Potentially Hemp

An analysis into the opportunity for the commercial expansion of hemp production in New Zealand

Report prepared by:

Perrin Ag Consultants Ltd

For:

New Zealand Agricultural Greenhouse Gas Research Centre

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Executive Summary

"Potentially Hemp" is the fourth in a series of reports prepared for the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC). These reports examine potentially viable diverse land uses in New Zealand that could provide alternatives to the largely monoculture and ruminant-dominated pastoral agriculture systems across our landscapes at a more expansive farm systems perspective.

This report builds on the recommendations derived from earlier work on the potential for expanding the commercial production of hemp, which identified a number of potential supply chain challenges to this occurring. "Potentially Hemp" provides further analysis and research into the key challenges facing this industry with particular focus on the significant capital investment required to grow hemp on farm, profitability of hemp compared with other land uses both pastoral and arable, key market challenges this industry is facing and regulations roll in the hemp industry.

The financial returns at a gross margin level for hemp seed were higher than hemp fibre. Further financial analysis results showed internal rates of return for growers were 4.1% and 6.7% for seed and fibre base on 50 hectare crops. The higher level of capital required to grow, harvest and store hemp seed was the main reason for hemp seed having a lower internal rate of return compared to hemp fibre. Its inability to compete with the financial returns achieved by dairy farms in New Zealand would seem to be a significant driver as to why it is not considered to be a commercially viable alternate land use for these farm systems. It was identified that returns from hemp could provide another cash cropping option for sheep and beef farms that had land suitable for arable cropping in their businesses. However, these opportunities are limited given the small number of sheep and beef farms that sit in this category.

Another reason that seems likely to be limiting the expansion of the hemp industry was the absence of a secondary market for hemp seed. Currently growers are at high risk of not receiving any revenue for seed crops that fail or for seed that doesn't meet food processing standards. This risk is too great for pastoral farmers considering hemp as an alternative land use option. A couple of secondary market options were identified, with the most promising market being the pet food market. However currently this market isn't an option due to regulations around any hemp or hemp product not legally being able to be feed to any animals in New Zealand.

There is no doubt that export markets provide a huge opportunity for the New Zealand hemp industry however it was concluded that establishing a solid domestic market was the best way for the industry to grow initially. This would enable a well-functioning supply chain to be established and streamlining of the regulatory process involved in growing hemp and ultimately increasing demand so financial returns increase to levels that can start to be competitive with land uses currently on land suitable for hemp cultivation, primarily dairy farming.

Several solutions for the hemp industry to consider, to become a viable land use alternative to pastoral farming systems in New Zealand include:

- Establish a solid domestic market.
- Research on the effects of feeding hemp products to companion animals to enable a potential secondary market. This will significantly reduce risk throughout the supply chain but particularly for growers.
- Improve hemp plant genetics so ensure that low THC cultivars do not produce higher than regulated levels.

- Further research on hemp economics especially beyond the farm gate and around incorporating hemp into sheep and beef farm systems.
- The strategic location of hemp processing facilities, particularly for fibre, to limit transport costs from farm to processor.

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1 Introduction

The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) has initiated and funded a Future Farm Systems Research Programme. It has two key parts – the first looking at case studies and co-designed solutions for the primary sector transitioning to a low emissions future [Part 1] and a second part envisioning what that low emissions future might look like [Part 2].

An analysis into the opportunity for the commercial expansion of hemp production in New Zealand is the fourth in a series of reports prepared for the NZAGRC. These reports examine potentially viable diverse land uses in New Zealand that could provide alternatives to the largely monoculture and ruminant-dominated pastoral agriculture systems across our landscapes at a more expansive farm systems perspective.

This report builds on the recommendations derived from earlier work on the potential for expanding the commercial production of hemp, which identified a number of potential supply chain challenges to this occurring. "Potentially Hemp" provides further analysis and research into the key challenges facing this industry with particular focus on the significant capital investment required to grow hemp on farm, profitability of hemp compared with other land uses both pastoral and arable, key market challenges this industry is facing and regulation's role in the hemp industry.

Industrial hemp (*Cannabis sativa* L.), one of the oldest crop plants know to humans, has been in decline since the first decades of the 19th century (Merfield, 1999). This decline was due to competition from substitute crops grown in Asia and its relationship with marijuana, which caused industrial hemp in 1927 to be listed in New Zealand's Dangerous Drugs and Poisons Act. This prohibited all cannabis cultivation. Many European, North American and ex-European colonial countries also banned industrial hemp cultivation for the best part of a century due to its relationship with marijuana. This significantly reduced the size of global industrial hemp industry until the 1990s when the global hemp industry started to make a comeback as the differentiation between industrial hemp and marijuana became better understood (Merfield, 1999). Since then, most countries have now legalised the production of hemp under regulation and license, a decision that is often controversial to many people involved in the industry.

New Zealand was slow relative to many other jurisdictions to allow hemp cultivation to become legalised with the amendment only occurring in 2018. This has led to the number of hectares grown increasing from 259 hectares in 2018 to approximately 1,200 hectares grown in 2020 (Marsh, 2020). The current value of the New Zealand hemp industry is also expected to grow, from currently being $4 million to reach $30 million by 2030 (Marsh, 2020).

There are currently no hemp seed or fibre exports from New Zealand. However key opportunities for target markets are in the United States and wider North America. The USA is the most promising market for demand in hemp products, where 26% of new hemp products globally being launched in the USA between 2012 and 2018 (MPI, 2019). Hemp has three key products being seed, fibre and hurd.

Key opportunities have previously been identified by Merfield (1999) and Brownlee (2018) which give insight into what could aid the expansion of the New Zealand hemp industry. These include suitable cultivars, agronomic information, processing facilities and markets.

Expanding the commercial production of the hemp industry in New Zealand has several potential benefits, including diversified revenue stream for farming business, reduced greenhouse gas emissions compared with pastoral farming, providing New Zealand farmers access to a rapidly growing international market and give New Zealanders greater access to a healthy plant-based food sources and natural plant fibres. These will be explored in further detail throughout this report.

2 Key challenges currently preventing sustainable industry expansion

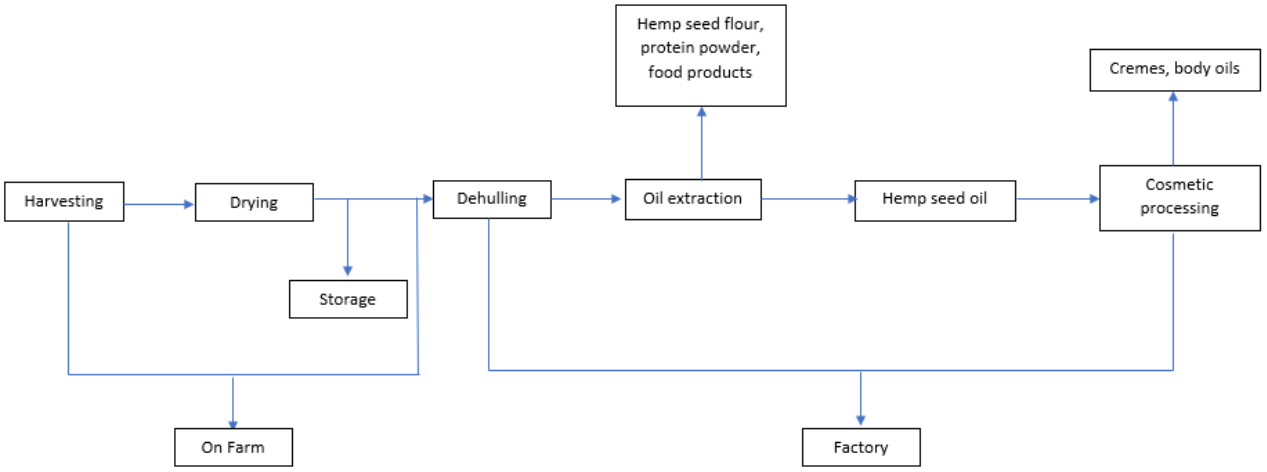

Figure 1: Key processing stages for hemp seed. Adapted from (McQuillan-Reese, 2022a).

