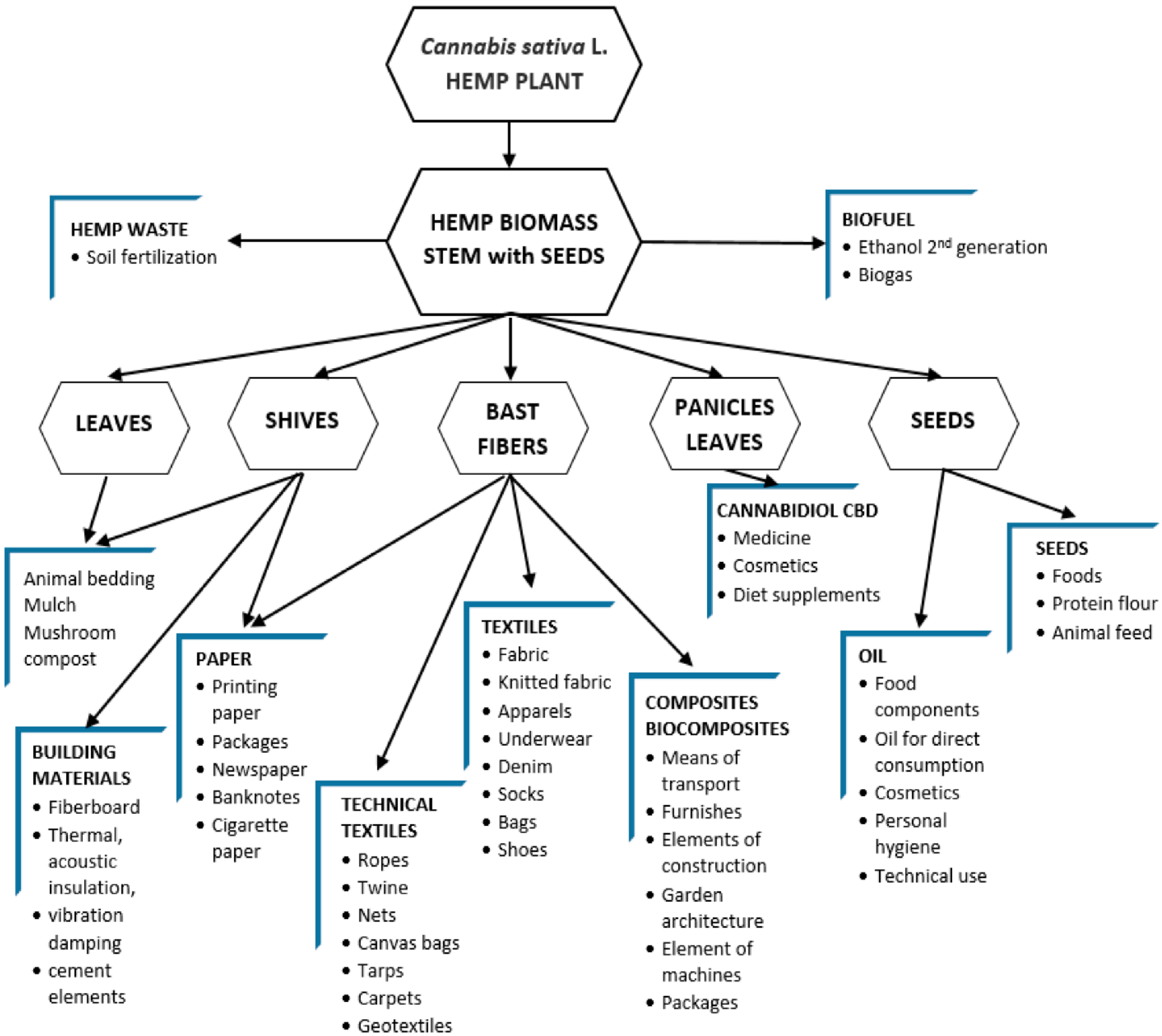


Figure 8. The diverse potential applications of the Cannabis plant as a raw material (Zimniewska, 2022).

The pulp and paper business has long faced formidable competition from the Cannabis plant. Hemp fiber, which makes up about 20%-30% of hemp stalks, is used to make eco-friendly paper (Tutek & Masek, 2022). In the car business, hemp fiber is utilized to manufacture dashboards, seats, and other interior components. However, the extracted hemp oil is an eco-friendly additive to paints and varnishes (Nachippan et al., 2021; Visković et al., 2023). A wide variety of goods, including horticultural planting materials, biodegradable mulching material, building-construction components, insulating materials, hurd-produced animal bedding, plastic bio-composites, and compressed cellulose polymers, are made from hemp fiber (Kaur & Kander, 2023) for a variety of uses. In agriculture, hemp straw is utilized as fodder because of the high nutritional value it provides for livestock, especially cattle (Wang et al., 2023). Industrial hemp is of interest to a variety of businesses due to the vast ecological potential associated with the Cannabis plant and the variety of raw materials it can offer (Malabadi et al., 2023). Figure 9 exhibits some of the possible applications of the Cannabis plant.

Figure 9. Potential industries that could use the Cannabis plant as their main raw material (Tutek & Masek, 2022).

For a long time, hemp seed was a crucial staple crop (Crescente et al., 2018; Visković et al., 2023). In addition to the many critical nutrients, antioxidants, and vitamins suggested for human beings (Jeliazkov et al., 2019; Burton et al., 2022; Strzelczyk et al., 2023), it also contains 35% edible oil (Hidayet & Tolu, 2023). Whole and dehulled hemp seeds, hemp flour, hemp oil, hemp seed cake (the residue of mechanical oil extraction), hemp seed meal, hemp hulls, and hemp protein extracts and concentrates are all products derived from hemp seeds (Burton et al., 2022; Frankowski et al., 2023). Oil extracted from hemp seeds is used to make salad dressing, and the oil and the seeds themselves are both high in healthy omega-3 fats and protein (Strzelczyk et al., 2023). Figure 10 shows the methods used to make the most common varieties of hemp seed-based ingredients for food. However, CBD oil is a non-psychoactive cannabinoid chemical derived from industrial hemp, and it does not have the same addictive properties as THC (Sun, 2023). Several nations have recently legalized CBD oil due to its potential health advantages and lack of addictive properties (Fauziah & Runturambi, 2023). CBD is utilized in a wide variety of items, including carbonated water, lotions, and pharmaceutical compounds, despite claims that it has beneficial health effects (Kaur & Kander, 2023). Research potential in these subfields is promising (Jeliazkov et al., 2019).

