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Graduate School of Environmental Studies

Thesis

Cannabis: an environmentally and economically viable method for climate change mitigation.

Author
Marc R Deeley

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Dedicated to

Maree, Ryan, Doug and every generation - present and future.

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Abstract

This thesis examines the problem of global climate change, taking as its starting point the recommendations of both the Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) (1992). It is argued that an approach which *directly* addresses the (scientific) causes of climate change via the *application* of biology and chemistry – termed an 'environmental approach' in this thesis – is better placed than conventional regulatory instruments (i.e. a carbon tax) to fulfil the objectives of the (1992) Convention. Moreover, it is argued that an environmental approach/method has the potential to address other (related) areas of environmental concern, such as the use of chemicals in agriculture and land degradation. Because such an approach would not entail the predominately negative economic effects of conventional regulatory instruments such as 'carbon taxation' it has the potential to be universally inclusive (through choice), extending global participation in the UNFCCC. An environmental approach is therefore elaborated upon which centres on the specific use of Cannabis (in particular, the *Sativa L.* sub-species) as a multipurpose source of biomass and industrial feedstock for energy, agricultural and commodity applications. It is argued that the unique physiological and chemical characteristics of Cannabis make it ideally suited for such applications within the overall objective of climate change mitigation by addressing directly our industrial reliance on fossil fuels and several of the key land-use/management and consumption related causes of climate change. It is concluded that Cannabis cultivation and the industrial utilisation of this crop could be environmentally and economically viable as a method for addressing the problem of global climate change.

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Introduction

Global climate change is arguably the most severe problem that the World faces today. Our climate influences every aspect of life on this planet from our ability to produce food and therefore our future development, to the distribution of biomes and the level of biodiversity that exists in the World – much of which remains scientifically unclassified or unknown. The degree to which climate change effects our lives must not be taken lightly. Take for example the increase in extreme weather conditions around the World which result in devastating droughts in some regions, flooding in others and a generally greater propensity for cyclones, tornadoes and hurricanes due to increased oceanic temperatures. If we continue to upset natures various equilibrium these events will certainly become the norm for a majority of the World's population. While these events will themselves lead to severe ecological problems they will also illicit many equally dangerous socio-political situations such as disputes over water resources and in the creation of 'environmental refugees'.

As this thesis will explore, the present situation is not completely negative in so far as we have both the time and resources to avoid the worst apocalyptic scenarios. Moreover, positive intervention in one area (i.e. climate change mitigation) may have positive ecological implications for others depending on the adopted course of action. Given that human development depends to a great extent on our general (environmental) well being it is in our best interest to make our development (environmentally) sustainable. This philosophy does not hold that human beings should make 'irrational' sacrifices in order to preserve the environment. It does say, however, that we should take into consideration the long-term environmental impact of our actions. In doing so we could ensure equilibrium between human activities and our planet that allows and indeed *enhances* future human development.

This forms the fundamental basis for environmental or 'green' philosophy since its inception in the 1960's with Rachel Carson's emotive – yet scientific – observation that the use of chemical pesticides/herbicides – then heralded as a technological cornerstone of the 'green revolution' – such as DDT, would eventually result in a 'Silent Spring' (1962) given the negative effect these chemicals have on Bird species. The philosophy, however, is best associated with J.E Lovelock's (1979) 'Gaia Hypothesis' which is particularly relevant for the current thesis. In brief, Lovelock's work acknowledges an intimate human/nature relationship within the overall context of an interconnected and dynamic natural world where all events – phenomenon or otherwise – constitute part of a self-regulating living organism ('Gaia'). Regulation is perhaps the 'wrong' word – 'Gaia' as I read it, especially in his later works[1] resembles more of a *chaos of causation* between events where the world would adapt to maintain life – *any life*.

Take for example the problem of rising sea levels attributed to the effect global climate change has on the polar regions. Presuming climate change is enhanced further this 'problem' will, in the *very* long term, theoretically reduce the amount of atmospheric carbon and other greenhouse gases responsible for the 'enhanced greenhouse effect' by increasing the oceanic biota (at the expense of the terrestrial biota) and therefore a key carbon 'sink' – with the possibility of eventually reducing or stabilising global climate change. Human beings are therefore in a unique position as our activities can have positive and (definitely do have) negative consequences not only for ourselves but *all* life on the planet. At this level there has been some philosophical progress borne out of a compromise between the economic imperatives of industrial (or Modern) societies use of natural resources (development) and the realisation that we do in fact have an intimate, moreover, reciprocal relationship with

[1] These include 'The ages of Gaia' (1988) and 'Gaia: the practical science of planetary medicine' (1991).

Gaia. In short, rising sea levels and an altered global climate may not be a problem for Gaia but it is most certainly a problem for humans and an arguably unquantifiable number of other life forms – we *are* responsible creatures!

Thus we have the term 'sustainable development' made practical by environmental policy and economics geared towards addressing the interaction between humans and our environment with an explicit need to secure an adequate environment for future development. In 1987 the World Commission on Environment and Development (WCED) or Brundtland Commission made these connections (i.e. environment, development and future well being) explicit in a report titled 'Our Common future' stating that:

'Humanity has the ability to make development sustainable – to ensure that it [development] meets the needs of the present without compromising the [environmental] ability of future generations to meet their own needs' (WCED, 1987, p8).

We are in a position to make this statement a reality by addressing the problem of global climate change as all life – present and future – would benefit. At a fundamental level of analysis, climate change can be prevented by altering or changing human activities that at present contribute to what is referred to as the 'enhanced greenhouse effect'. While there are several overtly technological options available to reduce, for instance, our reliance on fossil fuels such as wind, hydro, solar and nuclear power; it will be argued that the most beneficial option in terms of addressing other environmental problems - a key objective of the UNFCCC – will be to incorporate climate change mitigation strategy into agriculture.

Using specific forms of biomass (such as Cannabis) within an overall strategy that encourages sustainable agriculture and land management practices with particular emphasis on crop utilisation for energy applications would not only help to restore a balanced (human) relationship with nature by addressing several ecological concerns arising out of modern agricultural practices but would also reduce (to varying degrees depending on how extensively implemented) our need to burn the hydrocarbons that contribute so significantly to climate change.

Science has essentially proven the philosophical position of much environmentally conscious discourse. We are now aware of the extent to which our World – although dynamic in Lovelock's sense – is a closed circuit in which we are an integral (influencing) part and that even our culturally limited (Western) concept or pretension of intelligence necessarily means we have a moral responsibility to at least try and preserve it; even if this turns out to be a solely anthropocentric goal in so far as we are obviously more concerned with our own survival than that of other organisms given the history of human development to date.

Chapter One: ***Climate change and options for mitigation***

1.0 Climate Change

The scientific observation of global climate change is in no way a new activity (Houghton, 1997). Neither is the phenomenon itself, which for millions of years has seen the World shift in and out of ice ages (around 20,000 years since the last ice age), with dramatic fluctuations in the mean surface temperature of the Earth. However, there have been unusually large changes over much shorter periods in the very recent past. Human activities such as burning fossil fuels and land use conversions have artificially enhanced the 'greenhouse' effect leading to a greater proportion of radiation being kept in the atmosphere and in turn reflected back to the Earth's surface resulting in a rise in surface temperature (Houghton; 1997).

Much of the evidence in support of human induced climate change is derived from ice-core data and the fact that since the industrial revolution (the actual date for which data seem available is 1750) concentrations of those greenhouse gases (GHGs) most responsible for climate change i.e. carbon dioxide ($C0_2$), Methane (CH_4) and Nitrous oxide (N_20) have increased by 30, 100 and 15 percent respectively. From ice-core data, these gases are now at higher concentrations than at any time in the past 160,000 years (IPCC, 1996b). Agriculture is broadly responsible for 50 percent of human generated CH_4 and 70 percent of N_2O emissions contributing to 20 and 5 percent of global warming respectively. Fossil fuel combustion and land use conversions (i.e. forest to agriculture, especially livestock production) are responsible for the increase in CO_2 which accounts for 65 percent of the radiative effect associated with the *enhanced* greenhouse effect (IPCC, 1996b).

Enhanced (or accelerated) climate change represents a problem of phenomenal proportions for the maintenance of the natural equilibria on which all living organism's survival depends. Houghton (1997) considers that changes brought about by global warming to the hydrological cycle will have the most impact. We can at present observe many indicators of this disruption in the increasing incidence of extreme weather conditions such as storms, droughts and floods and the devastation that these events cause. Climatic projections (IS 92a) of the IPCC that consider a business-as-usual scenario (in so far as no action is taken) predict an additional increase in atmospheric carbon of 1400Gt with a subsequent rise in temperature of between 5 and 10^{o}C by 2200 and conclude that, **'[t]he associated changes in climate would be correspondingly large and could well be irreversible'. (Houghton, 1997, p102)**

It is estimated that the cost of these changes could be realised as soon as 2050 and would be in the range of 1-1.5 percent of GDP for developed countries. According to Houghton (1997) and IPCC (1996b) *this figure is substantially higher (5 percent) for developing countries due to their greater geographical vulnerability to climatic variations and the fact that more of their income/expenditure depends on agriculture and water resources.* Although extrapolations are difficult given the overwhelming number of variables[2] the total cost could be around 2 percent of Gross World Product (GWP) or 400 billion US dollars *per annum*. This figure is increased, assuming that damage remains over time, giving a cost per ton of carbon of $50.[3]

On a global scale, human activities currently add around 3.3 thousand million tons (Gt) of carbon (annually) into the atmosphere equivalent to a 1.5ppmv[4] annual increase, which represents 45 percent of total emissions (1.5 Gt from changes in land use and deforestation and 6Gt from fossil fuel emissions). The other 55 percent is removed by the land and ocean biota (Houghton, 1997). While this represents a simplified description of the problem there seems little need to repeat the

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[2] How for instance do we adequately account for loss of species (biodiversity) as a result of climate change?
[3] The cost of emitting one ton of carbon now given future damage (marginal cost), calculated using a variable discount rate, means that estimates range between 5 and $125 per t/C (Houghton, 1997).
[4] Parts per million volume.

comprehensive analysis of the IPCC (International Panel on Climate Change, 1990, 1996a, 1996b) especially as this vast body of research will be extensively drawn upon throughout this thesis.

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It has in fact been the weight of scientific knowledge about global warming that provided the impetus for the largest meeting of government representatives ever to have taken place. The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, 1992 (or 'Earth Summit') led to the signing of the United Nations Framework Convention on Climate Change (UNFCCC) by 160 countries. It should be pointed out that responsibility and focus for action lies firmly with the developed countries, resting as it does (other than simply liability) with fiscal ability to implement the objectives of the Convention and the socio-economic structures relevant to this, such as dominant industrial sectors and energy use/consumption.

1.1 Policy: an introduction

This thesis aims to provide a response to climate change complementary to the objectives set out in the UNFCCC (Article 2)[5] and recommendations of the IPCC (1996a, 1996b) based on published and peer reviewed scientific papers (see: www.ipcc.ch). There are several possible options open to policymakers in dealing with this problem, all of which have positive and negative attributes. However, the ultimate defining criteria for a successful policy is to engage the widest possible implementation which is especially important in the context of global climate change – as will become apparent. The scope of this problem necessitates that coherent policy is formulated at an international level in order to ensure that measures adopted nationally are in harmony with each other and targeted at meeting the same objectives. The US would be well advised to *think* globally and act locally.

[5] Article 2 states that: 'The ultimate objective of this Convention and any related instruments that the conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved in a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.'

The UNFCCC (1992), at least in terms of the number of signatories, represented the beginning of such an acknowledgement which could have innumerable ramifications for the future of (especially environmental) policymaking, increasingly taken at the global level.

Of course, many environmental problems are unique in that the consequences of environmental degradation resulting from anthropogenic (human) interference are essentially global. Despite this fact regions can (and do) have different levels of responsibility although some may (and already do) suffer the actual environmental consequences of atmospheric pollution and climate change disproportionately in relation to their emissions. Many low lying (Mozambique, Bangladesh) and small island States (Marshall Islands, Maldives) exemplify this situation (IPCC, 1996b, UNFCCC, 1992).