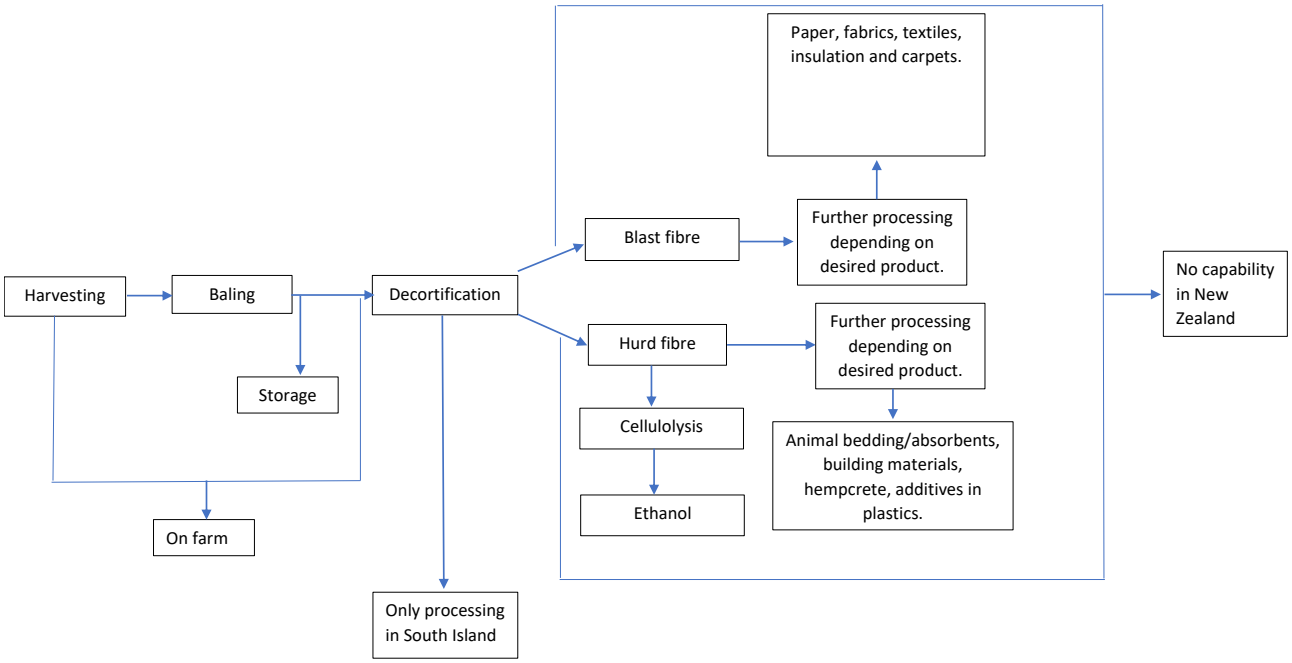

Figure 2**:** Key processing stages for hemp fibre. Adapted from (McQuillan-Reese, 2022a).

Infrastructure

Infrastructure plays a key role in most supply chains especially in agriculture. Hemp requires similar levels of on-farm and post-gate infrastructure to other arable products. Hemp is unique in the fact that it has both the seed and stalk (fibre) that can be processed. The amount of infrastructure needed for the industry to operate with two different supply chains adds complexity that other arable crops don't have.

Hemp seed infrastructure

Hemp seed is like other grains such as wheat, in terms of the level of infrastructure required on farm. Drying and storage facilities are the main on-farm infrastructure requirements for hemp seed

production (Figure 1). Drying of hemp seed needs to occur within three hours of harvest to maintain seed quality. The dryer needs to take the seed from a harvested moisture content of 28-25% to a moisture content of 8% for storage. Due to the speed at which hemp seed needs to be dried after harvesting, having storage facilities on farm to store seed is essential. The associated level of capital investment required on farm is dependent on the scale of production, an issue that will be explored later in this report.

Hemp seed requires further processing beyond the farm gate. Dehulling of the seed is the first stage in processing (Figure 1). This process can occur on farm but makes more sense to occur at the factory where additional processing is required to produce hemp products for sale. Pressing the seed for oil or milling/grinding the seed to make hemp flour or meal are the next key stages. After this there is a range of other processing activity that may occur depending on the intended product (Figure 1). All of these processes require capital investment at varying levels depending on the desired product stream.

Hemp fibre infrastructure

There are certain varieties of hemp that are grown for fibre which are different to the varieties grown for seed production. Hemp fibre consists of two types - the bast fibre and the hurd. The bast fibre makes up approximately 20-30% of the hemp stalk and the hurd approximately 70-80% of the stalk (Komar & Bamka, 2022). Once the stalks have been cut, they are left on the ground to dry for between 14-28 days until the stalk moisture content is below 15% (Komar & Bamka, 2022). Not only does this help with the storing of the stalks once baled but it starts to weaken the interactions between the fibres and the woody core and surrounding tissue. This process is called field retting. Retting can also be done using other methods such as water retting or through industrial processes e.g., enzymatic treatments (Manian et al., 2021). Once the stalks have been baled, they can be stored before they are processed. Harvesting, retting and storage are typically the main activities carried out on farm and therefore harvesting and baling equipment and storage facilities are the key infrastructure requirements required at the farm level (Figure **2**).

Decortification is one of the most important processes in the hemp fibre supply chain (Figure **2**). This process starts with retting, where the bast and hurd fibres are separated from the core stem and then a decortification machine is used which mechanically separates the bast and hurd fibres of the hemp plant (Manian et al., 2021). This typically occurs in a processing facility. From this point on the hurd and bast fibres are processed differently. The higher quality bast fibres are processed in products such as paper, fabrics and textiles, insulation and carpets (Komar & Bamka, 2022). Hurd fibres, which are shorter than bast fibres, make them ideal for use in materials such as fibreboard, animal bedding, additives in plastics, absorbents and building materials such as hempcrete or further processed into biofuels through the process of cellulolysis (Komar & Bamka, 2022). Both hurd and bast fibre processing require significant levels of infrastructure which currently doesn't exist in New Zealand beyond the decortification process (Figure **2**). Whether or not processing of hemp fibres needs to be done in New Zealand is discussed below.

Market

Market opportunities are one of the most important factors to any startup, or small industry looking to grow (Sevilla-Bernardo et al., 2022). The hemp industry is currently a relatively niche industry in New Zealand and therefore the identification and securing of markets play a significant role in the ability for this industry to grow into a commercially viable land use option for New Zealand famers.

Current primary market

The New Zealand hemp industry is worth NZ$4 million, based solely on the domestic market, mostly for hemp seed, as currently there are no hemp products exported out of New Zealand (Tupu.nz, 2022). With New Zealand only having a small population of 5.15 million people (Statistics New Zealand, 2023), there are significant limits on the ability for the New Zealand hemp industry to expand domestically. Almost all agricultural industries in NZ rely on export markets as the domestic market is too small to support growth and value. Ultimately export markets need to be accessed.

Secondary market for hemp

The lack of a secondary market for hemp seed limits growth.

An example of a secondary market is the rendering market for the meat industry in New Zealand. Rendering is a process that converts waste animal tissue into stable, usable materials (Cresswell, 2020). Without the rendering market the New Zealand meat industry would not be sustainable or potentially viable, as approximately 50% of each animal is deemed inedible for human consumption (Cresswell, 2020). Furthermore, secondary markets can be of significant value in their own right. Meat and bone meal and, tallow produced from the rendering process equate to an NZ$300 million industry while fish meal and fish oil add NZ$66 million to the fishing industry (Cresswell, 2020). The total export value of rendering products to the New Zealand economy is NZ$366 million (Cresswell, 2020).