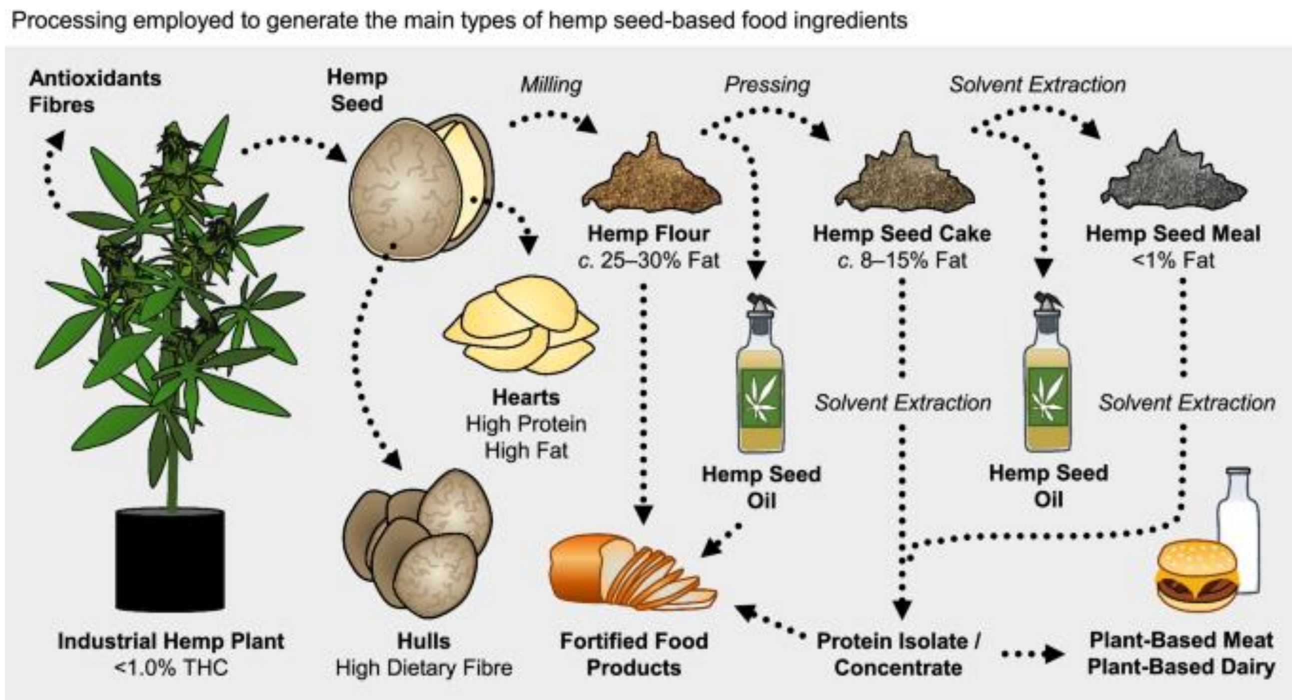


Figure 10. Processing employed to produce the most common forms of food ingredients derived from hemp seed (Burton et al., 2022).

The entire food sector, notably organic food, presents a strong rivalry for hemp-based food products. Incorporating hemp-based foods into diet is good for health (Malabadi et al., 2023). They influence cell regeneration, aging processes, cancer cell development inhibition, and immunity significantly (Fike, 2016; Sheik et al., 2023). According to research by Kaniewski et al. (2017), hemp seeds are loaded with antioxidant-rich nutrients like iron, calcium, zinc, phosphorus, magnesium, and vitamin E as well as micro and macro elements like edestin, choline, phytic acid, trigonelline, chlorophyll, lecithin, and vitamin K. Furthermore, it has a beneficial impact on the circulatory system by increasing blood vessel elasticity, enhancing blood flow, and decreasing the risk of ischemic heart disease and atherosclerosis (Tutek & Masek, 2022). Heart disease is a major problem in the developed world in the 21st century, however eating hemp cuisine can help reduce the risk of heart attack and improve the digestion process (Apostol, 2017).

Hemp seed oil has several uses in the cosmetics industry (Jeliazkov et al., 2019; Sarkar & Sadhukhan, 2023). Recently, a popular trend in the cosmetics business has been the use of hemp-derived ingredients (Naeem et al., 2023). Hemp-based cosmetics make use of hemp oil and extracts that contain regenerative, anti-aging, and anti-inflammatory ingredients. Hemp oil is classified as a "dry oil" due to its rapid absorption and lack of residual greasiness. Many companies now make cosmetics like lotions, oils, soaps, shampoos, and conditioners that contain hemp oil (Sarkar & Sadhukhan, 2023). The CBD and resin portions of hemp extract are responsible for the sedative and relaxing effects (Malabadi et al., 2023). Hemp compounds are gaining popularity in the pharmaceutical and medical industries as well. Nutritional issues, as well as post-traumatic stress disorder (PTSD), melancholy, anxiety, sleep disturbances, constipation, convulsions, and degenerative diseases like Alzheimer's, are the subjects of recent research (Pintori et al., 2023). CBD has also been studied for its potential to treat cancers in the brain, breast, prostate, skin, pancreatic, and colon (Afrin et al., 2020; Rupasinghe et al., 2020; Almeida et al., 2021; Pugazhendhi et al., 2021; Hasan et al., 2022; Nahler, 2022; O'Brien, 2022; Pennant & Hinton, 2023; Praphasawat et al., 2023; Kaur et al., 2023; Sheik et al., 2023).

Sustainability of Cannabis plant

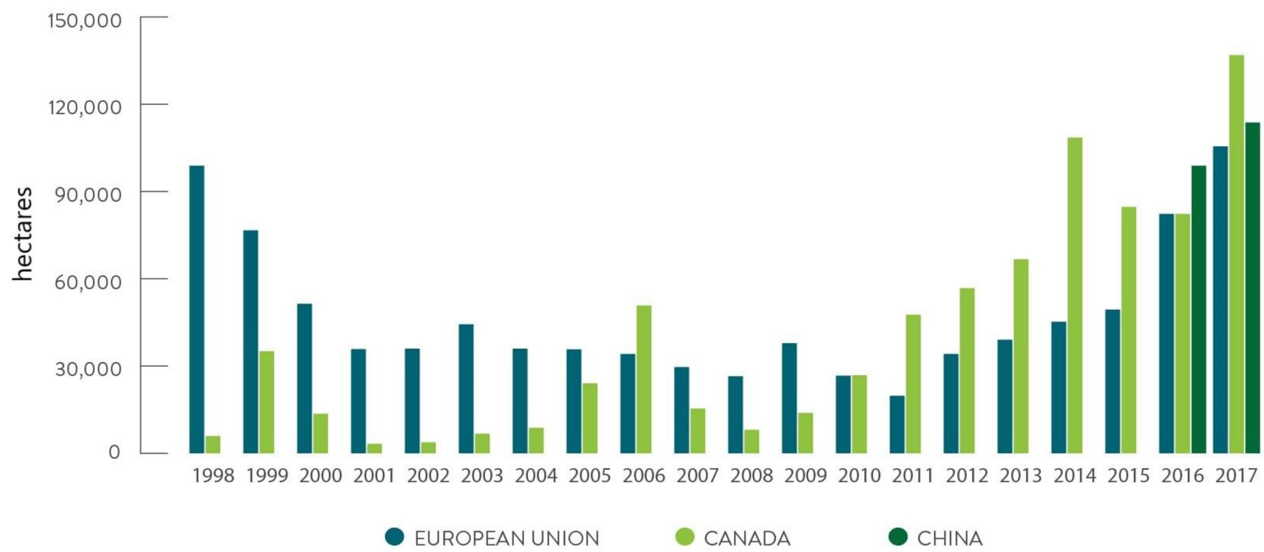
The economy, the environment, and society are the traditional cornerstones of sustainability (Raihan et al., 2022c; Raihan, 2023d). As a renewable resource, hemp is consistent with all three tenets (Kaur & Kander, 2023) of sustainability.

