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Potential of Establishing Industrial Hemp Value Chains in Northern Australia

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Abstract

Globally, industrial hemp offers consumers over 25,000 value-added products that are valued at approximately US$4.2 billion of current market value and likely to surpass US$26.6 billion by 2025. In Northern Australia, the industrial hemp sector is at infancy stages of development. Given the suitability of certain Northern Australia's geographical zones in terms of soil, water, and climate, a study was conducted to identify potential industrial hemp value chains. Probable value chains were developed by characterizing the production to market segments of the supply chains to determine the return on investment and analyzing the capacity of the stakeholders in terms of communication and relationships. Consequently, the strengths, weaknesses, opportunities, and threats (SWOT) of the developed value chains were analyzed. This study collected data from three complementary sources that included review of the literature, results of variety trials evaluation conducted in Northern Australia, and survey of hemp industry stakeholders. Results suggested that Northern Australia offers conducive growing conditions for hemp that allows for the development of three value chains including seed, fiber, and silage. The research recommended ongoing investment in the industry through engagement of public and private sector while focusing on further establishment of the industry.

Keywords

Fibre, grain, industrial hemp, Northern Australia, silage, value chain

1. Introduction

Industrial hemp (Cannabis sativa L) refers to the plant with low tetrahydrocannabinol (THC) levels in its flowering heads and leaves, generally below 1% depending on region and country (Zhao et al., 2021). In Australia, each state and territory have set their own THC levels within hemp plants under relevant Australian state and territory drug laws (Gleeson, 2019; MacPhail et al., 2021). Hemp varieties whose seeds contain more than 0.5 % THC content are not allowed to be planted therefore, only seeds with less than 0.5 % THC levels can be used for commercial or research purposes (Government of Western Australia, 2020; Northern Territory Government, 2020; Queensland Government, 2022).

Hemp is a high yielding and fast-growing annual crop grown for its fiber and seeds (Crini et al., 2020). Hemp offers a wide range of sustainable applications across industries, making it a valuable crop (Martinez et al., 2023). Its long 'Bast' fiber is used in textiles, paper, ropes, and bioplastics, while the shorter 'Hurd' fiber finds applications in animal bedding and in creating "hempcrete" for construction (Marsh, 2003; Andre et al., 2016). Additionally, hemp fibers are used in various niche applications, including ethanol production, acoustic and thermal insulation, bio-composites, and a range of other products (Ahmed et al., 2022). Hemp grains are used for food and oil production (Williams, 2019).

Hemp's global expansion is driven by its versatility and adaptability to emerging new applications (Sorrentino, 2021). Industrial hemp global market was at US$4.13 billion in 2021 and is projected to grow annually at 16.8% from 2022 to 2030 and therefore expect to hit a high US$10 billion (Grand View Research, 2022; Yano and Fu, 2023). Globally, around 30 European, Asian, North American, and South American countries lawfully produce hemp (Yano and Fu, 2023). The top world markets leading in hemp production includes Canada, China, and the European Union (Kaur and Kander, 2023). In Australia, hemp prominently grown in Tasmania, New South Wales (NSW), Queensland, Western Australia (WA) and Victoria. Tasmania has stood out as the primary state for hemp production, with around 1600 hectares planted during the 2019-20 growing season and a farm gate value of seeds AU$4.5 million (Industrial Hemp Taskforce Victoria, 2020; Gordon and Brodrick, 2020).

Industrial hemp typically has a growth cycle of four to six months, mainly dependent on genetics, management, and environmental factors (Biggs et al., 2016). Though it's usually dioecious, hemp breeding programs have led to the development of monoecious varieties that are currently worldwide (Clarke and Merlin, 2016). Hemp is adaptable to tropical and subtropical conditions though it is traditionally a temperate crop, which makes it suitable to be grown in diverse environments (Wimalasiri et al., 2021). Although it can yield satisfactorily with minimal care, achieving good results requires best management practices including good fertilization, adequate irrigation, and pest and disease management (Sunoj et al., 2023). Northern Australia's warm, frost-free, and moist conditions has made it well-suited for hemp, but selecting the right hemp genotype and end-use product is crucial for success of a new industry (Biggs et al., 2016).

In the context of hemp cultivation in tropical and subtropical regions, such as southern Europe and China, newly developed varieties show high fiber quality, increased yields, and better control over flowering behavior. Moreover, in those low latitude areas late maturing hemp varieties were identified as high yielding varieties (Salentijn et al., 2015).

In Northern Australia, establishing industrial hemp value chains has the potential to provide economic, environmental, and societal benefits that makes it an attractive option for the stakeholders. Despite increased global market size for industrial hemp end products, developing value chains for all or many of them for the Northern Australia hemp industry is challenging. Additionally, there is little research on the potential of hemp value chains in tropics (Horner et al., 2019). Therefore, this study was conducted to develop a decision-making tool tailored for Northern Australia industrial hemp value chain stakeholders in making informed decision regarding investment in hemp production and trade.