Currently there is no secondary market for hemp products in New Zealand, which is of greatest relevance for the hemp seed industry. If hemp seed doesn't meet food processing standard, there is currently no way for the farmer to recover any costs for growing the crop (M. Johnson, personal communication, February, 2023). This means the risk of growing hemp is extremely high. All arable crops grown have risks associated with yield quality and quantity from weather events, pests and diseases, which a secondary market for sub-quality product help mitigate (i.e., reject malting barley can be sold as feed barley).

Hemp stigma and regulation

International literature has acknowledged the stigmatisation around industrial hemp, which is probably the world's most recognisable, notorious and controversial plant (Small, 2015). It has been agreed by international scholars that the public misunderstandings of the difference between industrial hemp and marijuana have played a role in helping limit the popularity, potential and reputation of the plant (Conrad, 1997; Small, 2015; Cherney & Small, 2016; Vantreese, 1998)

In 1927 hemp was named in New Zealand's Dangerous Drugs and Poisons Act which prohibited all cannabis cultivation. It wasn't until 1996 when the New Zealand Hemp Industries Association (NZHIA) began to petition the government to allow for low THC hemp cultivation. In 2005 the growing of certain approved low THC cultivars of industrial hemp (no more than 0.5% THC) was allowed with a permit under the Ministry of Health (MOH) (McPartland et al., 2005). However, today industrial hemp is still listed in Schedule 3 Part 1 of the Misuse of Drugs Act 1975 and classified as a Class B and Class C controlled 'drug' that poses 'high' or 'moderate risk of harm' (Misuse of Drugs Act, 1975). Because of this legal classification, anyone who wants to grow, process or possess industrial hemp is legally required to get a license from the MOH. This process involves an application, police vetting checks and strict growing and THC testing regimes (Misuse of Drugs (industrial hemp) regulations, 2006). Hemp's connection with drug legislation meant that selling hemp seed as a food for human consumption was illegal until 2017 when changes were made to the Australia New Zealand Food Standards Code (MPI, 2018). Prior to this law change only hemp oil was able to be sold. The hemp seed meal, which comprises 75% of the entire seed, was not able to be used for human consumption.

These factors, including the regulatory hurdles for both growers and processors seem likely to be limiting growth in the New Zealand industry.

Marketing & awareness

Merfield (1990) argues that hemp's connection with marijuana is a key issue restricting the resurgence of hemp and has a part to play in the stalled development of harvesting hemp efficiently. This may have also limited the investor and government funding that would help the hemp industry grow.

The lack of marketing around the value of hemp products has potentially limited people's understanding and awareness of hemp seed and its benefits as a food source. Table 1 compares the key nutritional characteristics of hemp seed with other foods that are in a similar food group. Of particular note is the protein content of hemp relative to other sources of plant protein. Studies have explored the benefits of using hemp as a protein source in food manufacturing for baking and beverages (El-Sohaimy et al., 2022). Plant-based protein sources are becoming increasingly popular. In 2022 the global plant-based protein market was estimated to be worth US$12.2 billion and is forecasted reach US$17.4 billion in 2027 - a CAGR of 7.3% (Marketsandmarkets.com, 2022). With this potential, funding and research to help promote hemp's nutritional benefits would likely help the NZ industry grow both domestically and internationally.

Table 1: Comparing the nutritional value of different foods in a similar food group to hemp seed. Sourced form (USDA, n.d.).

	Hemp seed	**Buckwheat**	**Flax seed**	**Chia seed**	**Almond flour**
	Per 100 g	Per 100 g	Per 100 g	Per 100 g	Per 100 g
Protein	**30 g**	13 g	18 g	17 g	20 g
Carbohydrates	10 g	72 g	29 g	42 g	20 g
Total lipid fat	50 g	3 g	42 g	31 g	53 g
Total fatty acids	48 g	3 g	40 g	29 g	
Monounsaturated fatty acids	5 g	1 g	8 g	2 g	
Polyunsaturated fat acids	38 g	1 g	29 g	24 g	
Saturated fatty acids	5 g	1 g	4 g	3 g	3 g

3 Analysis of key challenges

Economics of the hemp industry

Understanding the economics of both growing hemp on farm and the industry beyond the farm gate is critically important in determining the ability of the hemp industry to becoming a significant land use option for New Zealand farmers.

Hemp gross margins

Table 2 details the hemp production gross margins for seed and fibre crops.

Table 2: Hemp gross margins for seed and fibre production.

Crop	Hemp seed	Hemp fibre
Revenue		
Sold yield (t/ha)	1	10
Price ($/t)	5,000	480
Revenue ($/ha)	**5,000**	**4,800**
Expenses ($/ha)		
Seed	400	800
Cultivation/planting	300	250
Fertiliser	844	767
Agri-chemicals	200	150
Irrigation	200	200
Harvesting	500	300
Repairs and maintenance	200	150
Drying costs ($/t)	20	-
Total expenses ($/ha)	**2,664**	**2,617**
Gross margin ($/ha)	**2,336**	**2,183**

With limited New Zealand-based literature and evidence relating to hemp seed and fibre crop revenue and expenses, overseas research was utilised to fill the gaps in New Zealand-based sources. Key sources of data for the gross margins are summarise below.

- Revenue was based on information from Tupu.nz (2022) and then inflation adjusted where appropriate.
- Seed costs were estimated based on estimates provided by Marsh (2020).
- Cultivation/planting and agri-chemical costs were based on the costs associated with growing barley from Lincoln University (2022) and then adjusted to fit with increased sowing rates for hemp fibre.
- Fertiliser rates were based on information from NZHIA (2019) and fertiliser prices came from price lists effective from April 2022 from commercial fertiliser suppliers.
- Irrigation costs were based on the costs associated with growing barley from Lincoln University (2022).
- Harvesting costs for hemp fibre were based on barley from Lincoln University (2022) and then adjust based on professional judgement for hemp seed.
- Repairs and maintenance costs were based on wheat from Lincoln University (2022).
- Drying costs were adapted from literature on drying wheat and barley.

- All husbandry costs are based on the farmer owning all the equipment required to grow, harvest and store the crop.

The NZHIA (2022) reported gross margins for growers between NZ$1,000 to $10,000 per hectare, while Marsh (2020) reported gross margins for seed and fibre to be between NZ$1,500 to $4,500 and NZ$2,500 to $4,000 per hectare respectively. These gross margins are intended to be representative of the status quo hemp producer in an established industry with commercial scale.

New Zealand's hemp industry is still a niche market with a small number of consumers that are usually willing to pay above average market prices for the products (Bailey & Ward, n.d.). This means hemp growers may currently be receiving higher prices than one would expect if the industry was well established and was supplying a more common (or commodity) product to a larger market. As a result, the gross margins summaries in Table 2 may be conservative compared to what currently some growers are receiving.

The gross margins presented in Table 2 do have some limitations.

- There is very little published literature on or evidence for the economics of hemp production in New Zealand, particularly the costs of growing hemp and the current market prices of hemp seed and fibre in New Zealand.
- The costs are estimates guided by the literature available and best professional judgement.
- There is a large range of hemp seed yields reported in New Zealand making the average yield achieved currently achieved by growers difficult to ascertain.
- Transport costs from the farm to the processor have been excluded. This cost is more applicable to fibre as it is a bulky product to transport and given the current lack of processing infrastructure in New Zealand it is likely transport distance will be long. It was reported in a study by Pecenka et al., (2012) that fibre transport costs range from €10 to €30 per tonne (NZ$16 to NZ$48) for transport distances ranging from 15 to 40 km. The current reality is that in New Zealand the distance could likely be 80 km or more. Therefore, depending on the distance from farm to processor, bulk transport could cost up to $1,000 per hectare. If the farmer had to absorb this cost from the assumed revenue, it would significantly reduce the gross profit of growing hemp fibre.