Economic sustainability of hemp

Sustainability in business is essential for ensuring economic sustainability, which is defined as the preservation of capital (Huang et al., 2022; Raihan & Tuspekova, 2022a; Raihan, 2023e). The economics of hemp are intricate, as they are with many other kinds of industrial plants (Kaur & Kander, 2023). Although hemp has been traded for millennia, the hemp business and its supply chain actors such as hemp producers, manufacturers, processors, input suppliers, retailers, and consumers are today experiencing significant economic difficulties (Mark et al., 2020). Three things about the Cannabis industry's finances are stable despite the industry's dynamic nature. To begin, the Cannabis plant has several potential uses and applications (Visković et al., 2023). Second, although only a fraction of the total market for these goods, sales of hemp food, clothing, toiletries, medicines, and nutritional supplements are on the rise (Kaur & Kander, 2023). Finally, corporate and policy shifts, infrastructure investment, and enhanced production methods have contributed to a resurgence in the cultivation of hemp throughout the past decade (Mark & Will, 2019), despite its dropping production worldwide due to its link with marijuana since the 1950s.

The Cannabis plant has enormous untapped potential in a wide variety of contexts. The Cannabis plant is one of the most essential plants within the bioeconomy, as seen from the agriculture sector, consumers, industry, the circular economy, and the environmental standpoint (Kaur & Kander, 2023). It is anticipated that the value of the hemp market worldwide will increase fourfold in the next years, from $4.7 billion in 2020 to $18.6 billion by 2027 (Zimniewska, 2022). Over the projection period, annual growth is anticipated to average 15.8%. Hemp-based products, for instance, seeds for oil, food, and beverages, and fibers used for technical applications, such as a composite used primarily for automotive and construction projects, but also in the textile industry, have become increasingly popular, especially in developing regions like the Asia Pacific (Crini et al., 2020). Even though the full potential of the Cannabis plant has not been tapped, the hemp business in Europe is expanding rapidly (Kaur & Kander, 2023). From 2015 to 2022, hemp production in Europe saw a 60% growth in acreage (Visković et al., 2023). Currently, it is estimated that Europe cultivates up to 25% of the world's hemp. France is the third biggest producer of industrial hemp worldwide (Kaur & Kander, 2023). France produces 60% of all EU output, next to Germany (17%) and the Netherlands (5%). Figure 11 displays the annual trend of agricultural land for hemp cultivation in the EU compared to Canada and China.

Positive economic and ecological effects on agricultural systems (Raihan et al., 2023b) are realized through the integration of agriculture and energy in "agrivoltaics," where solar modules are placed above hemp crops (Panchenko et al., 2021). The growth of the hemp food components market is being fueled, in part, by the increasing acceptance of hemp seed in the food supply (Tripathi et al., 2023). Estimates for the size of the global market for industrial hemp in 2025 range from USD 5.6 billion to USD 26.6 billion (Burton et al., 2022). The market is being pushed forward by rising textile sector demand and supportive government initiatives. In response to rising worldwide demand and decreased production costs, hemp cultivation has exploded across the Asia–Pacific area. Growth in the area is anticipated to persist through 2028 (Kaur & Kander, 2023). As a result of its growth, businesses and academic institutions are devoting more resources to creating cutting-edge goods. The possible cure for chronic diseases like diabetes is one important field of study, as is the development of biofuel and bioplastics. According to Naeem et al. (2023), the expansion of the hemp market is anticipated to be spurred by the variety of potential applications for the plant.



© 2019 New Frontier Data | Source: Hemp Business Journal: Global State of Hemp | *Nova-Institut and EIHA (European Union), Health Canada (Canada) and FOASTAT. Cultivation in China predates 2016, but historic data is sparse and inconclusive, and Hemp Business Journal did not begin tracking until 2016.*

Figure 11. Agricultural land for hemp cultivation in the EU compared to Canada and China.

About 30 nations across Europe, Asia, North America, and South America have legislated the cultivation of the Cannabis plant (Kaur and Kander, 2023). Canada dominates the global market for hemp-based goods such as hemp oil, hemp seeds, and hemp protein powder (Crini et al., 2020). Moreover, China produces about half of the world's supply of hemp fiber (Mcgrath, 2019; Sun, 2023). Seventy percent of China's hemp output is textiles, while the other thirty percent is CBD products, cosmetics, food, and vitamins (Sun, 2023). When it comes to both industrial hemp and consumer textiles, China is often regarded as an industry leader (Horner et al., 2019; Sun, 2023). Hemp has been farmed for thousands of years in China, however from 1985 to 2010 it was illegal to cultivate either the fiber or the seed. Its output has been rising quickly in recent years, and this trend is anticipated to continue (Mcgrath, 2019; Kaur & Kander, 2023). In addition, hemp is grown in many European countries, with production rising sharply in recent years (Chaowana et al., 2024). Among the many uses for hemp, hurds, organic seeds for food, hemp fiber for vehicle composites, pharmaceuticals, and the increasingly popular cannabidiol (CBD) are among the most common in the European Union (Mark & Will, 2019; Kaur & Kander, 2023). Hemp businesses can turn a profit if their hemp oils, fibers, therapeutic ingredients, and health supplements are competitive with the prices of similar products (Naeem et al., 2023). Hemp growers need to weigh the crop's profitability against that of competing crops and foreign hemp imports (Kaur & Kander, 2023).