2. Materials and Methods

To determine the potential of industrial hemp production and trade in Northern Australia, three complimentary sources were selected for data collection:

1. Review of literature: A review of literature on Northern Australia industrial hemp value chains was sourced from scientific databases, Google Scholar and the professional networks involved in research of industrial hemp products supply chains in Australia and internationally. Given the limited information specific to industrial hemp in the Northern Australia's context, recent literature related to other agricultural value chains in Northern Australia was also examined. Additional information was collected on hemp value chains to facilitate comparative analysis.
2. Industrial hemp variety trials: The primary objective of the Industrial Hemp Variety Trials (IHVT), contracted by Emerging Industries Program of AgriFutures Australia, was the evaluation of industrial hemp seed varieties at a network of trial sites in several locations in Australia. Katherine Research Station (KRS), Department of Industry Tourism and Trade (DITT), Northern Territory (NT) is one of the trial sites for this project. This trial commenced at KRS in 2022 March. Information on cultivation and agronomy of hemp was collected from this ongoing trial (https://agrifutures.com.au/related-projects/).

3. Stakeholder survey: A survey was conducted using a structured questionnaire by creating a set of questions to be used for interviewing stakeholders. The survey primarily consisted of respondents from southern WA, where hemp grain industry is relatively well established and inputs from potential stakeholders in the Northern Australian hemp industry. Potential interviewees were selected based on the following criteria.
    - Hemp biomass producers who usually grow more than 2 ha of hemp annually.
    - Producers who had established their own value chains, either within larger businesses utilizing industrial hemp or by processing and marketing products through physical shops or online platforms.
    - Researchers and agronomists from government-based organizations.
    - Service providers, including seed importers and suppliers of various inputs, who offered information or other tradeable commodities in the industrial hemp sector.

Under each value chain, inbound logistics (e.g., seed sources, fertilizers, irrigation, pest, and disease management etc.), farm operations (harvesting, outbound logistics (transport etc.), market and sales were discussed.

A SWOT analysis as well as an assessment of capacity, communication, and relationship factors were also conducted for all value chains based on the information sourced from the above three methods.

3. Results and Discussion

3.1 Potential value chains established

Three potential value chains were developed based on information gathered from the above methods, including grain/seed, hemp fibre and silage value chain for stock feed. Finnan and Styles (2013) concluded that hemp is a more sustainable annual energy crop for climate and energy policy, where they highlighted the potential uses of the crop that aligned with the value chains this study has reported.

Grain/seed value chain

Hemp became legal as a food product in November 2017 in Australia (Queensland government, 2021). However, state and territory hemp industries developed at various rates thereafter. Hemp seeds are high in nutrition and contain 30-35 % protein, 35-40 % essential fatty acids by weight and rich in Omega 3 and 6 (Callaway, 2004). Recent regulatory changes in Northern Australia (e.g., in the NT) have allowed use of hemp seeds for different value chains (Fig. 1) (Northern Territory Government, 2020).

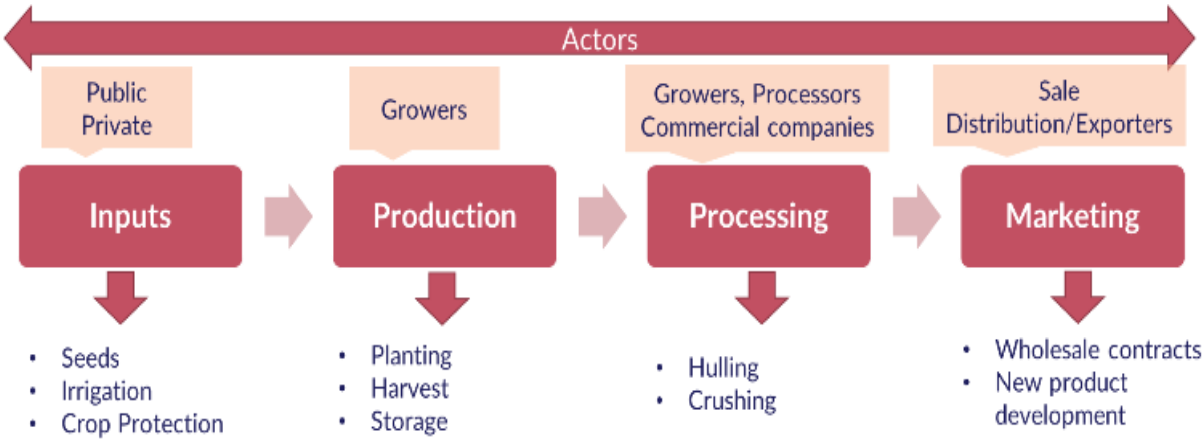

Fig. 1. Overview of potential industrial hemp grain/seed value chain

Inputs

Seed companies (public and private) are important actors in industrial hemp value chains. Information on selecting of seed varieties with good grain yield potential, low THC levels and non-grain shattering potential is critical for them. Storage of seed and preservation, and packaging methods, are identified to have significant impact on viability at sowing (Suriyong et al., 2015)

Just like any other crop, hemp nutritional requirements must be met for it to grow normally. Therefore, it is paramount to select a location with good and fertile soils meeting the nutritional requirements of the crop for its production and apply fertilizer to supplement limiting elements (Adesina et al., 2020)

Depending on environmental condition and management practices, irrigation of 3-6 ML water/ha/crop cycle (taken from the widely quoted Australian range) is recommended. This application usually gives the crop 1.125 ML/month of water that is required to grow hemp (Chris & Zurbo, 2008).