Although it is of importance that international policy takes account of these disparities in order to achieve successful implementation (or agreement) and therefore the objective of reducing emissions, there are several key questions. For instance, given that energy consumption in the so-called developing world is set to increase by around 70 percent over the next 50 years (IPCC, 1996b), how can this possibly be reconcilable with (some) developed world abatement legislation? Could we justify 'developing' countries being exempt from an international policy and therefore not developing alternative energy systems? Or further, does leaving developing countries exempt from policy merely ensure future markets for predominately Western owned oil conglomerates?[6]

[6] This is not to assume that harmony exists *within* the standard economic categories of 'developing' and 'developed' nations. There is complete dismay in Europe following President Bush's announcement that his country would abandon the Kyoto Protocol, especially as the US is the Worlds' most significant polluter and has an arguably disproportionate influence over global policies.

The implications of these questions are very real and demonstrate that formulating a legislatively practicable, comprehensive and *inclusive* international policy is extremely difficult to achieve. Given that such a policy would ideally, from the policy making perspective, have universal criteria, methodology and be in the most part standardised; it becomes clear that applying this to a heterogeneous socio-economic context is at best problematic and ignores to a certain extent the fundamental problem of climate change and its causes. These ideas will be considered in the context of an analysis of the following type(s) of policy.

- Conventional regulatory instruments
- Taxes and subsidies
- Tradable permits and /or quotas

(Adapted from IPCC, 1996a)

1.2 Market-based and regulatory mechanisms

1.2.0 Regulatory instruments

These instruments would essentially involve the setting of carbon limits for particular industries within a legislative framework that bans, alters or controls polluting activities. The use of this policy instrument within the international context of climate change mitigation is, although desirable in the achievement of the overall objective, highly unlikely. There are several reasons why this is the case. For instance, as mentioned there exist a diverse range of circumstances to which such a policy would have to be applicable. A fundamental area of concern regarding an international regulation would be the possibility of reaching an agreement to begin with. The UNFCCC (hereafter referred to as the Convention) has the basis of an international regulation as targets for CO_2 abatement are outlined but at the same time action to meet this target requires consent of Parties to the Convention for them to be bound by its conditions.

The extent to which a country is bound to the regulatory aspect of the Convention (specifically Article 4 part 2) is fundamentally a decision for that particular country. It is an important fact that countries bound to this regulatory aspect are those categorised as 'developed' (Listed in Annex 1 and 2 of the Convention). Of significance here is the necessarily broad commitment to,

'adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs.' (UNFCCC, 1992)

While the Convention takes account of 'differentiated responsibility' and State sovereignty over their resources/activities, this also serves to make salient the point that it is impossible for some countries to commit to such a regulatory objective. Doing so could jeopardise (inherently) unstable socio-economic structures and would not be an 'equitable' option. Moreover, the imposition of such a regulation – as recognised in the Convention – would be neither a legal or practical option. There is also a problem of definition. For instance, economies in S.E Asia (notably South Korea and Taiwan) are economically and socially developed to a considerable degree having sophisticated, internationally competing economies and are World leaders in many polluting industries (particularly steel, coal and automobiles).

However, due to the desired voluntary nature of the agreement, these countries do not have any obligation to implement Article 4 part 2 of the Convention. Although this (voluntary approach) is totally justifiable in the majority of countries categorised as 'developing' (especially in sub-Saharan - excluding South - Africa and small island States); its universal application does not facilitate the meeting of the objective(s). This point shall be the subject of further consideration at the end of this section.

1.2.1 International Carbon Taxes

This option could take many forms such as an international taxation authority or again could be left to the discretion of participating States. However, as a policy instrument in the mitigation of climate change, it shares many of the problems of an international regulation discussed above. There are also the following points of consideration:

- International inclusiveness
- Agreement on level
- Implementation
- Verification
- Domestic (national) co-operation

The first of these points is concerned with the extent to which a tax could be international. Any country not Party to such an agreement would be at a competitive advantage over other nations in their ability to attract a proliferation of high emission industries at marginally lower tax rates than other countries (under the agreement) could offer thereby creating '***carbon leakage***' (IPCC, 1996a). That country would therefore be increasing emissions to its own economic advantage but most significantly it would be enhancing an environmental problem with (boundless) global ramifications which would be borne by other States. Several so-called ***developed*** States actually provide substantial subsidies to their petrochemical industries, which merely serves to emphasise the problem.

1.2.2 Tradable carbon quotas

In effect, this policy option also requires an international emission level, such as that set in the Convention (a target of stabilising emissions at 1990 levels) and the allocation of emission quotas to individual States based on the global emission total and target. This would share many of the problems characteristic of regulatory approaches given the necessity of emission limits. In addition, such a policy involves an ‘implicit international tax’ (IPCC, 1996a) and will therefore share several problems associated with that particular option. The problems that arise in the trading of such quotas are innumerable as some countries would be better placed to purchase their ‘right to pollute’ if this was deemed necessary by the national government. Although this option is a more practicable ***international*** policy response compared with regulation or taxation there is too much room for abuse. For example, it may lead to the economic pressurisation of low emission countries to ‘trade’ quotas they would otherwise be unwilling to trade/sell, especially if they were likely to suffer as a direct result of global climate change.

The policies discussed thus far have to their credit the potential to allocate a suitable ***price*** to fossil fuels, which takes account of the pollution caused by associated processes and/or activities. These policies, however, could not be imposed at the international level without a certain degree of coercion and infringement on national sovereignty, which necessarily means that the implementation of such policies are left to the discretion (?) of individual (or groups of) States. Essentially, regulation and taxation (mitigation) policy are better suited to individual states rather than global policy in what Pearce et al (1989) term the ‘polluter pays principle’. It would, for example, be more plausible for countries with mature service-sector economies (such as the US or those in the EU) to be in a position to implement a carbon tax than would be the case for a country trying to stimulate heavy industry or being exceptionally reliant on natural resources such as oil, coal or gas.

Because of this there remains a greater or lesser degree of inequity in mitigating the problem of climate change that has much to do with the fact that these policies not actively change anything. If anything they represent a continuation of the status quo or 'business-as-usual' only with more regulation and less profit. The central and arguably defining characteristic of these policy instruments is the implicit (or otherwise) costs associated with them whether or not these are borne by Nation-States, industry or consumers. None of these options come without significant costs.

1.3 Environmental Policy Approach

Essentially this approach acts *literally* on the scientific basis of climate change, considering this basis as a catalyst for solutions rather than market and/or government regulation. Although the aforementioned policies do tackle the problem based on a scientific judgement in so far as the aim to reduce or abate emissions is a scientifically based goal; an environmental approach seeks mitigation through the application of scientific principles (in this case biology and chemistry) as distinct from economic principles. Importantly this is a point that receives appraisal in literature dealing with the problem of climate change. The IPCC (1990, p402) states that,

> **' . . . the greenhouse problem is a pollution problem over space and time, and one in which increased absorption can reduce atmospheric concentrations of greenhouse gases as effectively as reduced emissions.'**

This can be achieved in several ways via:

- Preservation of existing carbon 'sinks'[7]
- Enhancement of carbon sinks

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[7] Sinks, as defined in the UNFCCC, 'means any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere.' At present the terrestrial and oceanic sinks sequester 55 percent of all anthropogenic emissions, the remaining 45 percent is added to the atmospheric composition – resulting in global warming (Houghton, 1997).

•Creation of carbon sinks

These 'sinks' include marine activities (such as the photosynthetic properties of plankton) which account for up to 50 per cent (or 2.1Gt $C0_2$) of the total (4.2Gt $C0_2$) ***sequestered*** carbon (Houghton, 1997). However, this section (and indeed thesis) will concentrate on terrestrial mechanisms as they hold greater potential for enhancement by human activity and have themselves a significant influence over the ability of the oceanic biota to sequester atmospheric carbon. Some of these influences include agricultural run-off, pesticides, industrial pollutants, sewage plus climate change and all the anthropogenic factors attributable to it (Lalli and Parsons; 1993).

Terrestrial mechanisms for $C0_2$ sequestration are mostly associated with the chemical conversions that occur in green plant tissue (chlorophyll) in the process of photosynthesis. Plants require large quantities of (especially) CO_2 in order to grow, releasing oxygen as a 'by-product'. CO_2, which represents 50 per cent of greenhouse gases (GHGs) (IPCC, 1996b), is converted along with other chemicals (or assimilates) into food by the plant. The resulting growth and storage of carbon is realised in terms of **biomass**. It should be noted that mature forests, such as those found in tropical regions of the World represent climax vegetation that absorb only small amounts of Carbon compared to new plant growth.[8]

Only those (developed) countries listed in Annex 1 of the Convention are committed to 'protecting and enhancing its greenhouse gas sinks' (Article 4, part 2a). The reason for which is that for many of the Worlds countries these areas represent important sources of income. In effect they are a natural resource and under international law the sovereign state has ultimate control over their exploitation, regardless of the environmental consequences of doing so.

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[8] This is not to trivialise these areas; they are protected by international agreement (CBD, signed at Rio 1992 by 153 countries plus the EU) protecting the biological diversity located in these, mainly tropical regions. In addition, old growth forests represent a substantial store of above and below

ground carbon the removal of which becomes a source of atmospheric carbon and other GHGs (IPCC, 1996b).

Of major concern is the fact that a substantial proportion of these areas are being turned into *sources* of greenhouse gases, as fertile, often forested land (as a scarce resource) is converted for agricultural uses such as livestock or that the (*natural*) biomass is used as (firewood) fuel.[9]

> **'Deforestation, the changing of land out of forests, is the single most important land use related cause of the increase in atmospheric concentration of carbon dioxide.' (Adger and Brown, 1994, p233)**

Formulating an international agreement using a scientific-environmental approach to mitigating climate change is certainly not an easier task than is using the market-based or regulatory mechanisms. However, what is apparent is the possibility for an agreement based on, for example, reforestation. Such a policy would be directly in line with the commitments (Article 4) agreed to under the Convention; including the Annex 1 (developed) countries additional commitment to provide financial assistance for developing countries to achieve the Conventions objective(s). Provided, of course, that other international agreements (i.e. Convention on Biological Diversity) are respected in the process. For instance,

> **'(a)s much as 60 percent of Indonesia's roughly 2 million hectares of plantation (forestry) is thought to have directly displaced natural forest.' (Adger and Brown, 1994, pp24-25)**

A balance therefore must be struck between economic and environmental objectives where any international agreement is concerned. In several respects plantation forests are not the solution, although given that World consumption of paper (275 million tons in 1995) is expected to increase to around 480 million tons in 2010 (Mattoon, 1998, p20) it is certainly an *economically* attractive option for governments or the speculative investor[10].

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[9] See section 3.5.0 paragraph four.

[10] Global paper manufacture also accounts for a substantial proportion of industrial effluents released to water and therefore impacts on terrestrial and marine environments negatively.

One of the key disadvantages of plantation forests is the time (5-25 years) required (especially in the beginning of such a project prior to the establishment of a growth cycle) before any economic benefits can be accrued. This fact goes some way to explain why plantations have displaced many natural ‘old growth’ forests. Thus the option of plantation forestry is less attractive or literally impossible for the small landowner or farmer given the scale and initial investment required.[11] This fact is reflected in the comparatively small amount of forests that are managed for goods and services.[12]

An ideal environmental policy approach to climate change mitigation would include the following objectives:

- Sequestration of atmospheric carbon dioxide.
- Prevent the destruction of natural ecosystems (biodiversity).
- It would not burden developing countries with costly socio-economic regulations.
- It would not require significant changes to current land use (i.e. displacing people or activities).
- It would have a minimal environmental impact and/or address other environmental/pollution problems.
- It would also provide (socially equitable) economic incentives for ***global*** implementation.

(Adapted from UNFCCC, 1992 and IPCC 1990,1996a, 1996b)

[11] IPCC (1996b, p786) considers the average cost of plantation forestry to be around $400/ha.

[12] Forests globally cover 4.1Gha, 0.1Gha are plantations and 11% of the total are managed. This varies by region as 20% of mid-latitude, 17% of high latitude and less than 4% of low-latitude forests are managed (IPCC, 1996b, p776).

This thesis follows and elaborates on the conclusions reached by the IPCC (1996a, 1996b) which hold that it is advantageous to have a cross-sectoral (or multi disciplinary) approach to the problem of climate change given the context in which policy decisions must be taken. Linking policies in the areas of transport, agriculture and forestry with the cross-sectoral dimensions of energy, land use and society's demands for resources is integral to establishing effective mitigation policy. *Crucially, it is the strategic use of biomass in the energy sector which not only meets the above objectives but directly reduces emissions, in addition to sequestration, by substituting for fossil fuels*. One definitive argument arising from the work of the IPPC demonstrated in both the model of Low CO_2-Emitting Energy Supply Systems (LESS) and Integrated Model to Assess the Greenhouse Effect (IMAGE 2.0, IPCC, 1996b) is that the strategic utilisation of biomass in the above areas will have the most profound mitigation potential in both present and future scenarios.