As legal markets for cannabis develop and illegal markets continue to thrive, policymakers are tasked with regulating cannabis cultivation, distribution, and consumption in new ways. The combined economic values of legal and illicit global cannabis markets have been estimated at $214−344 billion (Wartenberg et al., 2021). Legal markets are projected to grow significantly by 2025. Still, today’s global markets remain dominated by illicit channels. While accurate estimates of cultivation area and production quantities are not feasible due to a lack of empirical data, the cultivation of the Cannabis plant has been reported in 151 countries for the period of 2010−2018, highlighting the broad geographical scope of production activities. Today, most cultivation appears to be outdoors; however, there have been indications of recent increases in indoor cultivation, particularly in the United States, Canada, Chile, Uruguay, Colombia, and Ecuador.

Environmental sustainability of hemp

The goal of environmental sustainability is the long-term conservation of natural resources for human use (Raihan & Tuspekova, 2022b; Raihan et al., 2023c). The Cannabis plant aids biodiversity, absorbs a lot of carbon, which helps slow down global warming (Raihan, 2023f), and doesn't need a lot of fertilizer or pesticides, so it's good for the environment (Dhondt et al., 2021). Hemp is either a carbon-neutral or a carbon-negative plant, based on the cultivation and processing techniques used. According to Adesina et al. (2020), Cannabis plants can take up roughly 22 tons of carbon dioxide per hectare. Through photosynthesis and subsequent bio-sequestration, high-biomass crops like hemp can store carbon in the plant's body and roots. Most of the plant's carbon is found in the stem, while only a small amount is kept in the roots and leaves (Raihan & Tuspekova, 2022c; Raihan, 2023g). A minimum of 13 tons of biochar may be produced from one acre of hemp every year (Adesina et al., 2020; Naeem et al., 2023). In addition, the extended shelf life of hemp products means that the carbon the plant stores is unlikely to be released back into the environment for quite some time (Parvez et al., 2021). Specifically, Bouloc et al. (2013) found that the lifespan of hempcrete is greater than 30 years. Moreover, plastics made from hemp could be a good way to keep polymers useful while minimizing our ecological footprint (Naeem et al., 2023). These bioplastics are low-cost biomaterials that could be used to replace petroleum products, and they are reinforced with natural fibers. The incorporation of fiber makes them more durable, recyclable, and environmentally friendly (Naeem et al., 2023).

The fibers from Cannabis plants may also be utilized for manufacturing eco-friendly paper. There is an urgent need for alternate sources because the paper industry's reliance on trees as a significant raw resource causes severe environmental degradation (Raihan & Tuspekova, 2022d; Raihan, 2023h). The paper made from the Cannabis plant is more eco-friendly and of higher quality than paper made from trees. Hemp paper is extremely eco-friendly, as it requires less water, land, pesticides, and fertilizers than conventional paper (Simiyu et al., 2022). Three to four times as many papers can be made from a single hectare of hemp as from the same acreage of forests, and the plant matures in a fraction of the time it takes trees to do so. Unlike its wood pulp counterpart, hemp paper production does not necessitate the felling of ancient trees that give off life-sustaining oxygen or the use of toxic chemical procedures. There are seven times as many opportunities to use recycled hemp paper as there are to use wood. Hemp paper made in this way doesn't need to go through a damaging bleaching procedure and the production process might utilize significantly less sulfur and acid chemicals (Tutek & Masek, 2022).

The Cannabis plant has numerous positive effects on the agriculture and environment as the plant can be used as a renewable industrial raw material (Gedik & Avinc, 2020; Tutek & Masek, 2022). The extensive root system of the Cannabis plant has been shown to have positive agronomic effects, including reduced fertilizer and pesticide consumption and increased soil oxygenation (Cherney & Small, 2016; Visković et al., 2023). It's great for using as a rotation crop as well (Barnes et al., 2023; Liu et al., 2023). The long taproot and extensive origin system of the Cannabis plant have been shown to prevent soil disintegration and improve topsoil quality when the plant is cultivated in a multi-crop system (Ranalli & Venturi, 2004; Kaur & Kander, 2023). The Cannabis plant can thrive with far less water and less chemicals than other natural fiber plants like cotton (Visković et al., 2023). Farmers who care about the environment should consider the environmental impacts of their farming practices at every stage, from planting to harvesting and processing (Raihan & Tuspekova, 2022e; Kaur & Kander, 2023). The Cannabis plant, in general, has a lower environmental impact than many other plant species, and this benefit will grow when new methods of harvesting are developed (Visković et al., 2023).

Moreover, recent research has found that hemp is exceptionally compatible with biodiversity (Kaur & Kander, 2023). The potential application of Cannabis plants in the restoration of mine shafts is intriguing and should be emphasized. The Cannabis plant is well suited for introduction as a pioneer organism in post-mining and damaged heap regions because of its excellent resilience to pests and diseases. With their ability to bind heavy metals in their system, contaminated soil can be cleansed quickly and ecologically, making way for the reintroduction of native plant and animal species (Crini et al., 2020; Visković et al., 2023). The Cannabis plant can be utilized to detoxify soil of toxic metals, such as lead, nickel, cadmium, and other harmful elements and substances as part of a bioremediation project. In addition, the Cannabis plant can produce eco-friendly materials such as carbon-sequestering polymers, heat-insulating materials, and concrete replacements that are both long-lasting and lightweight (Visković et al., 2023).

Hemp can be exploited as a feedstock for the production of heat, electricity, or fuel when the entire plant, including its low-grade fibers or hurds, is utilized (Visković et al., 2023). In order to provide heat, hemp biomass that has been compressed into pellets and then burned can be used in household wood stoves. Utilizing hemp as a crop for the purpose of producing electricity can be scaled up to produce "green" energy from generators if the biomass is converted into charcoal first. It is possible that this might be used to replace the combustion of coal in the cogeneration process, which now relies on residue from forestry and agriculture (Parvez et al., 2021; Raihan & Tuspekova, 2022f). Figure 12 below demonstrates how the Cannabis plant can be used as an amazingly effective biomass in the production of both thermal and electrical energy. Hemp-based biofuels have been recognized as one of the most effective tools for reducing dependency on imported oil while decreasing greenhouse gas emissions (Karche, 2019; Raihan & Tuspekova, 2023; Yano & Fu, 2023). This biofuel has the potential to lessen our dependence on fossil fuels and help maintain a healthy environment (Marrot et al., 2022; Raihan & Tuspekova, 2022g; Raihan et al., 2023d). Because of their large biomass and rapid growth, Cannabis plants are ideally suited to be utilized as a biofuel crop (Chaowana et al., 2023). Hemp is more effective in reducing greenhouse gas emissions than oil seed rape (OSR) and sugar beet, two crops utilized for bioenergy generation in Europe (Simiyu et al., 2022). Hemp's dual use as a biofuel does not pose an immediate threat to food security because it is not a staple food crop. Therefore, it has been determined that hemp is a superior fossil fuel alternative to OSR biodiesel and sugar beet bioethanol. Another study evaluating the bioenergy potential of several crops found that Cannabis generated more money per hectare than kenaf, switchgrass, and sorghum (Das et al., 2017). Carbon emissions and global warming may be reduced significantly if fossil fuels were replaced with biofuels (Raihan et al., 2023e) made from the Cannabis plant.