Hemp has proved to be highly sensitive to some herbicide residues in the soil (Humphries et al., 2019). However, there are few registered herbicides for hemp in Australia, e.g., Bromocide selective herbicides (Australian Pesticides and Veterinary Medicine Authority, 2023). *Helicoverpa spp*. are major pest of hemp crop, which can be controlled by in-season sprays of Chlorantraniliprole at flower bud stage and Dimethoate sprays is needed at grain fill stage to control vegetable bug (Kumar, 2022). Exotic and established pests that can affect hemp cultivation in the NT are listed in the pre-feasibility study of Cultivation of industrial Hemp in the NT (Peachy, 2021).

The need for suitable equipment and machines for input application, harvesting and processing will be a challenge to the Northern Australia farmers, although the equipment innovation will lower the cost of investment. However, most of the equipment's needed for hemp crop harvesting is similar equipment's' used for flax (Pari et al., 2015).

Production

Seeding of hemp for grain can be accomplished with a standard grain drill using either conventional tillage or no-till (Kaiser et al., 2015).

Cannabinoid testing of flower heads and leaves should be conducted mid-season or before harvest. If pre-harvest testing indicates THC levels above 0.5 % then growers will have to destroy whole crop that can results to huge loss (Government of Western Australia, 2020; Northern Territory Government, 2020; Queensland Government, 2022).

Hemp seed maturity is indeterminate, and the crop is harvested when 60-70% of seeds are hard and ripe (Kamat et al., 2022; Kreuger et al., 2011). Late combining of grain than optimal time generally results in lower quality seed, losses due to shattering, and possible bird damage. Grain should be dried to below 12% moisture for storage and at 8 to 10% for long-term storage (Kaiser et al., 2015). In Australia, conventional combine harvester can take seed off, but only after adjusting height of cutter bar to its maximum level. In order to improve efficiency of the grain harvesting operation, harvest timing is very vital due to nonuniform seed maturity (Lisson et al., 1995).

Processing

In Northern Australia, primary aim for producing hemp grain could be for human consumption. Prior to processing, hemp seeds are dried and cleaned properly. Hulling and crushing are the two common processing operations for industrial hemp seeds (Callaway, 2004).

Crushing process produces hemp seed oil and seed cake. The hemp seed cake is a rich source of protein and can be used as protein source for animal or human consumption (Horner et al., 2019).

Marketing

One of the most critical issues with the Northern Australian hemp industry is lack of market for products. This may discourage farmers from growing hemp.

The Australian hemp industry must take action to foster potential markets to encourage grain-related markets in Northern Australia, especially in the Northern Territory (NT). Furthermore R&D investment on market studies are necessary to establish the hemp industry in Northern Australia.

Fibre value chain

Industrial hemp fibre production in Australia is mainly focused on hurd fibre, whereas bast fibre is not being used anywhere in the industry (Stubber, 2022, pers. comm.).

Northern Australia has the potential to produce different hemp fibre value chains (Fig. 2). Hemp hurd fibre which has multiple uses, including production of hempcrete blocks for construction industry, weed mats, hydroponic mats, horticultural substrate, and anti-erosion blankets is key area of interest (Andre et al., 2016).

The utilization of hemp fiber in hempcrete production, for constructing slab walls or building blocks appears to be a promising value-added process and a cost-effective alternative to traditional building materials in the northern region of Australia (Barbhuiya et al., 2022).

Animal bedding and fibre extraction for textile industry requires complex operations hence not recommended as starting point in Northern Australia. However, fibre export has considerable future opportunity.