'If the development of biomass energy can be carried out in ways that effectively address concerns about other environmental issues and competition with other land-uses, biomass could make major contributions in both the electricity and fuel markets, as well as offering prospects of increasing rural employment and income.' (IPCC, 1996b, p15)

However, conclusions are sensitive to many of the key assumptions, 'such as the productivity of biomass energy plants, the rate of technological progress in agriculture, and the rate of population and income growth' (IPCC, 1996b, p816). Climate change also posses problems for the growth of 'new' biomass and for the areas of natural and plantation forests that already exist given that small (1^{o} C) alterations in mean annual temperature can potentially affect the 'geographic distribution of biomes – i.e., biogeographic regions' (IPCC, 1996b, p101). The implications of this means that while a standardised approach to biomass (i.e. for energy purposes) is highly desirable in terms of processing costs, the choice of biomass is an important factor given that climate change will continue for many years after atmospheric carbon levels have been stabilised.

Annual and perennial crops are far less vulnerable to changes in climate than are slow to medium growth forests (IPCC, 1996b, p389) and some share many of the bio-chemical characteristics of hardwood – as will be demonstrated in chapter two.

The utilisation of biomass in agriculture and industry represents an economically favourable alternative to, for example, the regulatory or 'top down' price fixing of fossil fuels – which in the long term will only achieve mitigation objectives through economically negative activities. Moreover, it will be argued that an environmental policy for climate change mitigation has greater practical potential in terms of implementation, inclusiveness and in meeting the objective of mitigation itself. The next chapter will detail the physiology and subsequent arguments for the integration of Cannabis into (perhaps) a World Agricultural Agreement with the central objective of mitigating climate change within the guidelines of the UNFCCC and IPCC recommendations.

<u>Chapter two: *Cannabis*</u>

2.0 *Cannabis:* an introduction

The name, *Cannabis* refers to a large, and as yet unquantified, population or family referred to collectively as Cannabinaceae which includes Cannabis, Humulus and possibly Humulopsis (Clark, 1999). The world's leading researcher on this topic, Ivan Bocsa (1998), considers this family to include only Cannabis and its sub-species. It is, therefore, the former category (Cannabis) on which this piece of work will focus. Within the Cannabis gene pool there are three main sub-species: *sativa*, *indica* and *ruderalis* – the latter being a wild or weedy form. All share the fact that they grow spontaneously or otherwise 'throughout nearly all equatorial to subarctic regions of the world' (Clarke; 1999, p13). In addition, all Cannabis genera are fully interfertile with one another.

For the purpose of clarity, it must be pointed out that while the taxonomic group *Cannabis* is applied in this chapter, there are many genetic distinctions between say 'hemp' (*Sativa L.*) and the *Indica* or *ruderalis* sub-species. Among these is the propensity to produce the chemical *delta*-9-THC, which is illegal in the vast majority of countries and therefore carries implications of an environmental, biological, economic and political nature for this thesis[13]. The variety commonly referred to as 'hemp' constitutes one, albeit broad, genera of the Cannabis family that belongs to the *sativa L.* grouping. These particular cultivars contain negligible to zero quantities of the chemical THC. European cultivation of hemp has been limited to three gene pool sections covering the following ecotypes: Northern and Central European, Southern European and East Asian. When taken together with the differences that also exist within each individual (ecotype) grouping, this gene pool (Cannabis) consists of an extraordinary level of genetic diversity in terms of ecotypes

[13] This fact will be addressed more fully at a later stage.

(geographic/climatic location), genotypes and their subsequent phenotypes (actual characteristics) and end use value.[14]

2.1 Physiology

Cannabis is an annual herbaceous crop that requires planting in the early spring as flowering is induced by longer nights (or shorter days). The characteristic growth pattern of varieties (hemp, *Sativa L*.) grown in the European (temperate) climate display 2-3 months of vegetative growth preceding a flowering cycle. Essentially, Cannabis is dieocius having distinct male (Y) or female (X) plants (usually of the ratio 1:1), the latter having most economic value and taking slightly longer to mature given the extended flowering cycle (Bocsa and Karus, 1998). Because Cannabis is anemophilous (wind-pollinated) the male plants, which mature faster, can be spotted and if desired by the cultivator be removed from the crop. Removing male plants is dependent on the use to which the crop is being put. For instance, if the crop is to be used for fibre, the female plants can mature for up to five months after flowering if no fertilisation occurs (Clarke; 1999). On the other hand, crops being produced for seed or oil will require male/female fertilisation to occur and so the male plants can be removed after fertilisation occurs to leave more room for the female plants to grow. The existence of monoecious (male and female flowers on one plant) varieties has enabled breeders to establish some cultivars to circumvent these breeding/cultivation restrictions (Clarke, 1999). In the EU,

> **'(t)he 32 commercially available registered hemp varieties consist of twenty-two monoecious, nine dioecious, (and one uni-sex female) sexual types'. (Clarke; 1999,p16)**

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[14] It is the author's aim to put forward a non-discriminatory account of this species considering both it's naturally occurring (and human) induced diversity. The intricacies pertaining to the Cannabis gene pool are of great interest, especially in terms of the wider theoretical ramifications for this thesis. As a result more attention will be devoted to this area at a later point.

End use is therefore an important factor in terms of crop management as the usual 4-6 month lifecycle can take anywhere between 2 and 10 months depending also on the location. For example, fibre crops can be harvested before flowering occurs thus negating some of the variables associated with a particular cultivar (van der Werf et al. 1999). This flexibility of use and/or management makes it ideal as a rotation crop. In addition, research has demonstrated improvements in soil quality of the land used for Cannabis cultivation when in rotation with other crops (Roulac, 1997). It has also been argued that Cannabis is entirely sustainable as it **'suppresses weeds and is virtually free from disease or pests'**[15] (Ranalli; 1999, p64) and therefore requires only modest levels of (organic) fertilisation. Because of these characteristics there are improved yields (up to 10 percent) of the crop following Cannabis when in rotation (Roulac, 1997)[16] and reduces or eliminates the need for herbicides.

Such observations tie in with the fact that *annual herbaceous* crops are generally leguminosae and have the ability to nodulate and fix (atmospheric) nitrogen (Lopez-Real, 1981). This is a possibility requiring investigation where Cannabis is concerned given the species sizeable and woefully under (scientifically) researched genetic pool. Another highly significant characteristic of Cannabis, probably emanating from genetic inheritance from weedy (*ruderallis*) forms is the possible ability to grow on degraded *and* even polluted land. Ranalli (1999, p69) points out that Cannabis is, **'able to extract heavy metals from the soil in amounts higher than many other agricultural crops'.**

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[15] Due to hemp's (Cannabis sativa) rapid early growth and the density of the crop, strong weed suppression is virtually guaranteed. Even thistles and couch grass are killed off by hemp (Bocsa, 1998). This situation may not follow where extremely poor soil conditions are prevalent. In addition, pest resistance could be undermined when cultivated in plantation conditions i.e. continuous cultivation in monoculture (Bocsa, 1998).

[16] This is verified by Hemcore UK Ltd, who contracts hemp cultivation with farmers in the South East of England (Roulac, 1997).

The aforementioned characteristics mean that Cannabis requires very modest fertilisation and little or no herbicides or pesticides when in a rotation cycle (van der Werf et al, 1999). This holds obvious enviro-economic advantages making the complete integration of Cannabis into all agricultural systems highly desirable in terms of both improved and created sustainability. When considered in conjunction with the use value of this crop, these attributes have serious implications for the future viability of more environmentally damaging crops such as cotton (*Gossypium L*.) which could be displaced by 'hemp' (Cannabis variety most favoured for fibre production) in a (more) sustainable textile industry (Alden et al, 1998). Or - farmers could rotate their cotton crop with Cannabis to reduce the chemical input required by the cotton crop. More attention will be paid to overtly economic arguments in the following section although it is often difficult to separate such interdependent issues.

Hemp (*Cannabis sativa L.*- hereafter referred to simply as Cannabis) is a green plant of the C_3 variety, (Geof Kime, Hempline Inc., personal communication; 1999) which means that during photosynthesis a three-carbon compound is produced. Other plants that share this (C_3) physiology include sunflower, rice, wheat and potato (IPCC, 1996b). While this remains constant, it should be pointed out that many of the different phytochemical characteristics associated with this crop are strongly dependent on the environment. It has been demonstrated that geographical situation can have the most profound effects given the varying temperatures, precipitation and seasonal variations that this entails, causing alterations in the biochemical pathways of the plant and thereby inducing several distinctions (Pate; 1999). One such example of this environmental influence over Cannabis is the production of *Cannabinoids* (chemicals unique to the C. family) which has implications for the international production of Cannabis.

The production of these chemicals (over sixty such metabolic compounds) in Cannabis serve several functions for the various ecotypes and so appear to be closely linked to the environmental variables or abiotic factors, often referred to as *stresses* that can effect an organisms survival. A useful examination of the interplay between environmental factors and plant physiology is provided by Pate (1999) who draws on a substantial amount of empirical research. Of particular interest is the climatic influence over the production of Delta-9-Tetrahydrocannibinol (THC) which contributes to the 3000 year old use of Cannabis for treating a diverse range of human medical conditions (Clarke; 1999). The production of THC and terpenes (unsaturated hydrocarbons) are most frequent in the *indica* sub-species which are predominately found in the equatorial and tropical biomes. These compounds, **'can be seen as analogous to the waxy coatings of the cacti and other succulents that serve as a barrier to water loss' (Pate; 1999, p26).**

There is evidence to suggest that cannibinoids (such as CBD and CBG) found in the varieties of low THC Cannabis grown for industrial purposes in temperate climates are in fact precursors to THC. And moreover, that their composition changes when UV-B radiation increases (280 to 315nm) given the apparently higher absorption properties of THC.

'CBD-rich English Cannabis devoid of THC produced significant amounts of THC and less CBD, when grown in the Sudan. This trend was accentuated in the next generation of plants.' (Pate; 1999, p27)

These observations have led to the conclusion that, ***'cannabinoids and their associated terpenes provide a survival advantage to the plant, particularly in the tropical biome'*** (Pate, 1999). One implication here is that different genera may possess enhanced rates of photosynthesis perhaps closer to those of C_4 crops (i.e. those producing a four carbon compound). This would be of most benefit where *genetic diversity* is concerned over potential rates of atmospheric carbon take-up: a point that will be discussed shortly. It has also been found, more generally, that THC production increases with the amount of stress placed on the plant such as when growing conditions become less favourable which covers several parameters including soil quality, low humidity and sparse rainfall (Latta and Eaton; 1975). Stress also occurs from damage to the plant by insects to which Cannabis has three primary defence mechanisms consisting of, **'a generous covering of nonglandular trichomes, emission of volatile terpenoid substances, and exudation of the sticky cannabinoids'. (Pate; 1999,p29)**

All of these substances are found in greater concentrations on the inflorescence (reproductive areas) than in leaves and are, therefore, in higher concentrations in the female plants (Pate, 1999). It would be fair to assume that all these defence mechanisms protect the long-term survival of the genera in so far as they ensure fertilisation and seed (the *scientifically* correct term being a fruit or nut; Bocsa and Karus, 1998) production. Given these facts the main implication for this thesis is that cultivars selected for their ability to produce fibre and seed in a temperate climate would adapt to both equatorial and tropical biomes by increasing their cannabinoid and terpene content. This process of adaptation could be enhanced greatly by crossing temperate varieties such as hemp with indigenous ecotypes of Cannabis. While the concluding chapter will consider in more detail the surrounding issues, de Meijer (1999; p149) argues that,

> **'(d)omesticated drug strains and truly wild populations may be an important source of novel alleles for various future breeding aims, including fibre hemp breeding.'**

The European or temperate cultivar, 'hemp' adapts to much the same climate as wheat, requiring an annual rainfall of about 0.65 m. Equatorial and tropical cultivars do have mechanisms to cope with desiccation (see above). However, given that most research into crop physiology has been located in temperate latitudes, it follows that the cultivars used are selected primarily for their fibre and to a lesser extent 'seed' content. Again the end-use (in conjunction with cultivar) determines variables such as crop densities, sowing date, and harvest date which in turn effects dry matter production – this being proportional to Photosynthetically Active Radiation (PAR) (van der Werf; 1999). In ideal conditions, dry yield **$(Y) = L \times RUE \times HI$**[17]. For the purposes of this work it is necessary to count the entire plant in this equation as we are interested in the total or gross rate of photosynthesis in relation to ***total*** biomass rather than (just) dry product of *economic* value, although this is important. Essentially this is because total sequestration of atmospheric carbon can only be established by considering the entire plant or total biomass production (TBP).