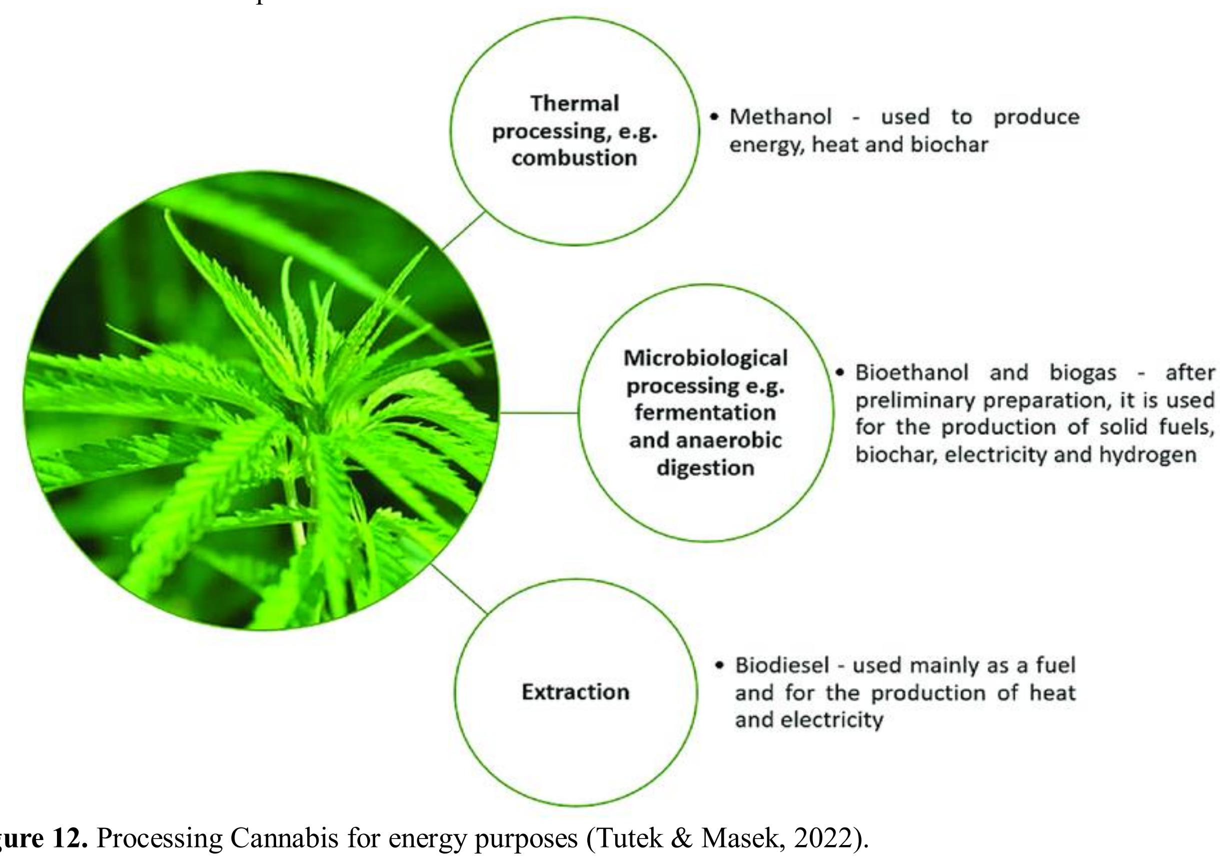


Figure 12. Processing Cannabis for energy purposes (Tutek & Masek, 2022).

Social sustainability of hemp

Investing in and providing for society's essential services and infrastructure are examples of social sustainability. It can be fostered within a society to improve communication, self-control, and morality (Kaur & Kander, 2023). Nurturing principles, interactions, and socialization are all aspects of human sustainability that are interconnected with social sustainability. The economic and ecological effects of the Cannabis plant provide evidence of its social sustainability. As a result of its many applications, it has gained widespread acceptance and contributed significantly to the economies of many nations.

The capability to establish regional and local supply chains is fundamental to the societal significance of industrial hemp as a raw material. There are two main drivers that promote regional distribution networks. First, because of their low density, bales of farmed hemp stalks are expensive to ship. Second, different climates and soil types produce different results when growing Cannabis. There is an incentive for processing and manufacturing hemp close to its source farms because of the economic benefits associated with doing so. The economic worth of regional produce increases as it is traded on an international or national level. When compared to shipping raw resources to distant sites for processing, producing higher-value goods and materials locally yields better economic benefits for the community's farmers and local manufacturers (Wagner et al., 2022). These motivators promote social sustainability by keeping money in the area.

Despite encouraging findings from preliminary research, determining the social sustainability of the Cannabis plant as a renewable industrial raw material is still in its beginning, and more study is needed to improve quantify, and evaluate the effects of cultivating and producing industrial hemp and processing hemp-based products.

Industrial hemp and sustainable development goals

The 17 sustainable development goals (SDGs) of the United Nations (UN) aim to end poverty, improve health and education, decrease inequalities, safeguard the environment, and boost economic growth by 2030 (Raihan et al., 2023f). All 193 member states agreed to the SDGs, which include 169 targets and global indicators to guide national, state, and municipal government priorities and collaborations. Sustainable growth balances current and future requirements (Raihan & Tuspekova, 2022h). Many SDG indicators recur across targets because complex challenges like health, equity, and climate change demand multidisciplinary solutions. In a contentious political atmosphere, the SDGs are popular worldwide and offer a template for galvanizing local assets to transform the globe (Raihan & Tuspekova, 2022i). Corporations, institutions, and non-governmental organizations are incorporating the SDGs into their business plans. Hemp industrialization is transforming healthcare, agriculture, energy, banking, technology, policymaking, and more. The growing industrial hemp and marijuana sector is improving epilepsy, multiple sclerosis, chronic pain, Post Traumatic Stress Disorder, and other treatments globally. As an alternative crop for paper, textiles, plastics, construction materials, and other green technologies that regenerate biodiversity, the Cannabis plant helps combat climate change. The global market potential for industrial hemp surpasses that of medical and recreational marijuana because of the wide range of applications associated with the Cannabis plant. The adaptability of the Cannabis plant is exemplified by its inclusion in the SDGs, which also contribute to dispelling misconceptions about the plant. The SDGs provide a framework for enhancing education, legislation, research, and partnerships to effectively promote hemp as a vital crop that offers multiple societal advantages. The manifold advantages of industrial hemp have led to the identification of 54 hemp-related SDG targets, aimed at enhancing multi-sectoral collaboration, research, and education on a global scale. The links of hemp across the SDGs are depicted in Figure 13.