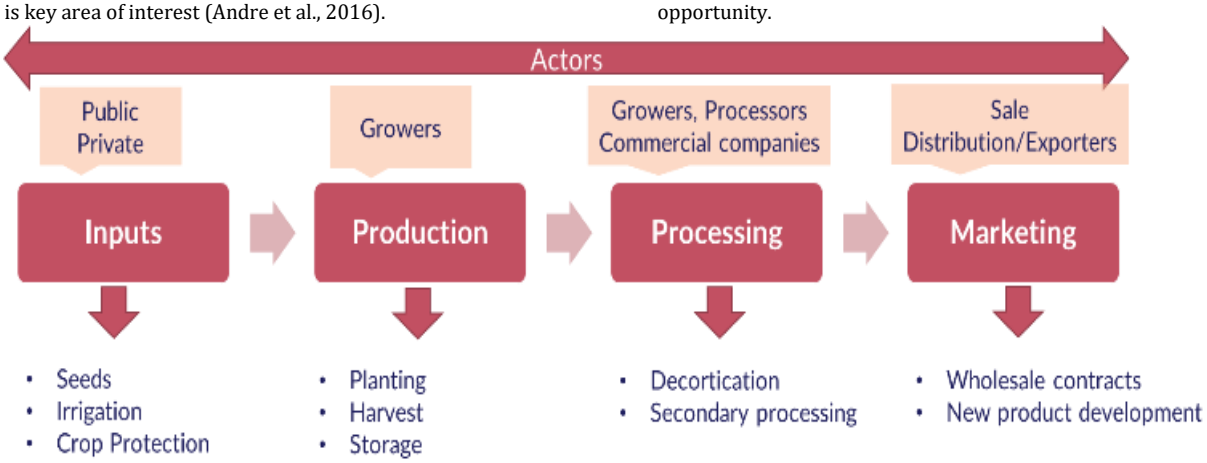

Fig. 2. Overview of potential industrial hemp fibre value chain

Inputs

Industrial hemp crop production needs for fibre and grain production are similar and therefore selecting seed suppliers who provide high quality seed is vital for achieving vigorous crop establishment and thereafter high yields. Currently, Northern Australia is getting supplies of hemp seed from both local and international seed suppliers.

Evaluation of suitable fibre varieties specific to Northern Australian soils and climatic conditions is under investigation by IHVT (https://agrifutures.com.au/related-projects/). Low THC level (< 1%), high seed germination percentage and seed vigor are desirable traits during selection of varieties.

Fertilizer application is vital for hemp fibre production, and nutrition is a significant determinant of profit (Van der Werf & Van den Berg, 1995). However, excess nitrogen application affects quality of fibre by producing lower bark yield (Grabowska & Koziara, 2006; Malceva et al., 2011) It is recommended to plan fertilizer applications on the basis of soil analysis prior to sowing.

Water requirement for both seed and fibre production is essential during critical crop growth stages which include seedling establishment, vegetative stage and pre-flowering (Van der Werf, 1991).

Specialized harvesting operations with proper retting period is very important for fibre quality (Horner et al., 2019).

Production

It is often recommended to drill fibre crops in narrow rows to increase plant population for getting higher yield per hectare (Horner et al., 2019). Another advantage of increased plant density is on suppression of weeds and reduction in self-thinning (Sunoj et al., 2023; Yazici, 2023; Ecofibre Industries Operations Pty. Ltd., 2016). Plant density can be adjusted depending upon the end product aimed from crop i.e. for shorter fibre, dense sowing is recommended (Deng et al., 2019).

Fibre extraction occurs typically from 8-10 weeks old crop when male plant approaches to flowering (Horner et al., 2019). Delay in harvesting especially when female plants are at flowering will cause difficulties in cutting and processing of fibre due to increased lignification and lodging of male plants (Dhondt & Muthu, 2021; Essien et al., 2021; Wulff, 2022).

Hemp stem cutting can be accomplished using specialized equipment like Kemper harvesting units, which cut the stalks to a length of 30-70 cm, facilitating efficient drying without tangling. It's advisable to rake windows to promote uniform drying and remove excess leaves (Ecofibre Industries Operations Pvt. Ltd., 2016). In Northern Australia, using a cotton gin for hemp fiber processing could be a cost-effective method.

Field drying of hemp stalks is essential for retting, which partially breaks down the stems to aid in decortication. Some buyers prefer white fiber, which can be obtained from un-retted stalks. Baling occurs once the plant's moisture content is less than 12%, and these bales can be stored until they are ready for transport to a processing facility (Ecofibre Industries Operations Pvt. Ltd., 2016).

Processing hemp for fibre is technically complex and requires huge investment in infrastructure especially for industries like textile. Hence this is still a challenging option for Northern Australian hemp farmers.

Processing

Hemp fibre decortication operation divides the stalks into bast and hurd fibre. Bast typically accounts 20-30% of the stalk and the remaining 70- 80% of the stalks consists of hurds. Bast fibre is long, outer portion whereas hurd is inner woody part of the hemp stalk (Bouloc et al., 2013). In the process of decortication, fibre separation is done through pectin degradation by microbial activity, favored by warm weather and moisture. There are different ways to separate hemp fibre from stalks, but mechanical decortication is the most established method. Secondary processing like softening, combing, and spinning depends on the end market product (Rachini et al., 2009).

The decortication system allows growers to add value to their crops but needs high investment. The lack of proven and cost-efficient technologies for hemp stalk processing is among the major issues (Campbell, 2022, pers. comm.). In the meantime, cotton gins can be an alternate fibre separation option for processors in the Northern Australia.

Marketing

Bast fibre has potential usage in textile and paper industry whereas hurd fibre can be used as building material, can be a critical industry in Northern Australia. Generally, domestic hemp fibre does not compete with imported fibre products in terms of cost, but replacing import of insulation and pet bedding with locally produced hemp products is an option to cut export expenses. Conducting market research on these innovative fiber-related products is providing encouragement for the growth of the hemp industry in Northern Australia.

Silage value chain

Industrial hemp is not legally allowed within Australia to be used as a forage for animals' feeds, as there are concerns that THC could be transferred into animal products (Blake, 2021). However, WA is currently conducting research trials to evaluate nutritional benefits of industrial hemp as a livestock forage and to assist in developing regulations for hemp as an attractive fodder crop for Australian farm businesses (Blake, 2021).

This has the potential to enhance the appeal of hemp as a forage choice for northern grazing systems while providing diversification of feed sources. The results from phase 1 of this study indicated no adverse effects of hemp stubble on intake or animal performance (Blake, 2021). With considering positive outcome from above research, Northern Australia has the potential to produce hemp silage value chain (Fig. 3).