Density of planted seed is a critical factor (along with sowing date, see below) in establishing canopy formation and therefore biomass per ha^{-1}.[18] For example, when the same cultivar is planted, all other factors being equal, at different densities i.e. 120 m^{-2} and 50 m^{-2} the respective yields would be around 15 t/ha^{-1} and 20 t/ha^{-1} (van der Werf et al; 1999, p95). This again, however, represents the *economically valuable* matter. Due to self-thinning at higher densities the amount of matter subject to biotic and abiotic decomposition is severely under estimated. Van der Werf et al (1999) considers this (economically wasted) biomass to be around 3 t/ha^{-1}.

Densities also vary considerably between crops grown for seed[19] ($4/m^{-2}$) and fibre ($100/m^{-2}$)(Clarke; 1999, p2) and can vary anywhere between 4-30 plants per m^{-2} for seed and 50-750 plants per m^{-2} for stem/fibre production (Ranalli; 1999, p67). A fibre crop, with a typical dry stem yield of 15 t/ha (60-70 percent of total biomass) has other components of roots (10 percent) and leaves (20 percent) which represents the total biomass that would also include seeds (5-15 percent) if left to flower

[17] L equals the amount of **light** intercepted during a growing season. RUE is the **radiation use efficiency** (the amount of dry matter produced per unit of light intercepted), and HI is the **harvest index** - the proportion of total dry matter consisting of plant parts of economic value (van der Werf et al, 1999, p88).
[18] **Ha is the abbreviation for hectare, this being equal to 2.471 acres. Symbol 't' refers to tons.**

(Ranalli, 1999). Total biomass production of this typical (fibre) crop would then be about 20 t/ha, increasing to around 23 t/ha when accounting for self-thinning[20].

The root system (10 percent of TBP) is also ecologically important as this can also help to prevent soil erosion. Cannabinaceae primary root can reach depths of up to 2.5 metres although this depends on several factors including cultivar, ecotype and soil quality (Bocsa and Karus, 1998).

Radiation use efficiency (RUE) increases dramatically when the crop canopy is formed which depends also on the date of sowing. For temperate cultivars (hemp), sowing can occur early (March) in the growing season as the seedlings are able to withstand a short frost of up to – 8° to – 10° C (van der Werf et al; 1999, p90). Thus, early planting using late flowering cultivars for fibre production in a temperate climate will increase the RUE and will in turn increase the total biomass (dry stem yields up to 18 t/ha; van der Werf, 1999) before harvesting. The optimum rate of planting for such cultivars for obtaining (maximum) dry stem yield is around 90 per m^2 (Ranalli, 1999).

2.2 Cannabis and climate change

Like all green plants and agricultural crops there is, for Cannabis, a delicate balance for photosynthetic potential, increased levels of atmospheric carbon dioxide and variations in other plant assimilates. This is made even more salient in terms of the interplay between biosphere and atmosphere as there are links and interplay between every aspect, an idea reinforced in the introduction when considering the 'Gaia Hypothesis'. Increased $C0_2$ and increased temperature impact on every possible

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[19]The lower seeding rates characteristic of seed production would mean later canopy closure and a lower initial primary biomass production countered only by the fact that there would be less self-thinning of the crop due to less competition for PAR (Ranalli; 1999).

[20] Self-thinning has environmentally beneficial aspects for agriculture as canopy formation of the Cannabis crop develops, old growth (leaves, which are high in Nitrogen) die and so perform a self- mulching function, creating in effect a mini-ecosystem fertilising the soil, preventing soil erosion and run-off (Roulac, 1997).

variable that plants require for growth, as this section will explore. In addition, the ability for any crop (or indeed agricultural practice) to contribute towards climate change mitigation will depend on the extent of ***total*** benefits rather than simply the amount of atmospheric carbon that can be converted into biomass during photosynthesis – these aspects form the focus of the following sections and chapter three.

Since all plants require carbon dioxide ($C0_2$) for growth there are feedback mechanisms of climate change which mean that under enhanced $C0_2$ conditions plants will in *theory* benefit in terms of greater yields (Leemans et al; 1996). Weerakoon (1999) experimented with rice seedlings, which like Cannabis is a C_3 crop, and found that in controlled environments with atmospheric carbon of 895ppmv (well above the X2 CO_2 or 'business-as-usual' scenario used by the IPCC, 1996b) photosynthesis increased by 50 per cent and biomass was also significantly enhanced. However, it would be premature to draw conclusions from such work as environments vary considerably in terms of precipitation and soil quality, aspects (to name but a few) clearly missing from the controlled environment of a laboratory. As most climate change models operate at X2 atmospheric carbon – as compared to the 280ppmv in 1700, which is now at a 1.5ppmv per annum increase over the 1994 level of 360ppmv (Houghton; 1994) – it follows that work concerning the adaptation of plants also use this baseline or 'business-as-usual' scenario.

According to Bazzaz and Sombroek (1996) the biomass production of C_3 plants will increase by roughly 30 per cent in conditions of X2 atmospheric carbon provided other factors remain constant. At present (given that we are at approximately 369ppmv) this 30 per cent can be reduced to around 10 per cent. Since biomass is the resulting product of the photosynthetic conversion of atmospheric carbon, the most accurate way to establish carbon uptake is to examine the productivity rate of Cannabis in terms of total biomass production (TBP). From the data in section 2.1 a figure of around (TBP) 23t/ha can be assumed. However, there exists little data to verify an exact figure for the amount of carbon sequestered during photosynthesis and estimates range between half (Houghton, 1997) and one third of TBP (Geof Kime, Hempline Inc., personal communication; 1999). Thus it could be assumed that around 11.5 t/$C0_2$ per ha is sequestered if half of TPB or 7.6 t/ha if one third giving an average of 9.5 t $C0_2$ per ha.

Assuming increased biomass as a result of the CO_2 fertilisation effect would increase this figure (at today's atmospheric carbon level, see above) by approximately 10 percent. This however is tenuous given the possibility of negative feedbacks to offset such advantages by for example decreasing water use efficiency (Bazzaz and Sombroek, 1996). The CO^2 fertilisation effect is ***not*** therefore accounted for in the energy calculations - where per/ha yields of Cannabis form a key variable - given in chapter three.

It is apparent from this section that there are many physiological and phenotypic factors that would serve to make Cannabis resilient to climate change. For instance, the ability to adapt to dry conditions and the possibility that Cannabis could retain its water use efficiency under such conditions would enable the plant to take full advantage of the 'fertilisation effect' of increased atmospheric carbon. As yet no research has been conducted to elaborate more fully on this possibility. In addition many further advantages could be derived from the substantial gene pool of Cannabis in terms of climate change adaptation, increasing the sustainability of agriculture and (more generally) for specific economic uses. The next section will elaborate in some detail how the Physiology of Cannabis translates into an array of economically significant end-uses.

2.3 Economic productivity of Cannabis

2.3.0 Seed

Thus far mention of the Cannabis 'seed' has been in the general context of overall biomass production or yield. However, one of the important aspects of this plant is that although referred to as seed (which technically speaking it is), the Cannabis plant actually produces an 'achene' or fruit.[21] In the context of a world agricultural system that, since the so-called 'Green Revolution' of the 1960's, has seen massive increases in the production of protein deficient and chemical dependent cereal crops, the introduction of Cannabis into agricultural systems could represent a return of sustainable plant based protein. According to research (Pate, 1999), the achene (nut or fruit) contains 20-25 per cent protein, 20-30 percent carbohydrates and 10-15 per cent insoluble fibre, 25-30 per cent oil as well as a rich variety of minerals. These include phosphorus, potassium, magnesium, sulphur, and calcium with modest amounts of iron and zinc.[22]

Cannabis achene is therefore a very useful and easily digestible food source for both humans and animals (Pate, 1999). Particular benefit could accrue to domesticated ruminants (cattle) whose diet are quite poor and results in the emission of a substantial proportion of methane (a pervasive and significant GHG, see section 1.0) (IPCC, 1996b, p757). Research into the role of Cannabis in this area of climate change mitigation could therefore have many positive implications. Food or 'seed cake' is obtained by either 'cold pressing' or using higher temperature techniques which remove a greater percentage of the oil (Pate; 1999). This depends largely on the

[21] Cannabis seed contains negligible trace quantities of the psychoactive substance THC (Pate; 1999, p246)

[22] Zinc is an important enzyme cofactor for human fatty acid metabolism. It is also a fair source of carotene, a "Vitamin A" precursor, and is a potentially important contributor of dietary fiber…No other single plant source offers a more favourable human dietary balance of the two essential fatty acids, combined with an easily digestible complete protein'. (Pate; 1999, pp243-252)

use and market for which the food is destined i.e. animal feed, oil production or human consumption.

Yield of oil is equal to around 33 per cent of seed weight (Geof Kime, Hempline Inc, personal communication; 1999) so at a yield of approximately 1350 kg/ha[23] we would expect around 450 kg/ha of oil. This oil is a valuable commodity as it can be used to many ends (summarised in section 2.4) including fuel oil (Kerosene directly displaced hemp oil as a source of lighting fuel, Clarke, 1999) for motor vehicles.

2.3.1 Stem

As the reader will be aware from previous sections, Cannabis (in particular the *Sativa L* genera – 'hemp') has been referred to as a 'fibre crop'. There are several uses to which this fibre can be put depending on the content of the stem which is determined by cultivar, development stage (age) of the plant (Ranalli, 1999) and also appears to be affected by plant density (van der Werf, 1999). Broadly speaking, the stem can be split into two (consistent) components of bark and core, which differ in their chemical composition. For example, in an Italian cultivar, bark (or bast, contains primary and secondary fibres) contained 67 % cellulose, 13 % hemicellulose, and 4 % lignin while the Core ('woody core' or shives) contained 38 % cellulose, 31 % hemicellulose, and 18 % lignin (Ranalli, 1999, p72). Thus today there exist two main uses for this crop based on these components for the paper pulp and textiles industries, the chemical composition being a very important factor. In fact, the yield of pulp corresponds directly with the cellulose and hemicellulose content of the fibre (de Groot et al, 1999; Biermann, 1993). This chapter will also explore the potential use of both of these components for biofuel (i.e. cellulosic derived ethanol) production.

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[23] 'With the present monoecious and unisexual varieties a potential seed yield of 1200 to 1500 Kg/ha can be achieved'. (Bocsa; 1999, p179) In addition a non-branching dioecious variety grown in Finland (FIN-314) has produced record yields of 2 t/ha (Pate; 1999).

2.3.2 Bast fibre (primary and secondary)

This particular component is best suited as a raw material in the manufacture of paper and/or textiles (20 percent of total stem fibre; Ranalli, 1999) due to the low lignin[24] content and length of the fibres (Primary fibres 5-40mm, secondary bast fibres are uniformly about 2mm) (Ranalli, 1999). The ultimate fibre cells for textile manufacture range from 5-55mm and have an average length of 20mm (Ranalli, 1999). A low lignin content has other environmental benefits given that wood pulp processes (both soft and hard) involve the chemical removal of lignin. Pulp from hemp (bast) can therefore be characterised as a non-wood pulp (de Groot et al, 1999). In addition, long fibres add to the strength of paper and the yield in chemical pulping corresponds to the cellulose content (see above) of the raw material (Ranalli, 1999; de Groot et al, 1999; Biermann, 1993).

2.3.3 Woody core

These (core) fibres account for 65 percent of the stem weight (de Groot, et al, 1999). Unlike most annual fibre crops that must be treated as straw (using this raw material in the pulp process involves effluent treatment to remove silica), hemp has a 'very low silica content' (de Groot, et al, 1999). In addition, the composition of the woody core is both botanically and chemically comparable to hardwood (de Groot, et al, 1999). It as argued that future technological developments could lead to this component being a 'valuable paper feed stock' in low pollution pulping systems (alkaline processes use around 50 percent less energy) (de Groot, et al, 1999).

[24] Lignin content is especially significant for pulp paper manufacture as it interferes with hydrogen bonding and so negatively effects paper strength and polluting effluents are produced in the removal of lignin leading to lower yields of pulp due to the chemicals degrading effects on hemicelluloses (Biermann, 1993).