Hemp seed and fibre on farm investment analysis

If a pastoral landowner was going to consider growing hemp, hemp for fibre appears to deliver the best investment returns, with an internal rate of return (IRR) of 6.7% on the capital invested, compared to 4.1% for hemp seed (Table 3). Despite the higher profitability of growing hemp seed (as measured by a higher gross margin and operating profit), this difference in IRR is explained by the different levels of capital investment required to grow each crop. To grow 50 hectares of hemp seed, an additional $387,500 of capital investment is required compared to growing 50 hectare of hemp fibre. A list of all capital required for growing 50 hectares of each crop can be found in the discounted cashflow analysis in Appendix 1: Discounted cashflow analysis for investment in infrastructure to grow hemp fibre and Appendix 2. It should be noted these analyses specifically exclude the value of the land utilised in the growing of hemp as it is assumed the landowner already owns the land.

Table 3: Investment analysis of hemp seed vs hemp fibre systems

50 hectares	Hemp seed	Hemp fibre
Initial capital*	$1,265,000	$877,500
IRR	4.1%	6.7%
Annual net surplus*	$111,289	$103,639
*This is pre interest and tax IRR over 10 years		

Any business wanting to invest in either type of hemp system will need to consider their weighted average cost of capital (WACC) relative to their specific investment IRR. If the business' WACC is less than the IRR, then financially the investment may make sense. However, the WACC will differ based on the source of capital and the interest rates, repayment or earning terms of the business partner or lender. If the investment is secured against other assets and thus the initial capital investment is all bank lending, than the IRR would need to exceed the average or fixed interest rate of this lending for the investment to be financially viable as its own standalone business.

When considering significant capital investments such as that required to enable growing hemp, sensitivity analysis is a useful way to see what impact changes in yield, price and area of crop grown can have on the business' profitability and ability to cope with risks.

Hemp fibre sensitivity analysis

Table 4 shows the impact that changes in yield and price can have on the IRR of a 50 hectare hemp growing business. Based on Table 4, a one tonne change in yield can have a large impact on the IRR. This therefore emphasises the importance of growers to understand the agronomic process required to grow hemp fibre successfully.

Table 4: IRR sensitivity analysis comparing hemp fibre yield and price

IRR		Yield (t/ha)				
		8	9	10	11	12
Price ($/t)	520	2%	6%	10%	13%	17%
	500	0%	4%	8%	12%	15%
	480	-1%	3%	**7%**	10%	14%
	460	-2%	2%	5%	9%	12%
	440	-4%	0%	4%	7%	10%
	400	-7%	-3%	0%	4%	7%

Table 5 summaries the sensitivity of IRR on yield and area of crop grown for hemp fibre growers. This analysis identified the importance of scale when growing hemp fibre.

With the level of capital assumed in the discounted cashflow, a business would not achieve a positive IRR on their investment if less than 41 hectares was grown. The maximum area the assumed bundle of capex could support was calculated to be 70 hectares, with the on-farm storage of bales being the first item of capital that becomes limiting. The storage facility accounted for in the cap-ex assumptions can store approximately 450 tonnes (45 hectares) of hemp fibre in bales. This is 90% of the total yield with an area grown of 50 hectares. It has been assumed that bale storage facilities already exist on farm and this can support a further 250 tonnes (25 hectares) of hemp fibre in bales. If more than 70 hectares of hemp fibre was grown further storage would need to be invested in on farm or renting of storage facilities off farm could be a useful alternative.

The smaller the area grown, the less plant and equipment is utilised resulting in lower IRR. If a grower was wanting to grow a smaller amount it would be appropriate to dial back some of the capital

investment if possible, particularly around the storage. On the other hand, the greater the area grown, for example 70 hectares, the IRR increases to 20% (Table 5). This increased IRR would be expected, as the plant is fully utilised, and the equipment is more fully utilised.

Table 5: IRR sensitivity analysis comparing yield and hectares of hemp fibre grown

IRR		Yield (t/ha)				
		8	9	10	11	12
Hectares grown	70	11%	16%	20%	24%	29%
	60	5%	10%	14%	18%	21%
	50	-1%	3%	**7%**	10%	14%
	40	-8%	-4%	-1%	2%	5%
	30	-16%	-13%	-10%	-7%	-4%

Hemp seed sensitivity analysis

Table 6 summarises the IRR for hemp seed when yield and hectares grown change. This analysis shows scale is even more important when growing hemp seed compared to growing hemp fibre with the level of capital assumed in each DCF. This can be seen by the lower IRR at the same area grown for seed compared to fibre. The minimum area required to maintain a positive IRR for seed, assuming the bundle of capex used, is 43 hectares.

The maximum area the assumed bundle of capex could support was calculated to be 80 hectares at a yield of 1 t/ha with storage of wet grain being the first item of capital that becomes limiting. It was assumed that two 40 metric tonne 55° silos (80 t total) were used for wet grain storage and two 35 metric tonne 40° silos (70 t total) were used for dry storage. At a ratio of 0.78:1 for weight of dry grain to wet grain 70 t of dry storage could support approximately 90 hectares of hemp seed. If another 40 t silo was installed for wet grain storage then additional dry grain storage of approximately 25 t would be needed. It is highly recommended that if growers are installing storage facilities, to ensure wet storage capacity and dry storage capacity match at the correct ratio, which ensures the capital invested in both wet and dry storage can be fully utilised if needed.

Table 6: IRR sensitivity analysis comparing yield and hectares of hemp seed grown

IRR		Yield (t/ha)				
		0.8	0.9	1.0	1.1	1.2
Hectares grown	80	11%	14%	18%	22%	25%
	70	7%	10%	14%	17%	20%
	60	3%	6%	9%	12%	15%
	50	-1%	1%	**4%**	7%	9%
	40	-5%	-3%	-1%	1%	3%
	30	-10%	-8%	-7%	-5%	-3%

Table 7 summarises the impact changes in yield and price has on the IRR of hemp seed growers. A key point to note around the results in Table 7 is the effect a change in yield has on the IRR. The limited literature available on hemp seed yields in New Zealand suggest yields range from 0 kg to 2,000 kg/ha with the average being around 800 – 1,000 kg/ha (Tupu.nz, 2022; Marsh, 2020). If yields drop below 800 kg/ha at a price of $5,000/t, a negative IRR can be expected. Furthermore, even if prices reach $5,500/t and yield is 700 kg/ha a negative IRR is forecast. If 1 t/ha was the average yield achieved by a grower,

>84% of the crop needs to make the seed processing grade at a price of $5,000/t for the crop to have a positive IRR. It is vitally important that growers understand what average yields they can achieve and what specifications are required by processors to ensure as much of the crop reaches this processing grade.

Table 7: IRR sensitivity analysis comparing hemp seed yield and price

IRR		Sold yield (t/ha)					
		0.7	0.8	0.9	1.0	1.1	1.2
Price ($/t)	5,500	-2%	1%	4%	7%	9%	12%
	5,250	-3%	0%	3%	5%	8%	10%
	5,000	-4%	-1%	1%	**4%**	7%	9%
	4,750	-5%	-2%	0%	3%	5%	8%
	4,500	-6%	-3%	-1%	1%	4%	6%

The key limitations and assumptions to the hemp seed and fibre investment analysis are as follows:

- All analysis is based on a 50 hectare crop and therefore the required capital for this level of scale has been used. It was decided that 50 hectares was the appropriate area to base the DCF off as it provided an appropriate representation of likely scale if farmers were looking to change land use to growing hemp.
- It was assumed that the machinery was to be either new or good quality second hand, with the values used reflecting this. Some machinery may need further investment to alter it in a way that allows it to best harvest hemp.
- For both DCF it was assumed that two tractors and trailers were required for the area grown of 50 hectares.
- Plant costs (drier etc.) for hemp seed were based on a second-hand hemp set up that is currently up for sale.
- Plant costs for hemp fibre was based on a new three-sided hay shed to store the bales.
- These analyses specifically exclude the value of the land utilised in the growing of hemp as it is assumed the landowner already owns the land.
- Yield and price information available was very limited. Price and yield information should therefore be used at a high level only. The analysis presented in Table 4 and Table 7 gives some perspective of what the IRR could look like if yield or price or a combination of the two changed.