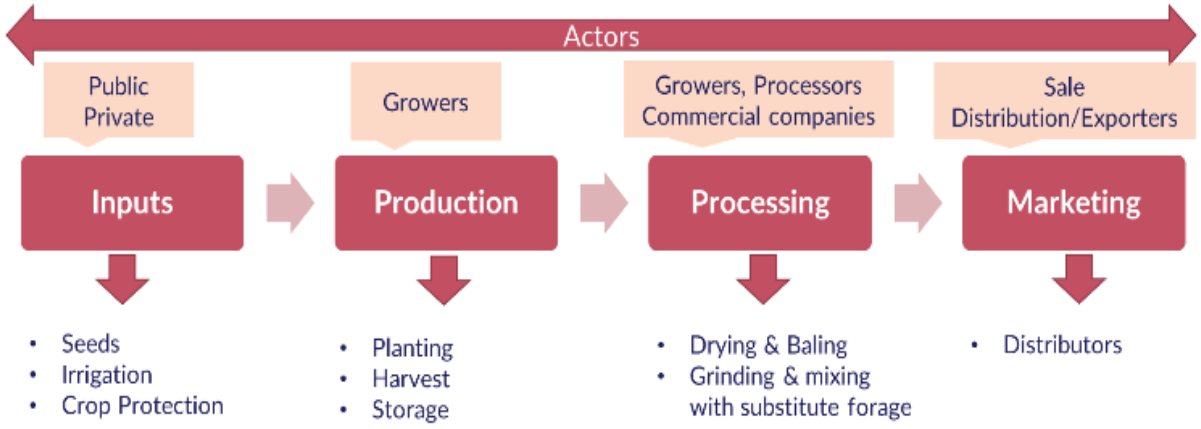

Fig. 1. Overview of potential industrial hemp silage value chain

Inputs

Input requirements for production of hemp forage will be similar to seed and fibre hemp production. Varieties having high biomass production potential should be selected for forage production. Among fertilizers, nitrogen application is most critical for getting higher green foliage as it supports plant vegetative growth. Water requirement will remain high to facilitate rapid plant growth (Wylie et al., 2021).

Processing

Harvesting operation depends on end use of plants, for silage production field harvesters are used for cutting and reducing size and then later on silage balers can bale out the chopped green material. Further investigation is currently being conducted in Australia to assess the viability of utilizing hemp stubble for livestock grazing purposes (Blake, 2021).

Marketing

Distributor's network can be established for the sale of silage bales, feed pellets or hay bales and market research is essential for identify and develop local opportunities.

3.2 Capacity, Communication and Relationship Analysis of Hemp Value Chains

Labor is a crucial component within all the value chains, but there are notable challenges in Northern Australia. A shortage of skilled labor for tasks like harvesting and processing poses a significant hurdle due to challenging conditions associated with these regions like remoteness and average wage levels that deter the influx of both casual and skilled labor. Additionally, reduced living standards in terms of amenities like internet access, phone connectivity, water quality, hygiene, health services, and educational facilities further discourage potential workers.

Moreover, the establishment of seed processing and storage facilities in the north faces obstacles due to the consistently high tropical temperatures and humidity throughout the year. Substantial investments are necessary for these facilities, requiring clear evidence of low-risk profitability to attract investors.

In Australia, hemp fiber processing facilities are currently limited in number. However, industry entrepreneurs are exploring the development of mobile processing units. Some drying and extractive equipment in WA has the capacity to support the establishment (McNeil, 2022, pers. comm). Nevertheless, the construction of fiber extraction facilities in Northern Australia necessitates long-term strategic planning.

Effective communication among various value chain participants and service providers, including input suppliers, farmers, retailers, crop consultants, processors, transporters, distributors, consumers, business partners, investors, shareholders, local communities, government authorities, and regulators, is crucial. These stakeholders often have divergent interests, attitudes, and priorities. Maintaining open lines of communication ensures that they receive pertinent information tailored to their specific needs, fostering positive attitudes toward the industry. Consistent communication with stakeholders and development of a mutual understanding can help cultivate enduring, productive relationships with key groups which offer multitude of benefits, and strategies. Regular meetings, field days, conferences, and informational materials like fact sheets can be employed to facilitate effective communication.

3.3 SWOT Analysis

SWOT analysis of the three value chains (Table 1) was also carried out based on data collected from a literature review, IHVT results and observations, and the stakeholder survey. These provide a backdrop to understand and addressing challenges in the future hemp industry and an efficient direction for the better utilization of strengths and opportunities available in Northern Australia.