According to the IPCC (1996b), there exist several advantages of using biomass in the energy sector not least because these can be used to offset and/or substitute directly for fossil fuels thereby reducing emissions of GHGs and sequestrate CO_2 via the process of photosynthesis. Moreover, biomass is a general term covering a large degree of diversity and chemical composition in terms of plant matter which are of variable significance as a raw material or feedstock for the energy (and transport) sector. The IPCC (1996b) consider that the types of biomass most suitable for these applications in the context of climate change mitigation are *fast-growing hardwoods*. Hemp or other cultivars of Cannabis are therefore perfectly placed to be utilised in this area given the plants chemical composition and additional agricultural benefits. Moreover, there exists at present much of the technology to translate this into a pragmatic climate change mitigation option with higher energy efficiency and lower unit capital costs (IPCC, 1996b).[25] This is especially significant given that,

> **'Bekkering's (1992) analysis of future global trends in greenhouse gas emissions has shown that reducing emissions from fossil fuels will have the greatest effect on atmospheric carbon concentrations between 1990 and 2100.' (Adger and Brown; 1994, p229)**

The following diagram outlines only a few of the possible uses to which Cannabis could be put. It should be noted that many of these uses are in commodity areas where fossil fuels and petrochemicals are predominately utilised. It is essential that more research be directed at this crop specifically for it's use as a biofuel. According to a paper published in Biomass and Bioenergy (Vol.15) '*Assesing the Ecological and Economic sustainability of Energy Crops*' which considers the viability of nine possible biomass contenders[26] via comprehensive life cycle assessments, Marjoleine

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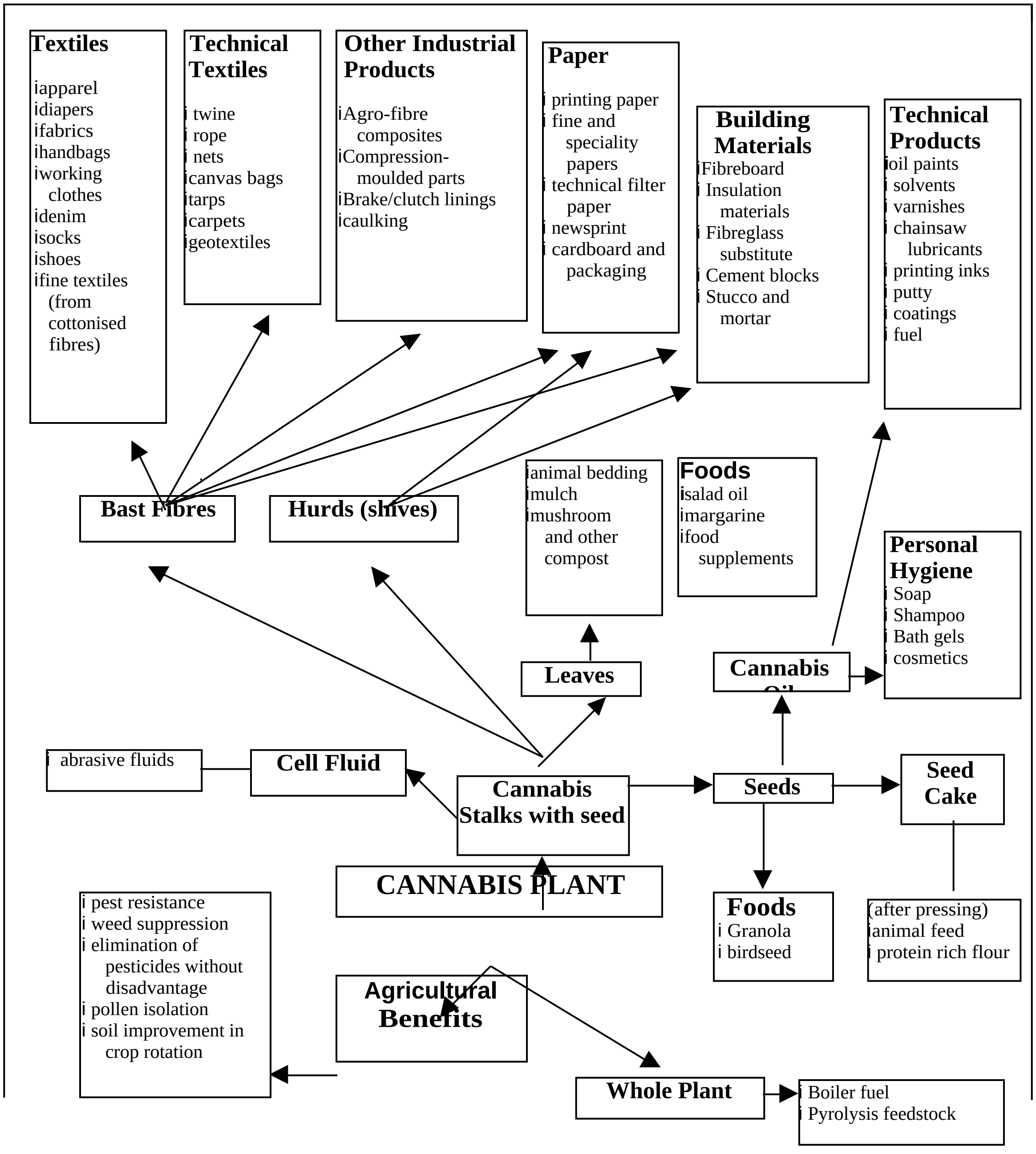
[25] IPPC refers specifically to the biomass-producer gas-engine and the more advanced but available biomass integrated gasifier/gas turbine or BIG/GT (IPCC, 1996b, p606). This and other mitigation options pertaining to the biomass potential of Cannabis in the energy and transport sectors will be elaborated upon in chapter three where other key variables such as land-use/availability will be accounted for.

[26] These include Rape seed, Sugar beet, Winter wheat, Silage maize, Hemp, Miscanthus, Poplar, Willow and Grass fallow.

et al (1998, p351) conclude that, **‘hemp comes out as one of the best options for energy cropping’.**

2.4 Modern uses for Cannabis.



Adapted from a diagram presented by Roulac (1997). Rather than being a comprehensive diagram, this serves solely to demonstrate the diversity of product and use for which Cannabis can be put. In addition, the possible ability for the 'woody core' or Hurds/shives to be used for energy applications has not been considered in this diagram.

2.5 Chapter two: Cannabis Summary

h Large C. gene pool: wide selection of genotypes and phenotypes (i.e. desiccation and frost tolerance)

h fast growing annual crop.

h extracts significant quantities of heavy metals from soil.

h long tap root, up to 2.5 metres helps prevent soil erosion

h requires modest (organic) fertilisation and near zero chemical fertilisation.

h ideally suited for integration into environmentally sound (i.e. organic) agricultural practices.

h increases yield of the proceeding crop in rotation cycle by up to 10 percent.

h gross primary biomass increments up to 23t/ha.

h CO_2 sequestration range between 7.6tC/ha and 11.5tC/ha.

h perfect substitute for cotton, requires less chemical inputs.

h suited to pulp paper manufacture: bast primary and secondary fibres low lignin high cellulose content.

h chemical composition of woody core comparable to hardwood,

h potential as a biomass feed-stock for energy and transportation applications.

h also has the potential to be a valuable food source of plant protein.

Chapter three: *Climate change mitigation potential*

3.0 Introduction

Thus far, we have examined policy alternatives for climate change mitigation and as a result have examined the characteristics of a specific form of biomass[27] and the potential contribution it could make to climate change mitigation within the industrial areas of agriculture and energy. This chapter will elaborate on this information by examining (theoretically) the climate change mitigation potential arising out of the utilisation of Cannabis for industrial purposes while considering two of the key variables involved – land-use and land availability.

There is to date no *comprehensively* accurate data regarding global land use and therefore land availability that could be used in for example, a 'dedicated biofuel programme' (IPCC, 1996b). Despite this problem, much of the analyses done in this area use FAO land-use assessments which are considered to be most accurate (IPCC, 1996b) and provide reasonable estimates of land use/availability. These will therefore be drawn upon in this chapter. By expanding on the work carried out by the IPCC and others in conjunction with the data/information from chapter two it will be argued that Cannabis cultivation has the potential to achieve the objectives set out in section 1.3.

[27] Biomass utilisation (for atmospheric carbon sequestration and energy applications) having the greatest mitigation potential of the said options according to the IPCC.
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3.1 Land-use

As a determining variable, land-use is sensitive to many socio-political considerations and differs regionally according to factors such as demographics, requirements for agricultural land and the management of agricultural land. For example, some analysis (IPCC, 1996b) consider that intensive agricultural practices in the EU will lead to 15-20 Mha[28] of ***good*** agricultural land being surplus to requirement by 2010 (IPCC, 1996b, p755).[29] On the other hand, this situation is unlikely to occur in tropical regions as only half of land-use conversions (i.e. from forests to agriculture) contribute to an increase in agricultural productivity. The other half, 'is used to replace previously cultivated land that has been degraded and abandoned from production' (IPCC, 1996b, p749). This type of (inefficient) land-use conversion contributes as a significant *source* of atmospheric carbon (1.5Gt/per year or 13 percent of total at 1990 emission levels) which could be remedied by increasing carbon storage in managed (i.e. agricultural) [30] or forested soils.

There is, however, a finite possibility for reforestation to occur given that adequate supplies of food, fibre and energy must be obtained from the remaining area. This is only deemed possible in the EU and US due to intensive farming methods (IPCC, 1996b). Since these methods contribute significantly to climate change *and* will also be affected by climate change (either directly or via mitigation policy), it would be highly undesirable to even consider an increase (globally) of standard intensive farming methods given their limitations of sustainability. Moreover, it would be advantageous for climate change mitigation policy to consider and address how the intensive agricultural (and consumer) practices in temperate regions could be

[28] **Mha refers to million hectares.**
[29]**Lehman et al (1996) calculate that there will be a surplus of agricultural land in the EU of 40Mha by 2010 and took into account strict environmental constraints on agriculture and aspects like the import of agricultural products**

[30] These practices include the ***prevention*** of low production levels, erosion, inadequate fertilisation, removal of crop residues, and intensive tillage (IPCC, 1996b).

rationalised and/or altered in order to promote (more) sustainable agriculture in conjunction with climate change mitigation policy (IPCC, 1996b).

3.2 Land availability for biofuel/energy crops

Contrary to popular belief there is more than enough available cropland to satisfy the World's rapidly growing population. Taking into account the unsuitability of some soils and terrain, the FAO considers there to be 3000Mha of potential cropland of which only about 50 percent is at present cultivated (around 1450Mha)(IPCC, 1996b, p809). In light of this, many of the analyses (e.g. Hall et al, 1994 and IPCC, 1996b) that consider between 10 and 15 percent of total global cropland to be available for biomass cultivation for energy requirements form reasonable and modest assumptions. Although it must be pointed out that this figure does not allow for variations between geographic area according to, for instance, socio-political circumstances.

In **temperate zones**, estimates of available cropland range between 8 and 11 percent **(or 26-73Mha)**, while for **tropical zones** with a generally higher demand for agricultural land (food requirements), this figure is reduced to 5-7 percent **(or 41-57Mha)** (IPCC, 1996b, p755). The cropland area available when temperate 'shelterbelts' and tropical 'agroforestry' are included adds **13-26Mha** and **41-65Mha** respectively (IPCC, 1996b, p755). In terms of actual land area, these figures correspond to those (above) of the FAO (1991) cited by IPCC (1996b).[31]

This data can be extrapolated to give a total mean cropland availability of 171Mha globally, marginally more than the 10 percent figure given by Hall et al (1994) for the potential cropland they considered available specifically for energy biomass

[31] When accounting for a small margin of error, these figures broadly agree with Hall et al's assumption that between 10-15 percent cropland is available for energy crops. According to the FAO data (in the context of Hall et al's study we assume 10 percent availability) a total cropland area of 145Mha would exist, so the 171Mha (based on the above data) used in this example is a reasonable estimate.

cultivation. *There is also the strong possibility that this could be increased substantially by using some of the world's land that has been degraded as part of a bio-remediation/reclamation programme*.

According to the World Resources Institute (IPCC, 1996b) there exist 750Mha of 'light', 910Mha of 'moderate' and 310Mha of 'severely' degraded land, the most promise being in the former area (IPCC, 1996b). Some estimates consider this to be as high as 2100Mha, 30 percent of which is considered to be suitable for reforestation or energy crop applications (IPCC, 1996b, p604). This fact is especially significant for tropical regions as the 5-7 percent of cropland available for energy crops could be dramatically enhanced using degraded agricultural land. Given the data regarding the physiological characteristics of industrial Cannabis (see chapter 2, section 2.1) there would appear to be many advantages in using Cannabis crops for the rehabilitation of degraded land, although this remains at a theoretical level given the lack of data on this topic.

