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Potential economic viability of growing industrial hemp (*Cannabis sativa*) at the Taupo, New Zealand effluent disposal site

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Abstract A cost-benefit analysis of growing industrial hemp (*Cannabis sativa*) at the Taupo District Council effluent disposal site, Taupo, New Zealand was compared to the actual costs and returns of the current operation of growing grass cut and sold as silage. The lack of agronomic data from hemp grown in New Zealand meant that major assumptions were made. One assumption was that hemp can be regrown from stubble for a second cut, as long as the first cut takes place before the onset of reproductive growth. If two cuts can be made in a season from a single sowing, hemp might be grown at similar economic returns to the silage operation if fibre prices are NZ$100–160/t. If only a single cut is possible, fibre prices need to be between NZ$220 and NZ$330/t. Prices for both situations are well below the price of NZ$600/t paid for imported fibre from China although the latter price includes the cost of retting. The relative low fibre prices required for achieving the status quo economically in relation to what a manufacturer is prepared to pay for hemp fibre indicates that growing industrial hemp in New Zealand could be economically viable. However, there is a need for field trials to establish hemp yields and to develop agronomic protocols in New Zealand.

Keywords cost-benefit analysis; *Cannabis sativa*; effluent; fibre; industrial hemp

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INTRODUCTION

Effluent was until a few years ago regarded as costly waste which the Taupo District Council (TDC), Taupo, New Zealand treated to remove the solid components and faecal coliforms before discharging it into the Waikato River. Technological advances allow utilisation of nutrients contained in treated effluent in a manner that yields an economic surplus while reducing environmental pollution. The treated effluent is currently irrigated over 135 ha of land on which perennial ryegrass (*Lolium perenne* L.) is grown. The grass is cut and sold as silage to livestock farmers. However, sanitary regulations in countries to which New Zealand exports its pasture products have forced a rethink of this practice (NZ Dairy Board 2001) and alternative crops have to be considered for the site. The criteria for new crops are that they can tolerate the growing conditions (climate and effluent disposal), restrict build-up of nutrients in the soil, provide products not compromised by the microbial loading of the irrigated effluent, and can be grown at a profit or at least at no extra cost to the TDC. The crop considered as an alternative in this paper is industrial hemp (*Cannabis sativa* L.). Hemp potentially produces considerable biomass that has to be carted off site, removing nutrients, and fed into industrial processes that mitigate problems with microbial loading. The hemp crop requires large amounts of water and the fibres are valuable. What is not known is whether hemp can be grown under climatic conditions prevalent at Taupo and whether enough fibre can be economically produced.

This paper considers the economics of growing hemp as an alternative to ryegrass on the Taupo effluent disposal site. A major problem for the analysis is that hemp hasn't been grown legally in New Zealand for many decades. The field trials investigating its potential for New Zealand grown in 2001/02 targeted seed yield for oil extraction and will only have limited relevance to growing *Cannabis* as a fibre crop. Seed crops require different hemp cultivars and plant densities. Harvesting the plant later in its life cycle has implications for fibre quality (van der Werf et al. 1995b; Mediavilla et al. 2001). Because of these factors, hemp fibre production potential has to be deduced from merging data from a variety of sources with variable degrees of accuracy that may or may not be transferable to New Zealand conditions. It is acknowledged that it is tenuous to transfer growth data from high latitude or tropical sites to mid-latitude temperate sites.

METHODOLOGY

The starting point for the cost-benefit analysis will be the current situation of silage production from ryegrass. The revenues and expenses typical for this operation excluding costs that are likely to be similar for both operations were used to generate a gross margin. Based on several values for industrial hemp fibre, the yields required to achieve at least a similar gross margin will be calculated. The likelihood of achieving those yields will be generated from published information from overseas field trials.

Taupo effluent treatment system using ryegrass silage

The TDC has two storage ponds, at the main sewage treatment plant with a storage capacity of 9000 m^3 and at the effluent disposal site with a storage capacity of 18 000 m^3. Both operate at 60% capacity to provide emergency storage capability in case of system malfunctions. The TDC has resource consent to annually release up to 9000 m^3 into the Waikato River, but targets zero discharge. Treated effluent is pumped from the small pond into the large pond daily, from where it is applied to the ryegrass pasture. The daily flow is c. 4800 m^3, which if spread evenly over the whole area is 3.5 mm per day (c. 1275 mm/annum) which is 83% of the system's capacity of 30 mm/ha per week (or 5785 m^3/day).

The chemical composition of the effluent and the average chemical composition of the herbage are listed in Table 1. This is an average composition and values fluctuate by ±20%. Except for potassium (K), cobalt (Co), and selenium (Se), more is applied than is removed, requiring K fertiliser to be applied (with the addition of Co and Se prills) at 200 kg K/ha and a cost of NZ$215/ha (inclusive of transport and spreading).