Table 1. SWOT analysis of the potential industrial hemp value chains

Strengths	Weakness
Suitable climate Availability of water resources Possibilities of off-season growing in Northern Australia compared with other states where hemp growing is not advisable during winter season. Hemp Seed: Grain yield from trails conducted in Northern Australia for few varieties was very encouraging. Hemp Fibre: Encouraging biomass yield from trials conducted in Northern Australia for few varieties. Good break crop for crop rotation. Hemp Silage: No adverse effects of hemp stubble with improve live weight gain studies in WA	Unavailability of quality seed Poor understanding of hemp agronomy Hemp Seed: Hard maintaining quality-due to high temperatures & humidity Limited grower skills/experience with hemp production Hemp Fibre: difficult maintaining quality-due to high temperatures & humidity. High logistics cost Hemp Silage: THC residues-ruminants, more research is needed to understand Cannabidiol. (CBD) digestion and metabolism in ruminants
Opportunities	**Threats**
Food market is potentially growing in Australia for hemp products. Hemp Seed: Value added products- hemp beer, plant-based milk etc. Developing domestic production of isolates instead of importing them (e.g. terpenes for cosmetics production). Hemp Fibre: Building industry in crisis, hempcrete is a good solution. Hemp Silage: Diversification of feed sources-northern grazing systems.	Competition with other industry Production issues-weed, bird damage, pest and diseases. Hemp Seed: High humidity for grain storage. Loosing viability of seeds in very high temperature. Hemp Fibre: Regulatory barriers to the use of hempcrete as a building material. Hemp Silage: Significant amount of research will be needed on a national scale.

4. Conclusion

This research output serves as a valuable decision-making tool for stakeholders interested in hemp production or investment in Northern Australia. The insights presented in this paper are intended to assist all participants within the Northern Australian hemp value chains in making well-informed choices regarding hemp production in the region. These findings are instrumental in guiding decision-making processes related to hemp production, whether for seed, feed, fiber, or as part of crop rotations.

Moreover, the research identifies critical gaps in knowledge, thereby highlighting opportunities for further investigation by research organizations and potential funding agencies.

The development of industrial hemp value chains is expected to facilitate engagement among growers, investors, and processors interested in cultivating hemp in Northern Australia. It will also contribute to a deeper understanding of the industry, allowing stakeholders to address challenges before embarking on commercial operations.

From a grower's perspective, the identified hemp value chains present new avenues for income generation and to support decisions regarding hemp cultivation or investment.

Recommendation

The research concludes in a series of specific recommendations as outlined below:

- Encourage state and territory governments in Northern Australia to maintain ongoing engagement and support for the industrial hemp industry. This collaboration is essential for fully realizing the potential of industrial hemp production within the regional context.
- Recognizing the need for further research in various areas is recommended, e.g., sourcing stable certified tropical seed lines from Asia or the subcontinent. Moreover, continuous R&D funding to conduct further research are necessary to develop the industrial hemp industry in Northern Australia. Participants should secure investments to maximize the industry's profit potential, alignment with society, environmental benefits, and its ability to work with other industries.
- Encourage market research efforts to identify local opportunities for innovative hemp-based products, such as cattle feed cake, animal bedding, nursery matting for hydroponics, or soil erosion control measures. Exploring these local markets can diversify the industrial hemp industry.
- Highlight the importance of developing suitable infrastructure, such as post-harvest facilities (e.g., driers, cleaners, and cool rooms), to enhance industrial hemp production. Collaboration among industry participants to secure funding for infrastructure development is essential for future crop opportunities in Northern Australia.
- Promote the strengthening of existing value chains and the exploration of new potential value chains as the industrial hemp industry evolves and expands in Northern Australia. This strategic approach enhances the industry's resilience and sustainability.
- Advocate for the development of strategies aimed at mitigating difficulties and reducing costs associated with regulatory compliance. Addressing regulatory constraints related to extraction and whole plant utilization is crucial to propel the industrial hemp industry forward while ensuring adherence to regulations.

Author Contribution

The paper was co-authored by I.V. Kumar and S. Nawaz, with M.S. Mazhar as a key reviewer.

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References

Adesina, I., Bhowmik, A., Sharma, H., and Shahbazi, A. (2020). A review on the current state of knowledge of growing conditions, agronomic soil health practices and utilities of hemp in the United States. Agriculture, 10(4), 129.

Ahmed, A.F., Islam, M.Z., Mahmud, M.S., Sarker, M.E. and Islam, M.R. (2022). Hemp as a potential raw material toward a sustainable world: A review. Heliyon.

Australian Pesticides and Veterinary Medicine Authority, (2023) retrieved October 16, 2022, from https://permits.apvma.gov.au/PER87802.PDF.

Barbhuiya, S., and Das, B. B. (2022). A comprehensive review on the use of hemp in concrete. Construction and Building Materials, 341, 127857.

Biggs, I.M., Wegman, K., McConchie, C., and Hunt, W. (2016). Industrial Hemp: Crop growth and grain production trial. Katherine Research Station: Department of Primary Industry and Resources.

Blake, B. (2021). Opening the Gates to Hemp Grazed Livestock in Australia – Phase 1. AgriFutures Emerging Industries. Retrieved April 14, 2022, from https://www.agrifutures.com.au/wpcontent/uploads/2021/12/21-152.pdf

Bouloc, P., Allegret, S., and Arnaud, L. (2013). Hemp industrial production and uses. CABI Wallingford, Oxfordshire, UK, Cambridge, 27-98.

Callaway, J.C. (2004). Hempseed as a nutritional resource: An overview. Euphytica, 140(1), 65-72.