Hemp compared to pastoral farming in NZ

For the New Zealand hemp industry to become a viable land use option for current pastoral farmers it needs to be able to compete financially with existing land uses. The operating surplus for hemp seed and fibre are $1,725 and $1,572 per hectare respectively. This compares with the mean operating profit (as measured by EBIT, earnings before interest and tax) of $3,189 per hectare for New Zealand dairy farms in 2020-21 (DairyNZ, 2023). With the mean New Zealand dairy farm profit on a per hectare basis roughly double that of hemp, it is difficult to financially justify dairy farms changing land use to grow hemp. With the methane reduction targets New Zealand is required to achieve by 2050 it is important to investigate how profitability of the average New Zealand dairy farm is with an agricultural emission levy accounted for. Table 8 summaries the effect a changing methane price has on cost of the levy dairy farmers would have to pay and how this levy effects farm EBIT on a per hectare basis.

It is important to note that even at a methane price of $1/kg CH_4 the mean dairy farm EBIT remains over $1,100 per hectare higher than hemp seed (Table 8). This provides additional evidence that it is

highly unlikely dairy farms would consider changing land use to growing hemp solely on a financial basis.

Table 8: Profitability of dairy with an agricultural emissions levy consisting of a changing methane price and fixed nitrous oxide plus CO_2 from nitrogen fertiliser price of \$4.25/t CO_2-e.

	Profitability without levy		Profitability with levy	Profitability change
Methane price ($/kg)	EBIT ($/ha)	Levy ($/ha)	EBIT ($/ha)	Change (%)
$0.11	$3,189	$44	$3,145	**-1%**
$0.20	$3,189	$71	$3,118	**-2%**
$0.50	$3,189	$163	$3,026	**-5%**
$1.00	$3,189	$315	$2,874	**-10%**

The mean operating profit for New Zealand sheep and beef farms in 2019-20 was \$576 per hectare (Farm Facts, 2021). Hemp profits sit well above that of the average New Zealand sheep and beef farm. Of course, only a small proportion of sheep and beef land comprises land use capability (LUC) classes 1-4, which are considered suitable for arable cropping (Landcare Research, 2010). It was reported by Beef and Lamb New Zealand (2022) that North Island sheep and beef class 5 finishing farms had mean earnings before interest, tax, rent and manager wages (EBITRm) of \$1,287 per hectare.

Typically, sheep and beef finishing farms are located on land that has a large proportion of land of LUC of 4 or below that would be suitable for arable cropping. These farm systems already have a level of cash cropping incorporated into the business which provides a diversified revenue stream which would typically occur on the best land and would likely return higher per hectare margins than the livestock enterprise. Typically, the types of crops grown are either wheat, barley or maize. For sheep and beef farmers with arable or cropping systems incorporated into their business, hemp could be used as another crop given the \$285 to \$438 per hectare increase in profit relative to the overall farm average. Further analysis would need to be done to assess the profitability of current crash cropping crops used by these farm systems.

In 2019-20 North Island finishing farms only made up 20% of all sheep and beef farms in the North Island and 36% in the South Island (Beef and Lamb New Zealand, 2022). It should be noted that these percentages are based on farm number and not area. These finishing farms are likely to be considerably smaller in area compared to non-finishing sheep and beef farms. In the North Island finishing farms only make up approximately 11% of the total sheep and beef land. Therefore, the area available for hemp production out of the total seep and beef area would be potentially much less than these percentages.

It is also prudent to assess the effect an agricultural emissions levy would have on sheep and beef class 5 farms profitability relative to hemp profitability. Table 9 summaries the effect a changing methane price has on cost of the levy sheep and beef farmers would have to pay and how this levy effects farm EBITRm on a per hectare basis. With a methane price of \$1/kg CH_4 farm profitability reduced by 11% from the non-levy profit to \$1,146/ha. This analysis further shows that hemp could be a useful land use option for these sheep and beef systems to consider, even more so when an emissions levy starts reducing profitability.

Table 9: Profitability of lower North Island class 5 finishing farms with an agricultural emissions levy consisting of a changing methane price and fixed nitrous oxide plus CO_2 from nitrogen fertiliser price of \$4.25/ t CO_2-e.

		Profitability without levy		Profitability with levy	Profitability change
Farm system type	Methane price ($/kg)	Farm EBITRm ($/ha)	Levy ($/ha)	EBITRm ($/ha)	Change (%)
Lower North Island Class 5 finishing	**$0.11**	$1,287	$20	$1,267	**-2%**
	$0.20	$1,287	$34	$1,253	**-3%**
	$0.50	$1,287	$81	$1,206	**-6%**
	$1.00	$1,287	$141	$1,146	**-11%**

The key limitations and assumptions to the hemp seed and fibre investment analysis are as follows:

- GHG base emissions levels for dairy and sheep and beef analysis were based on Farmax modelling done by McQuillan-Reese (2022b).
- The dairy model was based on a Manawatū dairy farm which used in Farmax Dairy and was based on the 2020/21 DairyNZ Economic Survey data for lower North Island owner-operators.
- The sheep and beef model was modelled in Farmax Red Meat and was aligned with the parameters for the average 2022 Beef and Lamb NZ Class 5 finishing farm in Taranaki-Manawatū region.
- These results should only be used at a high level.

Hemp compared to milling wheat in NZ

After analysing how hemp compares to pastoral farming in New Zealand it is useful to assess how hemp compares to the investment to produce other arable crops such as milling wheat.

Wheat is similar to hemp in that price and yield play a significant role in the level of profitability this crop is able to achieve. It was reported that at a yield of 10 t/ha, which is an average yield in the South Island the breakeven wheat price, is \$400/t and at a yield of 8 t/ha, an average yield in the North Island, the breakeven price is \$500/t (Foundation for Arable Research, 2022). The current average price used in gross margin analysis for milling wheat is \$550/t (Foundation for Arable Research, 2022). Gross margin profits for milling wheat are reported to range between \$1,594 to \$2,500 per hectare. This ranges accounts for milling wheat grown in different locations around New Zealand (Lincoln University, 2022; McQuillan-Reese, 2022b). Hemp gross margin analysis for seed and fibre (Table 2) sits at the lower end of the profitability achieved by growing milling wheat. When comparing DCF analysis between hemp and wheat, milling wheat has an IRR of 12.8% compared to 4.1% and 6.7% for hemp seed and fibre, respectively (Table 8). This is largely due to the lower level of capital investment needed to grow milling wheat. The machinery needed for growing milling wheat is minimal as a result of the significant use of contractors in the production system. This explains why the level of capital is approximately half to three times lower than that of hemp fibre and seed, which includes the cost to own of all plant and equipment in the capital investment needed. As the hemp industry grew, it is possible that third-party contractors may be prepared to invest in the required harvest machinery.

The investment and gross margin analysis indicate that hemp struggles to compete with arable crops such as wheat and therefore it would be unlikely current arable growers would consider adding hemp into their cropping systems. It was reported by McQuillan-Reese (2022b) that arable land uses are

largely less profitable than land uses such as livestock on suitable land, a factor that has resulted in significant trends away from arable cropping in the Canterbury region (one of New Zealand's largest arable growing areas). These results suggest that hemp is unlikely to be a large-scale viable land use alternative to pastoral farming or other arable crops in New Zealand at the current levels of financial performance.

Table 10: Investment summary of hemp vs milling wheat

50 hectares	Hemp seed	Hemp fibre	Milling wheat
Initial capital*	$1,265,000	$877,500	$456,850
IRR	4.1%	6.7%	12.8%
Annual net surplus*	$111,289	$103,639	$79,700
*This is pre interest and tax IRR over 10 years			

It should be noted that milling wheat investment analysis shown in Table 10 is sourced from McQuillan-Reese. (2022b). Some key limitations of the analysis are:

- It was assumed that some machinery was already owned by the business and a $200/ha capital value was given to upgrade equipment.
- All establishment, spraying, fertiliser, harvesting and post-harvest work for milling wheat was contracted out and the appropriate costs were included in the GM analysis. A grain trailer was the only machinery that was purchased and included in the initial capital cost. For hemp it was assumed that the grower had no equipment therefore all equipment was purchased and part of the initial capital cost. This explains why the initial capital cost is significantly lower for milling wheat compared to hemp.
- A yield of 8 t/ha was assumed as the analysis was based on milling wheat being grown in the North Island.