The silage produced at the site is thoroughly tested for contamination by micro-organisms, and has been well below maximum permissible targets. The silage is sold at NZ$39.50/bale (ex site), bales weigh 575 kg with a dry matter (DM) content of 35–37%. This amounts to NZ$0.186–0.196/kg of DM (NZ$2600–3130/ha). Cutting and baling are contracted out at NZ$23/bale.

Although most of the herbage is removed as silage, some is left behind that when sprayed with effluent results in a slimy mass of algae, herbage, and effluent. When this dries out, it forms a crusty layer on the soil surface, which is very difficult to penetrate, and leads to surface ponding. To overcome this, the area is depugged with a groundhog at least twice a year at an estimated cost of NZ$50/ha per event. Pasture density also deteriorates with the crusting and around half the area is undersown every year at a cost of NZ$75/ha for drilling and NZ$96 (16 kg @ NZ$6/kg) for grass seed. An overview of the income, expenses, and economic surplus of the current operation on the effluent disposal site is presented in Table 2. Only those costs that are specific to silage production are included, as effluent spreading, sprinkler replacement, and all other costs associated with the site are assumed to be the same regardless of the crop grown.

Table 1 Average element composition of the treated effluent brought onto the Taupo effluent disposal site, Taupo, New Zealand. Percentage compositions of harvested silage and removal of elements by the silage.

Nutrient:	N	P	K	Ca	Mg	Na	S
mg/litre	35	9.3	10	12	3	40	15
kg/ha per year applied*	545	145	156	187	47	624	234
Silage composition (%)	3.3	0.48	2.59	0.39	0.21	0.88	0.39
kg/ha per year removed†							
a	462	67	362	54	30	123	54
b	528	77	414	62	34	141	62

*Based on application rate of 1560 mm/year per ha (c. 2.1 million m^3/year over the site).
†Based on a production of: a, 14 t dry matter (DM)/ha; and b, 16 t DM/ha.

Alternative of growing industrial hemp

The technical feasibility of designing an irrigation system that can apply effluent to a hemp crop that grows to 2.5 m high has to be considered. Apart from irrigating the crop without damage, irrigation needs to be without high aerosol production to prevent the distribution of micro-organisms. Consequently big gun irrigators are rejected. Linear boom-travelling irrigators are also rejected because of their high operational labour costs, and side roll irrigators are not suitable for crops over 1.2 m height and neither are current popup sprinklers. Fixed sprinklers were assessed as suitable but are more expensive than centre-pivot irrigators. The price for current popup sprinklers is twice that of a centre-pivot system. The most cost-effective system was a centre-pivot boom irrigator with swing arms. This provides the best area coverage, adjustment possibilities for different field shapes, can be towed to a different area (increasing the effective area covered by a single system), has acceptable aerosol levels and uses the same amount of labour as fixed systems (K. Scott pers. comm.).

Growing hemp at Taupo, New Zealand

Merfield (1999) identified a New Zealand manufacturer who currently uses waste (low quality) hemp fibres from Chinese textile mills and medium grade fibre to produce insulation sheets. The price of imported fibre was NZ$600–700/t (1999 prices), which included transport costs and the cost of retting (done before the fibre enters the Chinese textile mills). Hemp fibre sheets would compete with fibreglass sheets in the insulation market. The insulation sheet market is large but the market share of hemp sheets may initially be small because of limited knowledge regarding the quality and durability of the product. Retting, the process used for fibre separation from the woody core, is necessary if hemp fibres are to be used for textiles or for other high quality industrial products. There are several methods for retting, historically stalks were left in the field and turned over as required (Merfield 1999). Irrigating the field retting stalks may be required to ensure adequate moisture levels. This method is not suitable for the Taupo situation, as it would interfere with potential regrowth from the stubble. Anaerobic storage of green chopped hemp, similar to silage appears to be a suitable alternative (Merfield 1999). It is difficult to ascertain how critical the lack of a hemp processing facility is in order to realise a competitive cost structure for hemp products.

Table 2 Financial aspects of the current silage cutting operations at the Taupo effluent disposal site, Taupo, New Zealand (NZ$/ha).

Item	Expenditure		Revenue	
Bales for sale			$2865	
Total revenue				$2865
Fertiliser	$215			
Cutting and baling	$1670			
Depugging	$100			
Undersowing	$80			
Total expenditure		$2065		–$2065
Economic surplus				$800

Table 3 Costs (NZ$/ha) of growing hemp (*Cannabis sativa*) (Merfield 1999).