Campbell, D., personal communication, May 18, 2022.

Chris, C., and Zurbo, B. (2008). Industrial hemp – a new crop for NSW. NSW Department of Primary Industry. Retrieved April 25, 2022, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/232823/industrial-hemp-a-newcrop-for-nsw.pdf.pdf.

Clarke, R. C., and Merlin, M. D. (2016). Cannabis domestication, breeding history, present-day genetic diversity, and future prospects. Critical reviews in plant sciences, 35(5-6), 293-327.

Crini, G., Lichtfouse, E., Chanet, G. and Morin-Crini, N. (2020). Traditional and new applications of hemp. Sustainable Agriculture Reviews 42: Hemp Production and Applications, 37-87.

Ecofibre Industries Operations Pvt Ltd. (2016). Industrial Hemp Fibre Production Guide, Qld and NSW.

Essien, B. A., Okereke, P. O., and Oyeleye, A. D. (2021). Industrial Crops Production. Agricultural Technology for Colleges, 122.

Deng, G., Du, G., Yang, Y., Bao, Y., and Liu, F. (2019). Planting density and fertilization evidently influence the fiber yield of hemp (Cannabis sativa L.). Agronomy, 9(7), 368.

Dhondt, F., and Muthu, S. S. (2021). Hemp and sustainability. Berlin/Heidelberg, Germany: Springer, 1-130.

Finnan, J., & Styles, D. (2013). Hemp: A more sustainable annual energy crop for climate and energy policy. Energy Policy, 58, 152-162.

Gleeson, P. (2019). The challenge of medicinal cannabis to the political legitimacy of therapeutic goods regulation in Australia. Melbourne University Law Review, 43, 558.

Grabowska, L., and Koziara, W. (2006). The effect of nitrogen dose, sowing density, and time of harvest on development and yields of hemp cultivar Bialobrzeskie. Journal of Natural Fibers, 2(4), 1-17.

Gordon, S., and Brodrick, R. (2020). A comparative analysis of cotton and hemp production in Australia. East Toowoomba: The Australian Cottongrower, 42-45.

Government of Western Australia (2020). Licensing industrial hemp activities in Western Australia, Retrieved May 20, 2022, from https://www.agric.wa.gov.au/plant-biosecurity/licensing-industrial-hempactivities-westernaustralia#:~:text=The%20industry%20in%20Western%20Australia,%25%20of%20tetrahydrocannabinol%20(THC)

Grand View Report. (2022). Market Analysis Report, Industrial Hemp Market Size, Share & Trends Analysis Report By Product (Seeds, Fiber, Shivs), By Application (Animal Care, Textiles, Personal Care), By Region (North America, APAC), And Segment Forecasts, 2022 - 2030. Retrieved May 14, 2022, from https://www.grandviewresearch.com/industry-analysis/industrial-hemp-market#:~:text=The%20global%20industrial%20hemp%20market,16.8%25%20from%202022%20to%202030

Hill, T., and Westbrook, R. (1997). SWOT analysis: it's time for a product recall. Long range planning, 30(1), 46-52.

Horner, J., Milhollin, R., Roach, A., and Massey, R. (2019). Value chains for the Missouri industrial hemp industry: Guide for

entrepreneurs to understand the value chains and business opportunities in offering fiber, grain, and cannabinoids.

Humphries, T., and Florentine, S. (2019). Cultivation of low tetrahydrocannabinol (THC) Cannabis sativa L. cultivation in Victoria, Australia: Do we know enough? Australian Journal of Crop Science, 13(06), 911-919.

Industrial Hemp Taskforce Victoria. (2020). Industrial hemp Update. Victoria State Government. Retrieved April 22, 2022, from https://agriculture.vic.gov.au/__data/assets/pdf_file/0015/603231/DJPR-AG-VIC-Industrial-Hemp-Taskforce-Interim-Report.pdf

Kamat, J., Roy, D. N., and Goel, K. (2002). Effect of harvesting age on the chemical properties of hemp plants. Journal of Wood Chemistry and Technology, 22(4), 285-293.

Kaiser, C., Cassady, C., and Ernst, M. (2015). Industrial hemp production. Center of Crop. Diversification. University of Kentucky, 27, 101-106.

Kaur, G., and Kander, R. (2023). The Sustainability of Industrial Hemp: A Literature Review of Its Economic, Environmental, and Social Sustainability. Sustainability, 15(8), 6457.

Kreuger, E., Prade, T., Escobar, F., Svensson, S. E., Englund, J. E., and Bjornsson, L. (2011). Anaerobic digestion of industrial hemp–Effect of harvest time on methane energy yield per hectare. Biomass and Bioenergy, 35(2), 893-900.

Lisson, S. N., and Mendham, N. J. (1995). Tasmanian hemp research. Journal of International Hemp Association, 2(2), 82-85.

MacPhail, S.L., Bedoya-Pérez, M.A., Cohen, R., Kotsirilos, V., McGregor, I.S. and Cairns, E.A., 2022. Medicinal cannabis prescribing in Australia: an analysis of trends over the first five years. Frontiers in Pharmacology, 13, 885655.