Figure 13. The association of industrial hemp with the SDGs.

No poverty (SDG 1)

Hemp has been recognized for its agricultural and sustainable food/energy potential for thousands of years across several continents and continues to be accepted by contemporary societies worldwide. Wide-scale hemp growing, and related sectors may quickly eliminate large amounts of poverty at the national and local levels in three ways that support all other goals. First, dramatically reducing unsustainable energy and resource-based conflicts worldwide; second, increasing access to locally/regionally-grown healthy and nutritious foods for humans and livestock—hemp is naturally organic and superior to corn and soy; and third, creating a carbon-neutral farming, processing, manufacturing, and consumption infrastructure with huge economic and ecological benefits.

Cannabis plant cultivation worldwide could help resolve issues over fossil fuels. Afghanistan, called the "Graveyard of Empires" for its history of thwarting energy-dependent colonial empires, is one example. It is also one of the poorest nations worldwide. Cannabis plants could replace opium, lowering drug use. This market could also contribute to regional poverty since farmers make minimal revenues. Cannabis plant cultivation nationwide benefits the population economically and reduces the power of extreme Islamic organizations and invading empires. Afghan farmers' desire to grow hemp dates back at least ten years, when global demand for hemp began to rise before the 2018 Farm Bill in the US. The U.N. Office on Drugs and Crime reported a 63% increase in opium cultivation in Afghanistan in 2017, hitting a record 328,000 hectares. A large fiber and seed-hemp crop in Afghanistan would undoubtedly make the country more peaceful, productive, and rich. This would enable self-sufficiency through the consumption of nutritious hemp seed-derived food, relieving a large percentage of the people from conflict and scarcity. The same goes for impoverished Southern Asian and sub-Saharan African communities. Malawi, one of the poorest nations, is another example. The region can support hemp farming, new industries, and sustainable resource development. These nations might become major hemp producers with UN support. Cannabis plants could replace opium farms in Afghanistan, tobacco plantations in Kentucky, and the global demand for petroleum, valuable minerals, and petroleum-derived products. Hemp planting at the national and corporate levels in industrialized nations like the US could minimize the need for historical incursion into Afghanistan and other countries. Hemp was the world's largest industrial crop until the late 19th century and hemp production was reduced mostly due to government mismanagement. Over numerous decades, incorrect propaganda has shaped the current resource and energy environment, requiring significant efforts to repair the damage.

Zero hunger (SDG 2)

Hemp, as a sustainable and renewable resource, possesses the capacity to offer substantial quantities of nourishing and healthful food products. These include hemp seed protein, which exhibits variable potencies based on processing methods, as well as hemp seed milk, hemp seed oil, hemp hearts, and hemp seed flour. Using these ingredients, individuals can create or enhance a wide range of culinary dishes, including bread and butter. The diet exhibits a commendable balance of nutrients and is deemed suitable for both human and cattle consumption, hence enhancing the nutritional value of animal-derived goods such as eggs and milk. The production of this food has the potential to yield cost savings and enhance nutritional value, thereby offering a viable solution in the face of climate change-induced disruptions to existing food supplies. Hemp possesses the potential to significantly contribute to the mitigation of worldwide malnutrition and hunger rates. The plant exhibits a high degree of manageability and may be efficiently processed into food products with low reliance on external machinery, mostly decorticators.

Good health and well-being (SDG 3)

The consumption of healthier food, particularly plant-based protein as a substitute for animal protein, the adoption of sustainable homes, the integration of hemp fiber in the textile industry to promote green practices, the reduction of resource-driven conflicts, and the stimulation of economic activity collectively contribute to the enhancement of human and animal health as well as overall well-being. Every aspect of the Cannabis plant, including the stalk, flower, seed, root, and stem, contributes to the enhancement of human and animal health and well-being. These components are free from any adverse side effects, psychoactive properties, or detrimental environmental consequences typically associated with traditional resources or their absence. Hemp possesses unparalleled potential in reducing childhood death rates, surpassing any other available resource on the planet. Research has demonstrated that cannabis possesses a range of therapeutic advantages, encompassing the alleviation of pain, mitigation of anxiety, and enhancement of sleep quality. Consequently, the cannabis sector has the potential to

contribute to SDG 3 through the production of cannabis-derived goods that are of superior quality and safety, thus enhancing individuals' health and overall well-being.
Within the framework of SDG 3, four targets pertaining to hemp and marijuana have been delineated. These targets encompass the prevention and treatment of substance misuse, ensuring access to safe and cheap vital medications, promoting research and development in the field of medicinal applications, and augmenting the allocation of financial resources and recruitment efforts within the health workforce. SDG 3.5 aims to address the issue of substance misuse through prevention and treatment measures. This statement underscores the necessity for expanded study on marijuana and hemp, since cannabis has potential alternative applications in comparison to opioid medicines, alcohol, and other addictive substances, with reduced risks of overdose and addiction. According to the study conducted by Lucas et al. (2013), a significant proportion of participants, specifically 41%, reported using marijuana as a substitute for alcohol. Additionally, 36% of participants indicated that they used marijuana as a substitute for illicit substances, while a substantial majority of 67% reported using cannabis as a substitute for prescription medicines.

Quality education (SDG 4)

With regards to facilitating the provision of high-quality education to the global population, one significant advantage of hemp pertains to its ability to generate and allocate economic resources at the local, regional, and national scales. It is evident that subject to the discretion of nation-states and regional authorities, this economic development has the potential to enhance education on a broad scale.

Gender equality (SDG 5)

Hemp, particularly in the form of hempcrete, presents itself as a significantly lighter construction material compared to conventional options such as concrete or steel. When cultivating hemp, a significant amount of physical power is not necessary. When it comes to the processing of fiber and seed, it is necessary to employ machinery or rely on individuals with significant physical strength in places where mechanical assistance is limited. This is owing to the substantial muscular power and endurance demanded by such tasks. Subsequently, there exists a comparable level of opportunity in many sectors such as textiles, house and building construction, food production, and an array of industrial industries including a multitude of consumer goods. A similar argument may be made about the establishment of extraction centers aimed at supplying communities with hemp extracts and dietary supplements specifically designed for female populations. Hence, the hemp industry has the potential to promote gender equality through the creation of employment opportunities for individuals of men and women within the hemp sector.