Key considerations of hemp profitability in New Zealand

Although there is lack of publicly available literature on hemp profitability and therefore the results reported in this section should be only used at a high level, this analysis is a significant step forward in assessing the profitability and investment returns for the New Zealand hemp industry from behind the farm gate.

The on-farm part of both the hemp seed and fibre supply chain only makes up a very small part of the overall supply chain (Appendix 3 and Appendix 4). Therefore, further work should look at analysing the processing pathways which exist within each supply chain to gain a better understand of the overall industries current and future economic potential. Without this information, it is difficult to comment currently on the industry's full potential as a viable economic land use alternative for New Zealand's current pastoral farming systems. Conclusions can only be drawn on how hemp performs at an on-farm level.

Further investigation into how sheep and beef class 5 farm profitability would look if hemp was included as one of the crops used instead of the typical wheat, barley or maize crops grown already as part of these systems is needed. If arable infrastructure already exists on farm that would reduce the significant level of capital required however hemp still requires specialised plant and equipment which need to be considered particularly for hemp seed.

Hemp profitability globally

The results shown in Table 3 suggest that growing hemp fibre is a better investment than growing hemp seed in New Zealand currently based on DCF analysis for a 10-year period. On a global scale in 2016, approximately 28,340 hectares of hemp seed was grown compared to approximately 48,580

hectares of hemp fibre- a total of approximately 76,890 hectares (Johnson, 2018). This data potentially corroborates our assessment that hemp fibre is more profitable than hemp seed production. However, it was reported that in 2019 the top 10 hemp producing nations grew 349,797 hectares of industrial hemp (Burton et al., 2022). This significant increase in area grown is largely due to increase in seed production as plant alternative proteins (food and beverage), personal care and paper markets have increased the demand for hemp seed production (Burton et al., 2022). Potentially there is a shift globally towards seed production, from which higher value products are produced. The New Zealand hemp industry is very much in its infancy, with an estimated 1,500 hectares grown in 2019-20 (Marsh, 2020). It could be concluded that fibre is still a better investment option currently but if seed prices increase due to an increase demand domestically for seed products, we could potentially see similar trends here.

Markets

As outlined in Section 2 there are no hemp products currently produced in New Zealand that are exported. This presents a significant opportunity for the New Zealand hemp industry to grow from if export markets were able to be accessed.

Why are export markets key to New Zealand economy?

New Zealand's economy is greatly dependent on international trade, with exports totalling $56.8 billion dollars in 2020, with 66% ($39.6 billion) of this being made up of agricultural exports (OEC, n.d.). On a nominal basis, New Zealand's product exports ranked 54th out of 226 countries and 26th out of 219 countries on product exports per capita (OEC, n.d.). In 2022 New Zealand's exports from the food and fibre sector increased to $53.3 billion making up 81% of New Zealand's total exports (New Zealand Government, 2022), up 15% from 2020.

With New Zealand's remote geographical location and small size in both land area and population, export markets overseas are critical to enabling New Zealand business to grow (New Zealand Government, 2012). New Zealand business are then able to benefit from economies of scale, and to specialise in areas they have an advantage in. Connections with international markets also allows access to resources, knowledge and ideas that can boost businesses productivity and stimulate innovation (New Zealand Government, 2012). It was also stated by that the more successful businesses based in New Zealand means more and higher-paying jobs for New Zealanders.

Export market opportunities for hemp

A research study conducted by MPI in 2019 looked at the potential export market opportunities for New Zealand producers of hemp and hemp products, identified product categories and then undertook more detailed analysis into selected markets and products. It was concluded that hemp seed products such as snacks, skincare and the United States as an export market presented the largest opportunity for the New Zealand hemp industry (MPI, 2019). Further analysis showed that the US had the most releases of hemp products, and a large share of hemp products, with 26% of new hemp products launched globally between 2012-2017, compared to 8.8% of all retail products (MPI, 2019). Germany, Canada, United Kingdom and France were the other key markets where hemp product launches have been between 11% and 5% of all new hemp product launches.

It is also important to note that the study suggested product launches follow trends around the relaxation of regulation surrounding hemp/cannabis products. The five largest retail markets are all countries that have legal hemp cultivation. This suggests that local markets are a common first target for hemp producers, and results in a high proportion of hemp products in these markets, relative to other products - countries that legalise products first can develop their market offering first.

There is no doubt that there are potential export opportunities for the NZ hemp industry but establishing solid domestic market first may be the best approach. As noted above this approach has worked well for other countries who are now significant players in the global hemp industry. Establishing a good domestic hemp market would allow for issues such as regulation processes to be ironed out and secondary market and infrastructure throughout the supply chain to developed. This would most likely enable a much smoother transition for the NZ hemp industry from domestic to export markets.

Export market challenges

A study conducted by Sim et al., (2021) looked at what types of challenges or barriers are faced when firms export goods and services overseas, how do these challenges and approaches differ between types of firms and what do firms do in response to these challenges. The study looked at 574 firms with roughly one third in the manufacturing industry, one third in the food and beverage sector and the rest either in the tech or services industries. There were 56% of firms that were medium sized with between 20 to 200 full-time equivalents (FTEs) and the 42% of firms had a revenue of less than $10 million. In total 24% of firms mentioned North America as one of their key markets. Given the apparent importance of the North American market for New Zealand hemp exports, the challenges identified in this study are likely to be relevant.

The challenges were divided into three broad categories:

- Getting in front of the consumer – entering the market
- Winning the consumer – successfully competing in the overseas market
- Operations and practicalities – staying in the market

The top five results in each category are summarised in Table 11. It is worth noting that market access isn't the biggest challenge facing firms entering into export markets, as was initially proposed by McQuillan-Reese (2022a); rather it is partners and channels.

The "Entering the market" results are probably the most relevant to the New Zealand hemp industry at its current stage of evolution. Further analysis showed that building the profile of their brand, having to use intermediaries to get their products to the consumer and creating partnerships or using other suitable channels to gain market presents were the top three challenges that featured on the surveyed firms' 'game plans'.

Further investigation into a food and fibre company identified participating firms' key challenges when supplying premium functional ingredients and specialty products for leading brand marketers and food manufacturers were:

- Market understanding (Chinese were hesitant to try products).
- Brand awareness (had to spend heavily on marketing their brand).
- Cost and pricing (competitors prices were lower).
- Resources (people on the ground).
- Regulation and certification.

This study and the results give insight into the potential challenges New Zealand hemp companies might face when looking to enter export markets such as the US. Marketing the product and brand awareness would appear to be the most relevant challenges for NZ hemp companies, particularly the volume of new and existing products. Partnerships or using existing channels to get product into market and making consumers aware of it could be a potential solution.

Table 11: Top five key challenges faced by New Zealand companies in export markets from entering the market to competing in the market and remaining in the market. Adapted from Sim et al., (2021)

Observed frequency	Entering the market	Competing in the market	Staying in the market
1	Partners and channels (distributors, retailers, wholesalers)	Brand awareness (creating knowledge of brand)	Governance and planning
2	Regulation and certification requirements of overseas market	Competition	Presence and recruitment ('boots on the ground')
3	Network and contacts (relationships and credibility)	Cost and pricing	Resources (people and money)
4	Market access	Market understanding	Culture and language
5	Supply chain	Conservatism (target markets insularity to foreign products)	Banking and tax

Secondary market

As discussed above, there are several benefits of a secondary market for an industry such as hemp which include:

- Reduced risk to growers
- More growers for processors
- Less wastage (more sustainable)
- Increased market size and profits

Hulled hemp seeds are the only way hemp seed can currently be sold legally in New Zealand. The hulls themselves, the hemp seed cake or meal produced from hemp seed oil production, and the stubble left behind after harvest currently have next to no market. These so-called waste products are considered a valuable stock feed but are unable to be fed in New Zealand because hemp or hemp products used as animal feed are regulated under the ACVM Act 1997 and it is an offence to use any ACVM regulated feed for this purpose (Beef and Lamb NZ, 2020). This extends to its use in food for companion animals. Furthermore, any traces of tetrahydrocannabinol (THC) in lines of export meat could also result in the product being rejected (Beef and Lamb NZ, 2020).