Other than utilising degraded land for energy crops, a key argument of this thesis is that a substantial proportion of (currently used or technically 'unavailable') agricultural cropland could also support Cannabis cultivation as a *multipurpose* energy crop. This involves the integration of Cannabis into sustainable systems of rotation that - as the reader will by now be aware - Cannabis is well suited to. The possibility of doing so will be explored below and should in theory confer several additional environmental and economic benefits to climate change mitigation policy in line with the recommendations of both the Convention and IPCC, 1990, 1996a, 1996b.

The following two sections/examples serve the sole purpose of demonstrating the potential impact that Cannabis cultivation could have in relation to a climate change mitigation strategy in the EU and then goes on to consider a simplified example of Cannabis as a multipurpose source of biomass for climate change mitigation at the global level. This example considers the possibilities for climate change in a scenario where Cannabis is integrated as an agricultural rotation crop and also takes on board the possibilities relating to land rehabilitation in conjunction with energy and paper production at the global level. Statistically, these sections operate in the context of carbon emission data pertaining to 1990.

3.3 Cannabis: energy crop for climate change mitigation (EU)

Hall et al (1994) consider it feasible that 10 percent of the total cropland, including that used for commercial forestry could be used for energy crops. This assumption means about 38Mha for Europe as a whole and approximately 15Mha for the EU. Given that there is adequate data for EU energy use, it is this last figure that shall be concentrated on. Data regarding the potential dry mass yield of Cannabis (stem) was around 15-20 tons per hectare, which can be averaged at around 17.5t/ha. Using Hall et al's (1994) data suggesting 18Gj/ton (GJ = 10^9) heating value for woody biomass[32], 15Mha of Cannabis could produce 2.6 percent (or 4.73EJ, where EJ = 10^{18}) of the EU energy requirement. If Cannabis were grown in rotation with three of the EU's main arable crops (wheat, barley and potatoes) the land area increases by 28.6Mha (OECD, 1997) giving a total area of 43.6Mha.

This would mean that 7.6 percent (or 13.73EJ)[33] of the total EU energy requirement could be produced using the industrial cultivation of cannabis while benefiting the soil[34] and, therefore, the crops following from it in the rotation cycle. Moreover, considering that oil accounts for around 40 percent of the EU primary energy requirement and 1527.2Mt of EU CO_2 emissions (OECD, 1997), if Cannabis were used to directly replace (proportionally) hydrocarbon oil this particular example has the potential to offset around 972Mt of atmospheric carbon emitted from oil

[32]The heating value is calculated from the short rotation grass, Miscanthus and short rotation coppice such as Willow (Faaij et al, 1997) at 18Gj/ton and 17.5t/ha for Cannabis energy per ha is equal to 315Gj. Industrial hemp, (Cannabis Sativa), could perhaps have a higher heating value given the woody core's chemical and botanical comparability to hardwood but due to a lack of data, the same heating value has been attributed.
[33] EJ = exo-joules, or Joules x 10^{18}
[34] See chapter two, section 2.1.
[34] Calculated using the ***total*** biomass yield of 23t/ha at an average uptake of between one half and one third of this total (estimate sequestration of 9.58 tC02/ha), as discussed in chapter two.

consumption ***and*** could sequester up to a further 417.7Mt CO_2 via photosynthesis in biomass.[35]

3.4 Global implications

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Considering the above data on land-use and availability, the global potential for this particular mitigation option is substantial. For example, using the same statistics on which the previous example was based taking 10-15 percent cropland to be available (i.e. 171Mha) globally for energy crop applications, the use of Cannabis could generate around 54EJ or 20 percent of global primary energy requirement (as at 1990). Translated into emissions, this would reduce global CO_2 emissions from its 1990 level of 6Gt per annum from fossil fuel combustion by 1.2 Gt and sequester[36] a further 1.64 Gt/CO_2 per annum. Of fundamental significance is the fact that according to the IPCC and others there was (in 1990) in total (i.e. includes land use conversions *and* emissions) a 3.3Gt shortfall in terrestrial and oceanic sequestration. This was equivalent to a 1.5ppmv CO_2 annual increase in atmospheric carbon that could have been reduced by 86 percent or 1.29ppmv using the additional biomass calculated for in this example, thus going some way towards stabilising CO_2 emissions at their 1990 levels in line with the requirements of the Convention (see chapter one).

It is estimated that global consumption of energy (expressed in EJ) will increase from the global mean of 270EJ (1990) to around 491EJ by 2025.[37] Much of this will be due to the increasing energy demands of developing countries (IPCC, 1996b). Moreover, a 'business-as-usual' scenario will see growing pressures on natural forests for the global consumption of paper (see section 1.3 para 4-5) and agricultural land, especially in the tropics. This section will therefore examine the possible impact of cultivating industrial Cannabis to mitigate these problems in the context of fulfilling the UNFCCC and IPCC policy recommendations.

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[36] On the basis of a ***total*** biomass increment of 23t/ha for Cannabis (see chapter two). Figures are based on 1990 levels of emissions and energy use, mean energy use being 270EJ and total emissions from fossil fuels being 6Gt (IPCC, 1996b).

[36]This estimate is derived from calculating mean energy use based on the projections of the IPCC (1996b, p14).

The international cultivation of Cannabis as both renewable energy source and fibre/seed crop would depend on the regional circumstances. An ideal scenario, for instance, would mean crop production satisfied local needs and/or markets (entailing local processing) with cultivars complementary to the local environment and climate. However, much of this remains at a theoretical level as the majority of plant breeding for fibre content has been in temperate regions and very little (if any) research has been carried out in tropical (or sub-tropical and boreal) regions with these cultivars. While section 3.3 outlined the possible impact of industrial Cannabis cultivation on EU cropland deemed suitable/feasible for energy crops and in a situation of rotation agriculture, it is possible to determine the impact when in *rotation*, for example, with **wheat**[38] crops at the global level.

In addition, allowances can be made regarding the area of land categorised as degraded but deemed suitable for reforestation or energy crop applications (see section 3.2). Considering these factors increases the potentially available land[39] to approximately **1097Mha** globally. Using the primary data from section 3.0, if total (stem) biomass is used for energy purposes this would create 346EJ of energy, representing a 76EJ or 28 percent increase over the mean *global* consumption of energy in 1990 which is equivalent to ***total global energy consumption in 2002***. While this would be highly desirable for climate change mitigation it is an extremely unlikely outcome, at least in the short term. However, if (as indeed we are) considering the *multipurpose* use of Cannabis biomass in a mitigation programme, such an area of land presents many additional opportunities for carbon sequestration.

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[38] The reason why only wheat crops have been selected is primarily logistical and serves to provide a simplified but global example of the benefits resulting from Cannabis in rotation systems for agriculture and climate change mitigation. The more crops Cannabis could be rotated with the greater climate mitigation potential for this thesis and - based on the information in chapter two - the more sustainable the respective agricultural systems.

[39] Globally, the data for areas of 'light degradation' suitable for energy crops is 710Mha. The land area harvested for wheat according to the FAO (1995) is around 216Mha. These figures have therefore

been added to the 171Mha of cropland assumed viable for such a project from the data provided by Hall et al, 1994 and IPCC, 1996b.

Not least of these is the potential contribution this could make to the pulp and paper industries. Based on the chemical composition of Cannabis, around 35 percent of the stem weight is suitable for non-wood (i.e. low lignin, high cellulose) paper production. In the present global (statistical) context, this translates into about 7Gt of raw material suited for paper applications.[40] Plantations currently provide only 370 million m^3 or 25 percent of the worlds industrial round wood (FAO, 2000) implying that the other 75 percent is met through the destruction of natural or semi-natural forests. In addition, many of these plantations (especially in south East Asia, see section 1.3) have directly displaced natural forests in order to offset the initial costs of plantation forestry, a problem that Cannabis cultivation through agricultural rotation and land rehabilitation could potentially solve.

Moreover, a study of land-use in the US estimated that in a situation where industrial hemp (*Cannabis Sativa L.*) was used to replace pulp log production, the land required for the same production (output) level was only 10 percent of that currently used (Alden et al, 1998)[41]. Again this has many positive implications where Cannabis is integrated into sustainable systems of rotation agriculture and as such more research is urgently required in this area.

[40] Since statistics dealing with plantation yields for industrial round-wood consumption deal primarily in volume (m^3) (FAO, 2000) there are problems in terms of quantifying this amount to make the data more relevant.
[41] Unfortunately, this study left out some of the primary data that would have been extremely relevant for this thesis such as yield per/ha of pulp log and hemp production in the context of land-use minimisation.

Remaining with this dual function (i.e. splitting Cannabis according to chemical composition for paper ***and*** energy applications), around 13Gt (65 percent of stem 'woody core') of hardwood material – suitable for energy applications – could be produced using the land available in this example (1097Mha). At 18Gj/t (heating value) this implies that approximately 225EJ (83 percent at 1990 levels) of the world energy primary energy could be met in a sustainable way while mitigating some of the problems brought about by changing land-use and deforestation for industrial (pulp paper) purposes. Sequestration of atmospheric carbon is also significant for this particular example.

Using the total biomass increment of Cannabis (see chapter two) the potential sequestration for this example is around 10.51Gt of atmospheric carbon! [42]

Obviously, geo-engineering at this level would require a considerable amount of research. It could be suggested, for instance, that flora and fauna will have already begun a process of climate change adaptation and any changes should be gradual. This however remains theoretical as the current rate at which carbon is added to the atmosphere is proportionally large.[43] We have, as discussed, increased levels from 270ppmv to over 360ppmv in the last three centuries. At the aforementioned level of sequestration via Cannabis cultivation, it would only take around 19 years to reduce levels to those of 1750, not accounting for continuing global increases in CO_2 emissions over the next century.

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[42] This figure is based **only** on the amount of atmospheric carbon sequestered during photosynthesis and **does not** include the sequestration of carbon stored in the conversion of (degraded) land back to agriculture and **does not** account for the additional sequestration from terrestrial sinks such as natural forests preserved from the pulp log market. It must also be pointed out that this figure **does not** account for the atmospheric carbon emissions from the utilisation of biomass as an energy feedstock as there is no available data. However, as section 3.5 examines, emissions from biomass energy would be considerably lower than those from fossil fuels – ethanol, for example, produces two percent of the life cycle emissions of fossil fuels in transport applications (IPCC, 1996b).
[43] This is in comparison to the sensitivity of plants to climate change. According to the IPCC (1996b), fluctuations of as little as one degree Celsius could threaten some species survival.

3.5 Commercial applications

3.5.0 energy and transport

In 1990, the share of global energy consumption in the transport sector was around 63EJ, equivalent to 1.4Gt of atmospheric carbon emissions (where the total emissions equal 6Gt/CO_2 from 270EJ of global primary energy consumption). Transport and energy form the basic primary sources of carbon emissions. By changing the feedstock (raw materials) of these industries (using several existing technologies) from hydrocarbons to carbohydrates in the form of biomass derived cellulose(s), serious advantages to climate change and general pollution mitigation could be achieved.

The use of biomass in energy applications does not entail simply burning it. Rather biomass can be used as a feed-stock in gasification processes which involves steam-reforming into hydrogen or methanol, both of which are perfect substitutes for fossil fuels and far less polluting (IPCC, 1996b). In transportation, for instance, the fuel cell vehicles (FCV's) which utilise hydrogen are more than twice as efficient than internal combustion engine vehicles (ICEV's) with similar performance (IPCC, 1996b).

Another application of biomass to the energy and transport sectors is in the production of ethanol (especially via enzymatic hydrolysis) which is most efficiently derived from fast-growing hardwood, the chemical composition of which is comparable to the 'woody core' of Cannabis. Even with comparatively low yields (12dt/ha/yr) compared to Cannabis; ethanol derived from other woody feedstock(s) (such as Willow or Poplar) yield twice that of grains. In addition, ethanol can be used in ICEVs with considerably lower life-cycle emissions (in gC/km) of around 2 percent of those in ICEVs using reformulated gasoline (IPCC, 1996b, p609). Clearly, the utilisation of these technologies in conjunction with an energy biomass programme would be a key factor in long-term climate change mitigation and general pollution abatement..