Clean water and sanitation (SDG 6)

Certain varieties of Cannabis plants are selectively developed for the purpose of phytoremediation, a technique that involves employing plants to extract contaminants from soil, water, or air. In the pursuit of achieving SDG 6, the cultivation of hemp presents a promising solution. This versatile plant possesses the unique ability to effectively address environmental contamination by virtue of its extensive root system. Through this mechanism, the Cannabis plant is capable of absorbing and sequestering heavy metals such as nickel and lead from the soil. Consequently, it serves as a regenerative cleanup crop that can be cultivated in proximity to hazardous materials. Hemp and cotton exhibit comparable characteristics; however, hemp seeds are more cost-effective and demand less water, fertilizer, and pesticides. Consequently, this leads to a substantial reduction of 77% in agricultural production costs, promoting the achievement of SDG 6.3, which aims to reduce pollution, as well as SDG 6.4, which seeks to enhance water-use efficiency across various sectors. In addition, diets based on hemp seeds would reduce the environmental impact of human waste and animal dung on sewage systems.

Affordable and clean energy (SDG 7)

The primary benefit of industrial hemp resides in its capacity to generate carbon-neutral ethanol and biodiesel derived from hemp seeds. The application of hemp biofuel possesses the capacity to substantially diminish the carbon emissions linked to human endeavors (Raihan et al., 2022d), all the while offering accessible and environmentally friendly energy sources. Hence, the utilization of hemp biofuel holds significant promise in enhancing energy efficiency, mitigating energy crises, and addressing environmental pollution concerns by substituting fossil fuels and thereby reducing emissions.

Decent work and economic growth (SDG 8)

The hemp supply chain in the 21st century is extensive and has yet to be fully investigated. It encompasses various stages, including large-scale farming, initial retting, advanced processing, and manufacturing of numerous consumer-based products. Additionally, the Cannabis plant has the potential for food supply, energy production, and livestock feed, which could reduce the need to clear rainforests. Consequently, the cultivation and utilization of hemp have the potential to generate a substantial number of environmentally sustainable manufacturing employment across both developing and industrialized nations. The legalization of the Cannabis plant has the potential to enable governments to harness hemp as a means of generating a substantial number of employment opportunities, thus fostering the development of numerous sectors within the global economy. SDG 8 can be accomplished by establishing legal and controlled markets for cannabis, facilitating job creation, and tax generation, and fostering entrepreneurial prospects for small-scale enterprises. The legalization of hemp production in Thailand has engendered novel prospects for farmers, given the versatile applications of hemp in several industries, including health and wellness, textiles, paper, and construction materials. Through the cultivation of hemp, local farmers have the opportunity to enhance the diversity of their crop portfolio, augment their revenue, and make a valuable contribution to the overall economic growth of the nation.

Industries, innovation, and infrastructure (SDG 9)

Hemp possesses the potential to serve as a raw material for the production of more than 20,000 consumer goods. Moreover, the transition from traditional petroleum-derived commodities such as wood and plastic to hemp is poised to give rise to a profoundly transformative era. In the context of developing nations, the utilization of a highly adaptable multi-crop like the Cannabis plant holds the potential to yield a wide range of essential resources such as housing, clothing, medicine, and construction materials during the initial phases. Despite the federal legalization of industrial hemp in the United States, a significant number of prominent firms, banks, and credit unions are hesitant to involve themselves with this plant. This reluctance stems from the ambiguous banking regulations and potential tax consequences associated with engaging in activities related to industrial hemp. SDG 9.3, which pertains to the target of enhancing access to financial services, emphasizes the necessity of implementing appropriate measures to facilitate the establishment of the legal hemp business.

Furthermore, the hemp and cannabis sectors have the potential to contribute to SDG 9 by fostering advancements in various aspects including cannabis production, product innovation, applications of cannabis, and distribution. This phenomenon has the potential to propel technological progress and generate novel prospects for both enterprises and individuals. The cannabis sector in Thailand has garnered interest from international companies, leading to foreign investments in the nation. This influx of investments has not only generated employment possibilities but has also contributed to the overall economic growth and potential of the country. The projected growth rate of Thailand's cannabis industry is estimated to be approximately 15% per year from 2023 to 2025. It is anticipated that the market value will potentially reach 1.17 billion USD by the year 2025.

Reduced inequalities (SDG 10)

Hemp, as a resource, confers empowerment upon individuals due to its environmentally friendly nature, cost-effectiveness, ease of utilization, and ability to offer equitable opportunities. SDG 10 provides a robust framework for effectively mobilizing resources and establishing the necessary infrastructure for the development of the hemp industry, thereby promoting and advancing equality. The two specific targets outlined under SDG 10 are as follows: Target 10.1 focuses on the objective of achieving income growth, while Target 10.2 aims to promote social, economic, and political inclusiveness. In section 10.3, the target is to abolish laws that promote discrimination. In section 10.4, the aim is to establish fiscal, wage, and social protection measures that can facilitate the utilization of hemp's potential to address inequality issues and include comprehensive solutions into policies, programs, and partnerships involving multiple sectors.

Sustainable cities and communities (SDG 11)

The utilization of hemp-based construction materials has the potential to contribute to the development of sustainable cities and communities. Hempcrete bricks are characterized by their reduced weight compared to conventional cinder blocks and their exceptional durability, enabling them to endure for extended periods of time. Without considering any other factors related to the adoption of hempcrete, it can be argued that its implementation alone has the potential to significantly enhance the health, cleanliness, and sustainability of cities and communities. In addition, the growth of the Cannabis plant has the capacity to sequester carbon, presenting the possibility of obtaining Carbon Credits. Furthermore, the establishment of legalized and well-regulated markets for cannabis has the potential to contribute to a decrease in crime rates and foster the creation of safer and more stable communities.

Responsible consumption and production (SDG 12)

The initiation of responsible consumption can be attributed to the utilization of the Cannabis plant. Hemp possesses the potential to significantly influence both the environment and human society due to its multifaceted applications as a food source, textile material, energy provider, construction resource, and constituent of biodegradable products. The broad adoption of major consumer and industrial markets has the potential to significantly mitigate economic, environmental, and social problems associated with hemp. The production of hemp products, encompassing various components such as seeds, stalks, and flower-based extracts, can be effectively achieved using carbon-neutral and environmentally sustainable methods. The implementation of this practice is currently underway on a limited scale globally. SDG 12 encompasses various targets, including the promotion of sustainable production techniques (SDG 12.1), which necessitates the adoption of corresponding policies by enterprises (SDG 12.6) and the reduction of waste (SDG 12.5). Hemp offers a viable means of fostering a more environmentally sustainable economy. Hence, it is imperative for governments, academia, and corporate partners to collaborate and engage in technological advancements to facilitate the industrialization of hemp.