Malceva, M., Vikmane, M., and Stramkale, V. (2011). Changes of photosynthesis-related parameters and productivity of Cannabis sativa under different nitrogen supply. Environmental and Experimental Biology, 9, 61-69.

Marsh, G. (2003). Next step for automotive materials. Materials today, 6(4), 36-43.

Martínez, B., Bernat-Maso, E. and Gil, L. (2023). Applications and Properties of Hemp Stalk-Based Insulating Biomaterials for Buildings. Materials, 16(8), p.3245.

McNeil, D., personal communication, April 14, 2022.

Northern Territory Government. (2020). Hemp Industry Regulations. Northern Territory Legislations. Retrieved May 16, 2022, from https://legislation.nt.gov.au/Legislation/HEMP-INDUSTRY-REGULATIONS-2020.

Pari, L., Baraniecki, P., Kaniewski, R., and Scarfone, A. (2015). Harvesting strategies of bast fiber crops in Europe and in China. Industrial Crops and Products, 68, 90-96.

Peachey, A. (2021). Cultivation of Industrial Hemp in the Northern Territory, A Pre-feasibility Study. Department of Industry Tourism and Trade, Darwin.

Queensland Government (2021). Low THC hemp foods. Retrieved May 16, 2022, from https://www.qld.gov.au/health/staying-healthy/food-pantry/food-safety-for-consumers/food-warnings-and-advice/low-thc-hemp-foods#:~:text=The%20sale%20of%20hemp%20seed,to%20a%20number%20of%20requirements

Queensland Government (2022). Growing industrial cannabis or hemp in Queensland. Business Queensland retrieved May 15, 2022, from https://www.business.qld.gov.au/industries/farms-fishingforestry/agriculture/niche-industries/industrial-cannabis-hemp

Rachini, A., Le Troedec, M., Peyratout, C., and Smith, A. (2009). Comparison of the thermal degradation of natural, alkali-treated and silane-treated hemp fibers under air and an inert atmosphere. Journal of applied polymer science, 112(1), 226-234.

Sahay, B. S. (2003). Understanding trust in supply chain relationships. Industrial Management & Data Systems, 103(8), 553-563.

Salentijn, E. M. J., Zhang, Q., Amaducci, S., Yang, M., and Trindade, L. M. (2015). New developments in fiber hemp (Cannabis sativa L.) breeding. Industrial Crops and Products, 68, 32-41.

Schmidt, T., personal communication, May 18, 2022.

Sorrentino, G. (2021). Introduction to emerging industrial applications of cannabis (Cannabis sativa L.). Rendiconti Lincei. Scienze fisiche e naturali, 32(2), 233-243.

Stubber, G., personal communication, May 16, 2022.

Sunoj Valiaparambil Sebastian, J., Dong, X., Trostle, C., Pham, H., Joshi, M.V., Jessup, R.W., Burow, M.D. and Provin, T.L. (2023). Hemp agronomy: Current advances, questions, challenges, and opportunities. Agronomy, 13(2), p.475.

Suriyong, S., Krittigamas, N., Pinmanee, S., Punyalue, A., and Vearasilp, S. (2015). Influence of Storage Conditions on Change of Hemp Seed Quality. Agriculture and Agricultural Science Procedia, 5, 170-176. doi:10.1016/j.aaspro.2015.08.026

Van der Werf, H. M. G. (1991). Agronomy and crop physiology of fibre hemp: A literature review (Report No. 142). Centre of Agrobiological Research, Wageningen, The Netherlands, 1-16.

Van der Werf, H. M. G., and Van den Berg, W. (1995). Nitrogen fertilization and sex expression affect size variability of fibre hemp (Cannabis sativa L.). Oecologia, 103(4), 462-470.

Van, I., personal communication, May 16, 2022.

Williams, D. W. (2019). Hemp Grain. Industrial hemp as a modern commodity crop, 26-36.

Wimalasiri, E. M., Jahanshiri, E., Chimonyo, V. G., Kuruppuarachchi, N., Suhairi, T. A. S. T. M., Azam-Ali, S. N., and Gregory, P. J. (2021). A framework for the development of hemp (Cannabis sativa L.) as a crop for the future in tropical environments. Industrial Crops and Products, 172, 113999.

Wulff, H. (2022). Growth and development of fibre hemp (Cannabis sativa L.): A thesis submitted in partial fulfilment of the requirement for the Degree of Master of Agricultural Science at Lincoln University (Doctoral dissertation, Lincoln University).

Wylie, S. E., Ristvey, A. G., and Fiorellino, N. M. (2021). Fertility management for industrial hemp production: Current knowledge and future research needs. GCB Bioenergy, 13(4), 517-524.

Yano, H., and Fu, W. (2023). Hemp: A Sustainable Plant with High Industrial Value in Food Processing. Foods, 12(3), 651.

Yazici, L. (2023). Optimizing plant density for fiber and seed production in industrial hemp (Cannabis sativa L.). Journal of King Saud University-Science, 35(1), 102419.

Zhao, H., Xiong, H., and Chen, J. (2021). Regional comparison and strategy recommendations of industrial hemp in China based on a SWOT analysis. Sustainability, 13(11), 6419.