While it is easy to get carried away with the ‘technological-fix’, it is worth bearing in mind that a substantial proportion of the world energy requirement is already met by biomass in the form of firewood. According to the World Bank, firewood accounts for 35 percent of energy supplies in developing countries (Jepma, 1995, p25). Although at the global level plantations supplement 25 percent of the industrial roundwood market they only contribute around 4.5 percent to the fuel wood market (FAO, 2000). It would therefore be pure speculation to assume an amount of natural (and semi-natural) forest preservation that Cannabis could potentially achieve by supplying this market. Integration into rotation agriculture represents a key variable in realising the potential for Cannabis as a (very) short rotation industrial feedstock in developing countries. Especially given that,

> **‘(d)espite the long term advantages of reforestation a fundamental question remains: how can people be motivated to invest time and labour in caring for trees when they may not be any benefit for years?’ (Gradwohl and Greenberg; 1988, p178)**

3.5.1 Integration of Cannabis for sustainable agriculture

If the theoretical propositions of Alden et al (1998) concerning industrial Cannabis and land use minimisation can be borne out in practice then serious benefits could accrue for even the smallest landowners/farmers. This benefit is doubled when the environmental benefits of Cannabis cultivation are considered in the agricultural context. As a goal of sustainable development organic farming is of fundamental importance. Global food security does not just depend on the quantity of goods produced. The way in which goods are produced effects, for example, the long-term sustainability of soil systems. In addition, it could be argued that quality also has a dramatic impact on demand.

The introduction of Genetically Modified Organisms into the food chain has received criticism from scientists in developed and developing countries alike due to the long-term scientific uncertainties associated with their propagation and consumption. These scientific uncertainties make the introduction of GM crops unsustainable and potentially hazardous for long-term food security (see section 4.0).

Many developed countries (mostly in the EU) are making a concerted effort to move away from intensive to more extensive agricultural systems in order to reduce the environmental impact of agriculture and for overtly economic (but associated) objectives such the reduction of surpluses – given their subsequent effect on prices. In the EU the Common Agricultural Policy (CAP) reforms of 1992 sought to break the link between farm incomes and volume of food (Ilbery, 1998). The ‘productivist’ philosophy behind GM crops does not fit well with these objectives and circumstances i.e. surpluses. Organic farming satisfies all the relevant criteria. So too does agricultural set-aside and non-rotational set-aside as described in EU Regulation 2078/92 or ‘agri-environmental action programme’. This was heavily influenced by international policy such as the UNFCCC and considered non-food crop set-asides for uses such as biofuel production with accompanying measures encouraging reforestation of agricultural land and organic farming (Ilbery, 1998)[44]. Changes to the CAP were themselves regulated for; being controlled via the Integrated Administration and Control System (IACS) established under Regulation 3887/92 (Ilbery, 1998).

This level of organisation may not be possible universally given the plethora of socio-political (and therefore economic) concerns at the global level that would mitigate against such co-operation such as the level of political and civil conflict endemic in many parts of the World. It does, however, demonstrate the possibilities for the

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[44] Industrial Hemp (Cannabis Sativa L, being controlled in terms of its ‘drug’ or THC content by EU legislation to be no more than 0.03%) is presently subsidised via the CAP. In 1994, aid for this crop was set at ECU641.6 per/ha.

integration of agricultural and environmental policy, which for too long had remained separate issues in the EU.

The encouragement of organic farming and more sustainable conventional practices at the Global level is fundamental to the successful integration of these policy areas and enhances dramatically the potential for Cannabis to be used in a multitude of functions, not least in the over-arching goal of climate change mitigation.

There are several aspects of intensive agriculture that are clearly unsustainable. Among these activities is an inadequate system of crop rotation that leads to greater reliance on (fossil fuel dependent) chemical fertilisers. These fertilisers also have a long-term impact on the quality and therefore the productivity of the soil. According to Verloo and Willaert (1990), phosphorus-bearing chemicals display high levels of heavy metal concentration. For example, cadmium (Cd) is potentially phytotoxic and represents a health hazard. Moreover, de Haan (1987) attributed more than 90 percent of the Dutch soil Cd burden to inputs from chemical fertiliser impurities.[45] As an ideal rotation crop, Cannabis has a greater potential than most to remove these substances from the soil thus aiding the transition to organic status which is undoubtedly a fundamental objective where sustainable agriculture (and development) is concerned. For instance, it has been

> **'calculated that organic farm systems in Germany emit only 39 percent of the overall fossil C required by conventional farms[46]. . . . Even energy inputs per ton of harvested crop were lower by 20-60 percent.' (IPCC, 1996b, p754)**

[45] Degradation of soil fertility under intensive agricultural practices can also be due to water and wind erosion, compaction, tranlocation of particles and lowering of organic matter content (Yassoglou, 1987).
[46] This is mainly due to the replacement of mineral N fertilisers by legume cropping (IPCC, 1996b, p754).

Moreover, where there does exist the problem of chemically polluted land Cannabis could be cultivated for industrial uses such bio-energy (woody core and bast fibre) and indeed paper manufacture (primary/secondary bast fibre), the plant being split according to its chemical composition, and could also aid the bio-remediation of such land (**see section 2.1 Physiology**) In cases where there is no significant chemical pollution, Cannabis could also be grown for seed[47]or food purposes either for human or animal consumption *in addition* to bio-energy or paper applications.

High intensity animal production is the largest consumer of fossil fuels in modern agriculture, primarily as a result of the large quantities of fertiliser required in the production of feed. According to IPCC, 1996b, 'reducing animal protein consumption in Europe and the United States by only one half of its present excess would decrease N (nitrogen) fertiliser requirements by about one half' (p754).[48]

The significance of this is borne out by the fact that the fixation of atmospheric N (nitrogen) into synthetic fertiliser requires about 1.2kg of fossil fuel equivalent for each kg of fixed nitrogen. The present global consumption, 80Mt of fertiliser N, corresponds to the consumption of 100Mt of fossil fuel (IPCC, 1996b, p754). When considered in conjunction with the points raised earlier there would seem already to be a strong case for the introduction of Cannabis, especially as a *multipurpose* rotation crop. In doing so the amount of land available for climate change mitigation policy is greatly enhanced. The choice for agricultural policy makers (in the EU, for example) is between an intensive system producing inferior quality products which will make available a substantial proportion of good agricultural land at the risk of degrading the rest. Or - to keep this land productive on a rotational basis achieving a better quality of production more efficiently while also undertaking pragmatic steps for climate change mitigation.

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[47] The data regarding properties of the Cannabis seed are detailed in chapter two.

[48] In addition, this 'excess' of animal protein consumption is responsible for a substantial proportion of global CH_4 emissions (see chapter one).

Chapter four: *conclusion*

4.0 Cannabis: an environmentally viable method for climate change mitigation?

It is apparent that Cannabis has the potential to confer several environmental benefits in addition to climate change mitigation. Not least is the ease with which Cannabis cultivation could be integrated into *sustainable* systems of agriculture or indeed into environmentally unsustainable situations as a method of improvement. The idea of 'sustainability' in agriculture engenders concerns regarding the long term security of food production which includes many aspects of production from soil quality – and all the variables that affect this – to the sustainability of products themselves. In addition, this definition could be extended to cover the impact agriculture has on surrounding environments, the hydrological cycle and therefore global warming. These all potentially affect the sustainability of agricultural systems and therefore food security. While this demonstrates the interconnectedness of events in nature and those induced by human activities, it is also intended to emphasise the positive impact Cannabis cultivation may have in this context.

For example, we observed earlier that problems such as the over-cropping of erodible soils lead to unsustainable practices of land conversion particularly in the tropics. Systems of rotation – using crops with long tap roots such as Cannabis – could help prevent the degradation of agricultural land, removing or at least lessening the need to convert more land (i.e. forested areas) for agricultural purposes. Some may be inclined to argue that less intensive systems of agriculture could result in food shortages. Cannabis however, as well as being a protein rich food crop could promote environmentally beneficial methods of agriculture (via rotation cultivation) that could help secure a ***long-term strategy*** of land management ensuring that food shortages do not occur. This would be enhanced greatly by using Cannabis as a key bioremediation crop to restore unproductive land back into agricultural use.

Shortages are arguably far more likely to occur in areas where there is a deficit of suitable land due to *intensive* agricultural practices combined with inadequate land management (IPCC, 1996b).

Arguments suggesting that the way forward lies (solely) in the technological advances of genetic engineering are mistaken. Claims made by GMO corporations, such as Monsanto, that less chemical fertilisers could be applied to food (GM) crops with guaranteed yields and quality have not been borne out by the experiences of conventional farmers in the United States – many of whom have been using GM seeds for almost a decade. Moreover, claims that GMOs could 'feed the world' are extremely tenuous to say the least. To address these points, research into GM yields has demonstrated a mean 4 percent yield drag in RR[49] soybeans. Even comparing the top five varieties from each, RR still yielded five percent less than conventional soyabeans (E.A. Clark, 1999).

According to other research, GM soya is unsuitable for some (hotter) climates as soil temperatures reaching 40-50 degrees Celsius resulted in crop losses of up to 40 percent due to stem splitting (Coghlan, 1999). Moreover, research carried out at Cornell University, New York, has demonstrated that genetic diversity of agricultural crops – as opposed to genetic standardisation – is the way forward. Experiments using rice (another C3 crop), where all commercial varieties are derived from just two Sativa varieties, showed that crossing these with 'wild' genera boosted yields by between 10 and 20 percent (Coghlan, 1999). It is far more plausible, therefore, that years of continuous (protein deficient) cereal production will require *alternative and rotational* crops rather than genetically modified crops to,

'allow control of those weeds, pests and diseases that still cannot be controlled in the cereal crops themselves, and perhaps more importantly

[49] RR refers to 'Round-up Ready' – varieties engineered to be resistant to Monsanto's 'Round-up' herbicide.

[would] help restore organic matter to the soil following years of depletion by cereal crops' (Forbes and Watson, 1992, p 257).

There is *absolutely* no scientific foundation for claims that GM crops will 'feed the world'.[50] It is often argued that those in the West who oppose this technology do so only because they can afford to and that decisions should be left to individual countries. However, GM technology represents, for a **nation-state**, the 'cheap fix' for many social and agricultural problems as individual or small farmers would not be able to afford this technology (Mack, 1998)[51]. Their respective States, however – burdened with debts – could (and have, in the case of Brazil and Kenya) encourage(d) the use of these crops as an economic **alternative** to the capacity building of agricultural infrastructure, refrigeration facilities and transportation networks[52] with no regard for the long term sustainability of this technology – which is far from established. In effect, the technology has preceded the science.

It is also the case that the food we eat today is not varied enough in terms of nutritional content. The bulk of the worlds' food is derived from only twelve crop plants and three types of livestock (Tivy, 1990, p7). For this reason many of the worlds poorer communities suffer from malnutrition as a result of cereal rich but protein deficient diets. The technological 'solution' involves engineering crops with enhanced nutritional value but according to the British Medical Association (representing 115,000 doctors), the use of anti-biotic marker genes in GM crops

[50]Trials run by the UK's National Institute of Agricultural Botany (NIAB) in 1997 and 1998 showed yields from GM winter oilseed rape and sugar beet were between 5-8% less than high yielding conventional varieties. (reported in Farmers Weekly (UK), 4th December 1998). In addition, according to the Norfolk Genetic Information Network, research at the University of Purdue (1997) found transgenic varieties of soya yielded on average 12-20 percent ***less*** than conventional varieties grown at the same location and the University of Wisconsin (1999) found that of 21 trial sites over 9 northern (US) States, GM yields were less in all but four sites compared with conventional crops.

[51] *If GM is ever **proven** to be safe it would be fair to assume that the price would increase given the amount money this would require and time it would take.*

[52] A recent Channel Four (UK) broadcast (Equinox 20/03/00) actually put forward the argument ***for*** GM because many food crops in developing countries 'rot before they reach the market'. However, rather than encourage the use of technology that has yet to be rigorously tested for its safety and long-term sustainability (such as slow ripening GM tomatoes) the West has an obligation, for example, to underwrite debts to allow countries to expand their agricultural (and social) infrastructures in addition to climate change mitigation policy/strategy.

poses a slight but “completely unacceptable risk” of enhancing drug resistant bacteria (cited in E.A Clarke, 1999).

This is coupled with concerns about pest resistance to the pesticides and herbicides that (GM) crops are engineered to be resistant to – such as Monsanto’s ‘Round-up’ herbicide (E.A. Clarke, 1999). Integrating Cannabis as a rotation crop into agricultural systems could potentially alleviate this regional (malnutrition) problem while mitigating climate change and other environmental problems associated with intensive agriculture such as pollution by ‘carcinogenic nitroso compounds’ found in areas of high nitrate pollution (Tivy, 1990, p250). Given these facts combined with the information in chapter two, there is a very strong case for the integration of Cannabis into both conventional and organic farming methods for climate change mitigation and general environmental improvement. One of the key areas where this would be possible is in the energy efficiency of agricultural systems[53]. The least efficient system is that of ‘feedlot’ cattle production as it produces only one tenth of the energy input – a fact that has led some to ‘question the long-term viability’ of such a system (Martin and Keable, 1981).