The scale of this potential market has yet to be quantified. It has been reported by Marsh (2020) that 1 hectare (1 t/ha) of hemp seed produces 250 litres of hemp seed oil, with approximately 750 kg of hemp meal/cake produced as a by-product. Hulls from the dehulling process are also a potential waste stream, but there is no literature available to quantify the weight of hemp seed hulls. For fibre in a study by Pecenka et al (2012) it has been suggested that 25% of the stalk is made up of bast fibre, 55% is made up of hurd fibres and the remaining 20% being waste. So, for one hectare (10 t/ha yield) roughly 2 t of the stalk is waste. There was no evidence available to suggest what can be done with this waste.

Regulation

There is no doubt that regulation has impacted the ability of the hemp industry to grow both in New Zealand and globally (Brownlee, 2018). A key reason as to why regulation exists is to ensure levels of THC in industrial hemps products are not too high to cause intoxication. Table 12 summarises the maximum levels of THC allowed to be present in different hemp food products by different countries. To put these numbers in context 1% THC is the minimum THC concentration to cause intoxication (Brownlee, 2018). New Zealand and Australia have strict levels of THC allowed in the plant and different food products. It is interesting to note that the European Union has even tighter rules on THC levels. New Zealand only allows industrial hemp cultivars with low THC levels (<0.5%) to be grown. This means that some cultivars grown may contain higher than the maximum THC levels allowed in industrial hemp plants (Table 12). Regulations are essential in monitoring and testing for THC level to make sure the levels are safe for human consumption. It has been reported by Burton et al. (2022) that low THC cultivars can produce higher than legal levels of THC when gene expression for cannabinoids are expressed when the plant is under stress, i.e., in hot drought like conditions. This further gives weighting to the importance of make sure regulation is in place to monitor THC levels in plants and food products hemp is used in.

The results shown in Table 12 also help provide perspective on the need for understanding international regulation. If New Zealand is to export hemp products the regulatory standards on THC levels products that need to meet may be different from the rules domestically. There are differing THC regulations between countries. It would therefore be important the New Zealand hemp industry is aware of these differences and put processes in place to ensure export products meet the importing countries standards. A 2022 study that looked at the hemp industry on a global scale highlighted the need for harmonised specifications and standardised methodology for testing hemp products for THC to enable easier trading and regulation of hemp between countries (Burton et al., 2022)

Table 12: Maximum THC levels permitted in different hemp food products in Australia, New Zealand, European Union and USA. Adapted from (Burton et al., 2022)

Hemp products	Australia/New Zealand	European Union	USA
Industrial hemp plant	0.35%	0.2%	0.3%
Hulled hemp seed	5 mg/kg	3 mg/kg	4 mg/kg
Hemp seed oil	10 mg/kg	7.5 mg/kg	10 mg/kg
Hemp flour and protein powder	10 mg/kg	3 mg/kg	Not specified
Milled hemp seed as ingredients	5 mg/kg	3 mg/kg	Not specified

It is clear that regulation is absolutely essential in the hemp industry both here in New Zealand and around the world. As mentioned earlier, hemp is still listed as a Class C Controlled Drug under Schedule 3 in the Misuse of Drugs Act 1975. It has been mentioned in a study by Brownlee (2018) that hemp's marijuana connection stigma is perceived as one of the largest constraints to the growth of the New Zealand hemp industry. There is no doubt that there are some fundamental changes that, could be made to legislation to make a clear distinction between industrial hemp and marijuana, such as removing industrial hemp (THC <0.5%) as a Class C drug. Clearing up this so-called "grey" area in the legislation will potentially help the hemp industry to grow, notwithstanding the need for legislation to regulate the industry so the products produced are safe for human consumption.

4 Conclusions

Hemp is a natural food and fibre product that has a wide range of end uses. There are significant opportunities for the hemp industry in New Zealand but there are some fundamental barriers that have to be overcome before this industry could become a commercially viable land use option for pastoral farmers that might be able to make a meaningful contribution to a low emissions primary sector.

This report identified four key barriers that were restricting the hemp industries growth in New Zealand these were:

- The levels of infrastructure required throughout the supply chain.
- A lack of a secondary domestic and primary export market.
- Hemp stigma and the regulation surrounding the industry.

Further analysis on these barriers concluded there were two key reasons found to be significantly limiting hemp becoming a commercially scaled land use alternative for pastoral farming systems in New Zealand.

The production of hemp seed is more profitable than hemp fibre, but further investment analysis showed the hemp fibre required significantly less capital to be invested on farm than for hemp seed production. When the financial analysis for hemp was compared against pastoral farming systems, hemp was significantly below the profitably levels of the average NZ dairy farm, even after a potential agricultural emissions levy was accounted for. Analysis of sheep and beef farms that had suitable land for growing hemp showed that hemp could be a potential cropping option to incorporate into this business which already contain some level of cropping. However, the reality is the number of these farms that exist within the NZ sheep and beef sector are low and therefore these farms alone would not provide for significant land use change from pasture to hemp. At the end of the day if hemp is to become a significant land use option for pastoral farmers to consider as an alternative low methane land use, it needs to have profitability levels competitive with that of dairying.

The absence of a secondary market for hemp seed appears to limit the expansion of the hemp industry. Currently growers are at high risk of not receiving any revenue for seed crops that fail or for seed that doesn't make food processing standards, which will likely reduce the appeal of adoption. A couple of secondary market options were discussed with the most promising market being the pet food market. However, this market isn't currently an option due to regulations around any hemp or hemp product not legally being able to be feed to any animals in New Zealand. This barrier significantly reduces the attractiveness of growing hemp for the limited number of pastoral farms that could potentially benefit doing so.

Regulation was identified as a barrier limiting the growth of the hemp industry. It was concluded that hemp's connection with marijuana and still being listed as a Class C drug impacts the industry's ability to grow at a faster rate. However due to the nature of hemp and the fact that levels of THC in hemp plats and products needs to be highly regulated to ensure food products are safe for human consumption, regulation plays a very important role in enabling the hemp industry to exist.

While hemp plants have the potential to produce great products, until some fundamental barriers are addressed within the industry does it have the potential to be a viable land use option that can compete with pastoral farming systems that exist on the same class of land need for hemp production.

Some solutions to what the sector can do to overcome these challenges include:

- Focus on creating a robust and vibrant domestic market first before looking to export.

- Having multiple businesses within the same area investing in infrastructure to reduce the average weight of capital on any one business, which will improve margins.
- Research into the effects of feeding hemp products to companion animals to enable a potential secondary market. This will significantly reduce risk throughout the supply chain but particularly for growers.
- Improve hemp plant genetics so ensure that low THC cultivars do not produce higher than regulated levels.
- Further research on hemp economics especially beyond the farm gate and around incorporating hemp into sheep and beef farm systems.
- Strategic planning of hemp processing facilities especially around fibre to limit transport costs from farm to processor.