Climate action (SDG 13)

The hemp industry has the potential to contribute to the achievement of SDG 13 by adopting sustainable and environmentally friendly practices in their production processes. This can be accomplished through the implementation of organic farming methods and the reduction of water and energy consumption, particularly when compared to the cultivation of alternative crops like cotton. Furthermore, it is imperative for the industry to actively support and invest in research and development endeavors aimed at the creation of novel technologies capable of effectively curbing carbon emissions and mitigating the adverse consequences of climate change (Raihan, 2023i). The Cannabis plant has been found to contribute to mitigating the adverse effects of global warming and climate change by engaging in carbon sequestration, mitigating desertification, substituting fossil fuels with biofuel derived from hemp, and curbing deforestation to accommodate the growing agricultural needs to meet societal demands for food, fiber, and other commodities.

Life below water (SDG 14)

The integration of the hemp supply chain has several beneficial outcomes, including reduced reliance on fish protein and fish oil aminos, coastal revitalization, diminished plastic pollution in oceans, and decreased petroleum use. The Cannabis plant has the potential to significantly mitigate the emission of anthropogenic carbon dioxide into the atmosphere, as well as lessen the discharge of detrimental pollutants into the ocean resulting from agricultural practices such as cotton cultivation, deforestation, topsoil degradation, livestock farming, and other agricultural activities. The utilization of hemp-based biodegradable products has the potential to mitigate marine pollution and safeguard underwater biodiversity through the substitution of plastic materials. Hemp has the potential to serve as a substitute for petroleum-based energy and its derivative products in the context of offshore drilling.

Life on land (SDG 15)

The hemp industry contributes to environmental conservation efforts. Cannabis plant, as a regenerative crop, possesses the capacity to rebuild soil organic matter and facilitate the restoration of deteriorated soil. This characteristic aligns with the targets outlined in SDG 15.3, which aims to rehabilitate soil and land that has undergone degradation. Certain varieties of Cannabis plants are selectively developed for the purpose of phytoremediation, a technique that involves employing plants to extract contaminants from soil, water, or air. Cannabis plant possesses extensive root systems that effectively infiltrate the soil, facilitating the absorption of heavy metals such as nickel and lead. Consequently, the Cannabis plant serves as a regenerative crop capable of remediating contaminated areas, even when cultivated in proximity to hazardous substances.

Furthermore, the Cannabis plant relies solely on wind for pollination and exhibits a notable capacity for generating a substantial quantity of pollen. This characteristic contributes to the establishment of an ecosystem that is very appealing to various bee species, which plays a vital role in promoting sustainable agricultural practices (O'Brien & Arathi, 2019). Although the Cannabis plant does not generate nectar, its blooms, which are abundant in pollen, contribute to the ecological significance of the Cannabis plant as a crop. Hemp, as a sustainable crop, exhibits the advantageous characteristic of necessitating minimum water usage, positioning it as an ecologically conscious substitute for conventional crops. Hemp has the capacity to yield three times more metric tons than cotton, aligning with the target of SDG 15.3, which aims to restore life on land (Schumacher et al., 2020). In addition, the cultivation of the Cannabis plant has the potential to contribute to the preservation of wildlife biodiversity through its ability to mitigate unlawful poaching and hunting. This is due to the economic incentives derived from hemp cultivation, which divert the attention of poachers and hunters away from capturing rare and endangered animals.

Peace, justice, and strong institutions (SDG 16)

The implementation of a program aimed at releasing individuals convicted of minor drug offenses from incarceration and integrating them into various sectors of the emerging hemp industry can perhaps contribute to the cessation of the worldwide campaign against illicit narcotics. These equity programs can be improved by integrating SDG targets 4.4: relevant skills for employment and entrepreneurship; SDG 4.5: decent work; SDG 8.3: job creation and entrepreneurship; SDG 11.a: strengthen national and regional development planning, and SDG 16.6: develop accountable and transparent institutions at all levels. The governments can also create hemp education programs for everyone, especially at-risk youth around how hemp can be used to day-by-day build a better future for all intelligent life on earth!
Furthermore, SDG 16.6 targets the development of accountable and transparent institutions at all levels. The hemp industry has the potential to contribute to the achievement of this objective by establishing diverse industries and organizations with several purposes, for example:

- Hemp agronomics and farming
- Hemp fiber applications in the automotive industry
- Hemp biofuel applications throughout human society
- Hemp business entrepreneurship
- Hemp medicine and cannabinoid-based science
- Hemp fiber applications in residential and commercial construction
- Hemp food, nutrition, and herbal supplementation
- Hemp bioplastic applications
- Hemp as part of societal digital transformation technologies
- Hemp musical instruments and spaceship components

Partnerships for the goals (SDG 17)

Various stakeholders, including farmers, entrepreneurs, startups, corporations, politicians, NGOs, and local businesses, derive advantages from the utilization of hemp. SDG 17 outlines a strategic framework for harnessing the untapped potential of hemp and sets specific objectives to be achieved. SDG 17.14 emphasizes the need to strengthen policy coherence, while SDG 17.16 highlights the importance of establishing multi-stakeholder partnerships. Additionally, SDG 17.17 underscores the significance of successful collaborations between the public sector, commercial sector, and civil society. These three targets provide valuable frameworks for exploring potential avenues to expand the industrialization of hemp. The integration of the 54 SDGs into the business plans of the industrial hemp and cannabis industry is recommended. This industry, being in its early stages, could actively participate in shaping collaborations across several sectors and contribute to the advancement of sustainability.

Conclusion

This review study delves into the exploration of the potential and historical magnitude of the Cannabis plant in human culture. Additionally, this study illustrates the associations of the Cannabis plant with the SDGs. Using the Cannabis plant as a renewable raw material, this study concluded that hemp has the potential to positively improve product sustainability, which has contributed to its rapid rise in popularity. Many people admire the Cannabis plant for its many benefits, including its compatibility with nature, its potential as an economic venture for local business owners, and its usefulness as a cover crop for small-scale farms. The majority of the study's findings on hemp's sustainability related to its ecological effects, followed by its economic impact. However, the social repercussions and social sustainability are poorly understood. This may be because research methods for assessing societal effects in terms of sustainability and life cycle assessment (LCA) are still developing. However, new research into circular economies is beginning to consider the societal effects of these systems alongside the environmental and financial ones. In addition, the future demand for the Cannabis plant will be determined by the pricing of hemp products, which in turn will be determined by customers' perceptions of the health and environmental benefits of using hemp products. Research potential exists in these areas because neither a worldwide organization nor the federal government currently gathers worldwide information on the cultivation of hemp or its impact. The Cannabis plant has a lot of potential in terms of sustainability, despite the current gaps, because it naturally fits into every aspect of sustainability and SDGs. As such, it satisfies the demand for a sustainable raw material alternative and provides a possible response to the critical climate problem. The full potential of this extremely promising multi-purpose crop cannot be realized without more investigation into appropriate agronomic production practices for greater productivity and sustainability.

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