Cultivation and drilling	NZ$250
Seed @ NZ$7/kg sown @ 50 kg/ha	$350
Fertiliser (K-based)	$16/t of stalk yield
Harvesting and transport	$100 + $10/t of stalk yield

Merfield (1999) made an estimate of the cost of growing hemp in New Zealand (Table 3). The K content of the effluent is adequate for the first 3 t of hemp produced and K-based fertiliser would only be required for any hemp produced in excess of 3t/h.

Based on calculated economic surpluses in relation to yield and fibre prices (Table 4), if the fibre price was NZ$150/t, c. 12 t of fibre has to be produced to achieve financial returns similar to the current operation. The yield requirement reduces as the fibre price increases from 9 t/ha at NZ$200/t to 5 t/ha at NZ$350/t. The probability of achieving such production levels is examined.

Yield potential of industrial hemp

To determine the yield potential of hemp, use will be made of the following growth rates (van der Werf et al. 1995a,b); from seedling emergence to full canopy cover (90% Photosynthetically Active Radiation (PAR) intercepted) 34 kg DM/ha per day. From full canopy cover to flowering 183 kg DM/ha per day and post-flowering 119 kg DM/ha per day. Seedling emergence after sowing requires 88.3 degree days (base 0°C), generally 8–10 days and full canopy closure requires 340 degree days (base 2.5°C) which takes c. 50–55 days.

Fibre crops need 1900–2000 degree days (base 0°C) in a growing season to mature. Young plants can survive moderate frosts to –5°C. Frosts in September at Taupo (NZ Met service 1977) have in the past occurred at a frequency of 6.3%, the frequency for frosts between –4°C and –5°C was 0.3% and no frosts below –5°C have been recorded. The frequencies are 1.9% and 0% for October and 0.6% and 0% for November. Thus sowing in mid September appears to be relatively safe, especially since it will take 8–10 days for the seedlings to emerge. The accumulated heat units between mid September and the end of January is 1930 degree days (base 0°C), sufficient for a mature hemp crop. Consequently the target date for cutting the crop was set at 31 January. It is questionably if this would leave enough degree days (c. 1650 degree days, base 0°C) for a subsequent cut to produce fibres. The quality of any such fibres would probably be less as would the quantity produced of any such fibres. Hemp grown for fibre requires c. 98 days from sowing to harvest which would bring the second harvest to around the middle of May. Temperature also influences the time from sowing to harvest.

Potential crop yields vary from 10.5 to 18.8 t/ha (Table 5) depending on sowing date and temperature. In most years it should be possible to sow the hemp in mid September with a projected yield of 16.7–18.8 t/ha.

In all published work on industrial hemp, one crop was harvested per sowing. A second crop would be started from seed again with no attempt to generate

Table 4 Economic surplus (yield minus costs) from growing hemp (*Cannabis sativa*) ((NZ$)/ha).

	Price of hemp fibre/t							
Fibre yield t/ha	$150	$200	$250	$300	$350	$400	$450	$500
8	340	740	1140	1540	1940	2340	2740	3140
12	836	1436	2036	2636	3236	3836	4436	5036
16	1332	2132	2392	3732	4532	5332	6132	6932
20	1828	2828	3828	4828	5828	6828	7828	8828
24	2324	3524	4724	5924	7124	8324	9524	10724
28	2820	4220	5620	7020	8420	9820	11220	12620

Table 5 Theoretical yield (t/ha) by 31 January in relation to sowing date and temperature variation relative to the long-term average.

Sowing	Days after emergence	–1.5°C	–1.0°C	–0.5°C	0°C	+0.5°C	+1.0°C	+1.5°C
15 Sep	129	16.7	17.1	17.5	17.8	18.2	18.5	18.8
1 Oct	115	14.7	15.1	15.5	15.8	16.1	16.3	16.6
15 Oct	100	12.6	13.0	13.3	13.5	13.8	14.0	14.2
1 Nov	86	10.5	10.7	11.0	11.2	11.4	11.6	11.8

a second crop from a single sowing. Field retting would probably severely damage the hemp stubble making regrowth impossible. Physiologically the development stage of an annual plant determines whether or not a plant will regrow from its stubble. Flowering in annuals generally indicates that the plant has entered the final phase of its life cycle. Preventing annuals from flowering can turn them into biennials or perennials e.g., annual ryegrass (*L. multiflorum* Lam.), ragwort (*Senecio jacobaea* L.). Therefore if industrial hemp is harvested before flowering has been irreversibly initiated, the plant should remain vegetative and develop shoots to replace those that were harvested. In areas in India hemp is considered a weed and is cut several times a year to control it (N. T. Yaduragu pers. comm.).