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Appendices

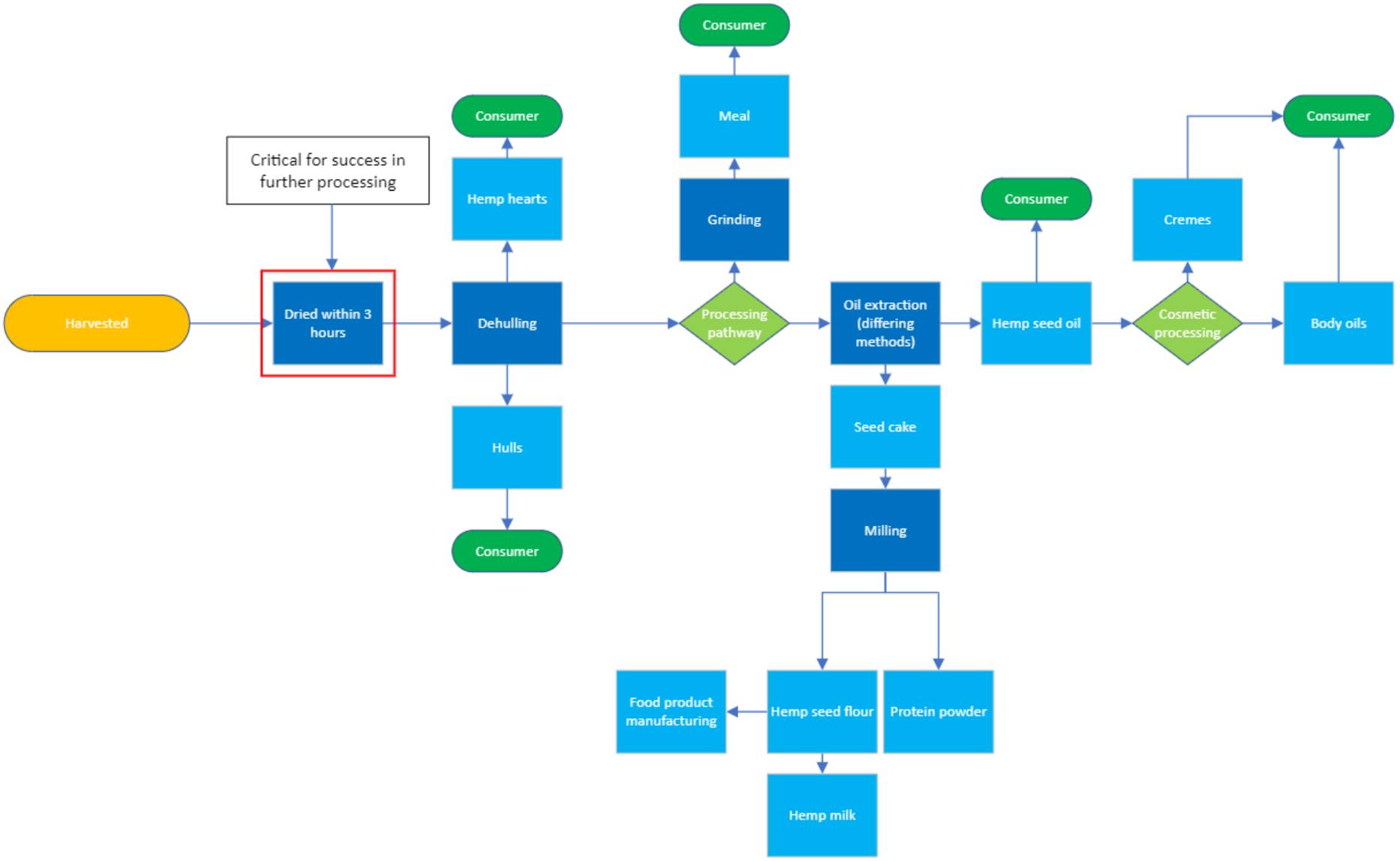
Appendix 1: Discounted cashflow analysis for investment in infrastructure to grow hemp fibre

Years	0	1	2	3	4	5	6	7	8	9	10
Area (ha)		50	50	50	50	50	50	50	50	50	50
Sold yield (t)		500	500	500	500	500	500	500	500	500	500
Price ($/t)		$480	$480	$480	$480	$480	$480	$480	$480	$480	$480
Gross farm revenue		$240,000	$240,000	$240,000	$240,000	$240,000	$240,000	$240,000	$240,000	$240,000	$240,000
Seed		-$40,000	-$40,000	-$40,000	-$40,000	-$40,000	-$40,000	-$40,000	-$40,000	-$40,000	-$40,000
Cultivation/planting		-$12,500	-$12,500	-$12,500	-$12,500	-$12,500	-$12,500	-$12,500	-$12,500	-$12,500	-$12,500
Fertiliser		-$38,350	-$38,350	-$38,350	-$38,350	-$38,350	-$38,350	-$38,350	-$38,350	-$38,350	-$38,350
agri-chemicals		-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500
Irrigation		-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000
Harvesting		-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000
R&M machinery		-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500	-$7,500
Total working expenses		-$130,850	-$130,850	-$130,850	-$130,850	-$130,850	-$130,850	-$130,850	-$130,850	-$130,850	-$130,850
Insurance, administration, legal, license		-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511
Operating expenses		-$136,361	-$136,361	-$136,361	-$136,361	-$136,361	-$136,361	-$136,361	-$136,361	-$136,361	-$136,361
Operating surplus		$103,639	$103,639	$103,639	$103,639	$103,639	$103,639	$103,639	$103,639	$103,639	$103,639
CAPEX											
Storage building	-$187,500										$153,201
Seeder	-$50,000										$9,844
Disc	-$80,000										$15,750
Baler	-$80,000										$15,750
Rake	-$30,000										$5,906
Mower	-$50,000										$9,844
Tractors	-$300,000										$59,062
Trailers	-$100,000										$19,687
Total CAPEX	-$877,500										$289,044
Asset value (plant and equipment)	-$877,500										$263,451
Annual cashflow	**-$877,500**	**$103,639**	**$103,639**	**$103,639**	**$103,639**	**$103,639**	**$103,639**	**$103,639**	**$103,639**	**$103,639**	**$367,090**
IRR (10 years)	**6.7%**										

Appendix 2: Discounted cashflow analysis for investment in infrastructure to grow hemp seed

Years	0	1	2	3	4	5	6	7	8	9	10
Area (ha)		50	50	50	50	50	50	50	50	50	50
Sold yield (t)		50	50	50	50	50	50	50	50	50	50
Price ($/t)		$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Gross farm revenue		$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000
Seed		-$20,000	-$20,000	-$20,000	-$20,000	-$20,000	-$20,000	-$20,000	-$20,000	-$20,000	-$20,000
Cultivation/planting		-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000	-$15,000
Fertiliser		-$42,200	-$42,200	-$42,200	-$42,200	-$42,200	-$42,200	-$42,200	-$42,200	-$42,200	-$42,200
agri-chemicals		-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000
Irrigation		-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000
Harvesting		-$25,000	-$25,000	-$25,000	-$25,000	-$25,000	-$25,000	-$25,000	-$25,000	-$25,000	-$25,000
Drying costs		-$1,000	-$1,000	-$1,000	-$1,000	-$1,000	-$1,000	-$1,000	-$1,000	-$1,000	-$1,000
R&M machinery		-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000
Total working expenses		-$133,200	-$133,200	-$133,200	-$133,200	-$133,200	-$133,200	-$133,200	-$133,200	-$133,200	-$133,200
Insurance, administration, legal, license		-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511	-$5,511
Operating expenses		-$138,711	-$138,711	-$138,711	-$138,711	-$138,711	-$138,711	-$138,711	-$138,711	-$138,711	-$138,711
Operating surplus		$111,289	$111,289	$111,289	$111,289	$111,289	$111,289	$111,289	$111,289	$111,289	$111,289
CAPEX											
Combin (modified to hemp)	-$250,000										$49,219
Drying, storage and handling equipment	-$475,000										$388,110
Tractors	-$300,000										$59,062
Trailers	-$100,000										$19,687
Seeder	-$60,000										$11,812
Discs	-$80,000										$15,750
Total CAPEX	-$1,265,000										$543,640
Asset value (plant and equipment)	-$1,265,000										$543,640
Annual cashflow	**-$1,265,000**	**$111,289**	**$111,289**	**$111,289**	**$111,289**	**$111,289**	**$111,289**	**$111,289**	**$111,289**	**$111,289**	**$654,929**
IRR (10 years)	**4.1%**										

Appendix 3: Existing supply chain for hemp seed (McQuillan-Reece, 2022a)



Appendix 4: Existing supply chain for hemp fibre (McQuillan-Reece, 2022a)