There is no published information on the rate of development of hemp after cutting and the assumption made in Table 6 was that the cutting date was comparable to the day of emergence. The cut plants have an established root system which could be an advantage as the plant can invest a greater proportion of assimilates to shoot production. At the same time temperatures gradually decline after February which possibly could gradually slow down development. However, growth starting at higher temperatures would also accelerate development. Table 6 shows the yield potential of a second cutting based on either faster or slower development in relation to temperature deviations from the long-term average. The fibre quality of a second cut is likely to be poorer (shorter fibres) than the first cut, which may limit the potential uses of the second cut and subsequently lower the value of second-cut fibres.

Fibre proportion of total DM produced

The proportion of fibre depends on the length of the growing season, the hemp cultivar used and plant density. The stem makes up c. 85% (range 83–90.8%) (van der Werf et al. 1995b) of the total shoot DM produced, with inflorescences, green leaves, and dead leaves making up the remainder. The bark (stem tissue outside the vascular cambium) of hemp stems contains the longest fibres (up to 20 mm long), whereas the core fibres are short (0.5–0.6 mm). The value of the fibre is determined by its quality, and although quality does not appear to matter much for production of insulation sheets, it does matter for the paper industry, where longer fibres are required which are more highly valued. First-cut fibres may be more suitable for high value uses than second-cut fibres.

Table 6 Theoretical yield (t/ha) of a second hemp (*Cannabis sativa*) crop grown after 31 January and harvested on 31 May (Day 120) in relation to the rate of development and temperature deviations from the long-term average.

Development rate	–1.5°C	–1.0°C	–0.5°C	0°C	+0.5°C	+1.0°C	+1.5°C
+20%	21.8	22.0	22.2	22.3	22.4	22.6	22.7
+10%	20.0	20.2	20.3	20.4	20.6	20.7	20.8
0%	18.2	18.3	18.5	18.6	18.7	18.8	18.9
–10%	16.4	16.5	16.6	16.7	16.8	16.9	17.0
–20%	14.6	14.7	14.8	14.9	15.0	15.0	15.1

Table 7 Bark yield (t/ha) based on projected dry matter (DM) yields (Tables 5 and 6), the time from emergence to harvest, and the regression function % bark in stem DM = $61.0 - 0.100x$ (x = days since emergence).

	% bark	–1.5°C	–1.0°C	–0.5°C	0°C	+0.5°C	+1.0°C	+1.5°C
15 Sep	48.1	7.2	7.4	7.6	7.7	7.9	8.0	8.1
1 Oct	49.5	6.6	6.7	6.9	7.0	7.2	7.3	7.4
15 Oct	51.0	5.8	6.0	6.1	6.2	6.3	6.4	6.5
1 Nov	52.4	4.6	4.7	4.9	4.9	5.0	5.1	5.2
2nd cut, –20%*	49.0	6.4	6.5	6.6	6.6	6.6	6.6	6.7
2nd cut, 0%	49.0	8.0	8.1	8.2	8.2	8.3	8.3	8.4
2nd cut, +20%	49.0	9.6	9.7	9.8	9.8	9.9	10.0	10.0

*Development rate similar to that used in Table 6.

Van der Werf et al. (1994) derived the following regression equation:

% bark in stem DM = 61.0 – 0.100x

where x is the number of days after seedling emergence. The bark component of the theoretically produced biomass, where the stem proportion was considered to be 90% (no inflorescences) is given in Table 7.

It is now possible to compare the estimated returns from growing hemp with the current actual from silage. Assuming the second crop grows at a comparable rate to the first crop, that average temperatures continue to match their long-term average and that all bark can be utilised the fibre prices required to achieve similar economic returns to silage are NZ$100–160/t. Sowing date has only minor influence on this price. If no second cut was possible prices need to be between NZ$220/t and NZ$330/t for 15 September and 1 November sowings respectively. There is no published information on the element composition of hemp stems and fibre. Therefore no statement can be made as to whether hemp can adequately remove nutrients in effluent.

CONCLUSION

Industrial hemp appears to potentially offer attractive economic returns in comparison to the current pasture based operation at the Taupo effluent disposal site. Based on the data presented here and assuming that the current importer of processed hemp fibres would source fibres locally, it would see economic benefits to both the TDC and to the importer. Prices as low as NZ$150/t of fibre would leave sufficient margin to cover the cost of processing the fibre and make it suitable as the basis for insulation sheet production. However there is a need for field trials to both develop an agronomic protocol for growing hemp in New Zealand and to establish its yield potential. The impact of the lack of a hemp fibre processing plant in New Zealand cannot be quantified. Such a plant will be built only if sufficient growers were committed to providing it with raw materials for processing. One major obstacle for this to happen is the current legal restrictions on growing *Cannabis*.

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