Thus not only could the multipurpose characteristics of Cannabis aid (more) sustainable systems of agriculture in the tropics while providing a welcome source of plant based protein but it may also help to challenge the intensive cattle production of the Western World, referred to as ‘excessive’ by the IPCC[54]. From the evidence presented so far the cultivation of Cannabis in agricultural systems would represent an integrated approach to deal with several related problems and indeed causes of climate change. To re-cap, there are several related environmental and socio-industrial factors/practices which contribute to the overarching problematic of climate change.

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[53] See section 3.3 ‘Integration of Cannabis for Sustainable agriculture’.

[54] This would rest on consumer choice which at present we do not have the only plant based protein in the Western world is soya, much of which is either of GM origin or has been mixed with GM soya.

These can be broadly summarised as:

- Fossil fuel consumption
- Deforestation
- Degradation of agricultural land and desertification[55]

Cannabis cultivation for biofuel and industrial wood pulp within an agricultural regime geared towards land rehabilitation and preservation within rotational crop systems could have the most profound mitigation potential by addressing the above factors simultaneously. Sections 3.3 and 3.4 outlined the mitigation potential of Cannabis using the agricultural land considered by research to be available for energy crops which proved to be highly significant as using only a fraction of the total potential land availability (i.e.171Mha) for cannabis cultivation, specifically in energy applications produced 54EJ or 20 percent of global energy use as at 1990 (270EJ). In addition, there would obviously be less need to cut down 'old growth' trees if pulp was to be derived from Cannabis plantations in conjunction with that grown in agricultural systems.

The prospect of utilising Cannabis in land reclamation/regeneration is also a significant and real possibility where industrial plantations are concerned given the physiological characteristics of the crop. It is probable however that Cannabis plantations would require significantly more chemical inputs than would be the case in rotational systems (Bocsa and Karus, 1998, see also chapter two section 2.1). Again, on the basis of evidence the advantages of Cannabis cultivation for climate change mitigation could far outweigh (minor) disadvantages such as this, although decisions are seldom – if ever – taken on the basis of their environmental credentials alone.

4.1 Cannabis: an economically viable method for climate change mitigation?

Cannabis is certainly an economically valuable crop given the plethora of possible uses to which its constituent parts could be put – not least in the energy sector. However, economic value of a product is determined by both demand and supply and the market(s) in which these are expressed.[56] On this level the world market for hemp (Cannabis *Sativa*) derived industrial pulp is *very* small at around 120,000 tons/year (FAO, 1995). This however does not constitute *real demand*, as there are several political issues that 'artificially' determine industrial and therefore consumer behaviour – the essence of which shall be the subject of further deliberation later.

At a holistic level enhanced climate change represents costs of almost unquantfiable proportions. How for example, do we quantify losses of species or for that matter the displacement of entire communities due to flooding? These questions raise several issues and make objective financial judgements very difficult. However, as noted in section 1.0, the IPCC and others consider that the cost attributed to climate change can best be described as a 'fixed' cost for atmospheric carbon, which over time turns out to be around 50 US dollars per ton.[57] ***In 1990, total atmospheric carbon totalled 750Gt*** or 750 thousand million tons (IPCC, 1996b).

When the full cost of climate change (if possible) is taken into account almost *any* measures to mitigate this problem would be cost effective. According to the IPCC and UNFCCC mitigation measures should also confer direct benefits on individuals – which would certainly, at least in theory, aid their implementation. The benefits that would accrue to farmers and consumers alike from the integration of Cannabis into

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[55] These problems are often a direct result of the agricultural practices used such as intensive cropping without rotation and the overuse of chemical pesticides and herbicides (see section 3.3).
[56] The market is political in so far as demand and supply do not necessarily follow in any particular order but can be created and thus influence each other purely as a function of this.
[57] The use of different discount rates to calculate future damage costs means that the range of value is between 5 and 125 US dollars per ton of atmospheric carbon (Houghton, 1997).

sustainable agriculture have been examined but costing these adequately (such as the reduction of chemical inputs and increased yields of other crops) is beyond the scope of this piece of work and would obviously be an extremely ambitious undertaking given the current lack of large scale agricultural research on the Cannabis species

From the research drawn upon in this thesis there could actually be ***more*** economic than environmental benefits were Cannabis fully integrated into a World Economy (or agreement or, better still, strategy) based on the use of agricultural bio-products as opposed to the current state of affairs which relies heavily on fossil fuels. From IPCC projections of future energy use it is apparent that we will become increasingly reliant on biomass this century and beyond. I would be inclined to argue that such projections must be taken in a context where ***all*** commodities are less dependent on fossil fuels for their production, not just energy. The following digression will elaborate.

Within economic discourse many considered the emergence of information technology (IT) to represent a new 'wave' of development but they forget (I presume) that this (IT) is a *mechanism* that allows the economy to function – it is a tool to assist in what we already do i.e. manufacture, buy and sell commodities[58]. In addition, 'waves' of development in capitalist society are dependent not just on relative prices, new technologies or "entrepreneurial dynamism" but the *techniques* which influence all of the above. Assuming that raw materials are a (if not *the*) fundamental requirement of industrial society, it is fair to assume that a shift from the oil based economy is inevitable given the industrial reliance on finite and environmentally *unsustainable* resources. *Eventually* the price of fossil fuel will force alternatives, such as biofuels onto the market. Although, by the time this (market effect) occurs - assuming no fossil fuel shortages occur in the next (22nd) Century - the effects of climate change could be too dramatic to reverse (Houghton, 1997, IPCC, 1996b).

[58] It is easy to forget that our desktop PCs were manufactured using plastics derived from petrochemicals. In the future these could be manufactured from biomass derived plastics.

Cannabis is possibly the most diverse and useful plant known to humanity and we already have much of the technology to manufacture many thousands of commodities from it (see section 2.4). Moreover, because we have possessed the ability to do so since the 1930's, the reasons why industrial society has not utilised this plant is open to suggestion! There are several conspiracy theories featuring heavy-weight industrial players of the day such as Randolf-Hearst (then owner of both the New York Times and large areas of natural forest in the US) and the DuPont corporation which, at that time, had patented techniques for the manufacture of artificial fibres from petrochemicals (Roulac, 1997).

Kondratiev's (a 20th Century Russian economist) theory states that 'waves of development' occur due to changes in *relative prices* between manufactures, food and raw materials (Harris, 1988) and would seem to fit with the above 'conspiracy' theory (i.e. that Hearst and DuPont conspired to remove a formidable competitor) in so far as the hemp industry in the US was ***taxed*** out of existence in the 1930's – leaving petrochemicals with no competition (see Roulac, 1997).[59]

Thus far all industry to date has been heavily reliant on fossil fuels of one kind or another and it would be reasonable to suggest that the – as yet – undefined K5 (after Kondratiev) 'wave of development' will utilise biomass to the same extent as all the previous waves of development have utilised fossil fuels – K4 being fuelled by petrochemicals and the motor industry. Cannabis could fill many (if not all) of the gaps in an economy shifting from a fossil fuel to biomass industrial base as is implied in the IPCC projections of future energy supply – this being a definitive feature of industrial society. By this rationale, within the context of a global response to climate change mitigation, a suitable conclusion would be that the production of Cannabis

[59] Despite this fact, the US government did embark on a highly publicised 'Hemp for Victory' campaign during the Second World War to ensure a domestic supply of industrially required material (Roulac, 1997).

could confer economic benefits on every country and individual landowner that participates.

However, due to the global dominance of fossil fuels, policies are required to stimulate expansive cultivation of such an environmentally beneficial alternative. This could be achieved via the extension of global climate change mitigation policy as enshrined in the UNFCCC to include those countries at present not Party to the Convention by the adoption of a biomass cultivation initiative – in which Cannabis on the basis of research would be a major contributor. As chapter three discussed a sizeable proportion of all farmland could be utilised for Cannabis rotation, not to mention land rehabilitation.

There are other mechanisms by which this crop could enter the global market besides direct legislation or international agreement. For instance there are several problems related to the supply of plant-based oil and protein for both human and animal consumption. Today the bulk of the World plant based protein is derived from Soya and most of that grown in the US has transgenic properties due to genetic engineering. The OECD (1999) states that there is a strong demand for plant based oil and protein, especially as a feed ingredient and projections show that production will increase by 34 percent or 64Mt by 2004 (OECD, 1999).

Moreover, oil seed rape is favoured for its oil content (35 percent oil) while soya is favoured for its protein content (OECD, 1999) both of which are surpassed or equalled by Cannabis with 33 percent oil by (seed) weight and 25 percent protein by 'seed' (see section 2.3.0). If there are restrictions placed on the cultivation of transgenic crops due to the lack of knowledge regarding their safety and therefore long term sustainability – or indeed that consumers themselves reject this food – Cannabis is in a perfect position to enter the food and feed market as a perfect non-GM substitute for these products.

4.2 Logistics

Unlike previous waves of (economic) development in which benefits accrued only to those countries with large oil reserves and/or the technological means to manufacture commodities from them, a biomass economy would not be regionally specific but would be distributed internationally. Cannabis fits perfectly into such a scenario as it can be produced at almost every latitude covering, therefore, most climatic zones. Because it is an annual crop and displays a high degree of genetic diversity it would not be affected by climate change to the same extent as other choices of short rotation woody feedstock for industry (IPCC, 1996, p389).[60] Moreover, the use of a standardised industrial feedstock makes far more economic sense than does using a heterogeneous supply of biomass, as technology could be tailored specifically and standardised to reduce cultivation, harvesting and processing costs. In addition, due to the environmental benefits of Cannabis as a rotation crop participation could be universal and non-specific to the size of land-holdings – thus ***enhancing rural employment***.

In the context of international agreements concerning climate change mitigation (i.e. UNFCCC) such an economy would almost certainly require technology transfer from rich to poor to enable regional biomass processing – an idea that has been accepted by the 160 signatories to the Convention. This would be essential in order to take advantage of the multipurpose characteristics of Cannabis. For example, it would be advantageous to have the technological capacity at a local level for the dual processing of paper and biofuel (such as ethanol) as this would be based on a separation of the constituent parts of Cannabis as described in chapter two. In addition, if seed

[60] This assumes that even if mitigation policies are implemented, because of the extent of atmospheric pollution from CO_2 , N_2O and CH_4 global warming will continue for an unspecified number of years. In many respects mitigation policy is essentially damage limitation for the long term future wellbeing of the Planet as this problem ***is*** reversible.

production was locally desirable in this multipurpose scenario then it would also necessarily involve technologically advanced dual processing facilities.

As mentioned earlier, there are also some serious political considerations for this thesis which would also effect logistics. According to research (see section 2.1) the environment Cannabis is cultivated in can affect the biochemical pathways of the plant. While this confers benefits on the plant in terms of its ability to cope with a range of climatic conditions, it also effects the production of the Cannabinoid Delta-9-tetrahydrocannibinol – categorised as an illegal narcotic in most countries due to domestic and international drug laws (mostly of US origin). This situation would put developing countries (in other words those who would benefit most from this climate change mitigation, environmental and economic policy) at an unfair disadvantage in relation to the countries of temperate regions who can cultivate low THC varieties of Cannabis Sativa or 'hemp' for fibre and seed *within* these regulations.[61]

An international agricultural agreement on Cannabis cultivation would necessarily address this issue either by relaxing laws governing the THC quantity in plants due to climatic variations or by embarking on a tropical breeding programme to try and reduce the apparent correlation between UV-B levels and *Delta*-9-THC production. Research in this area is urgently required given the overwhelming benefits that cultivation of this crop would bring to these regions and indeed the World in terms of climate change mitigation and through the preservation of the bio-diversity found in old growth forests currently destroyed by land-use conversion and industrial

[61] Even in temperate regions there is much confusion associated with the cultivation of Cannabis. In the US, for example, the legislators that passed the 'Marihuana Tax Act' of 1937 sought to distinguish between Sativa and Indica varieties due to their botanical distinctions but this still led to over regulation and taxation (Roulac, 1997). However, a later act in 1970 made **no such** distinction making the cultivation of hemp (Cannabis Sativa L.) impossible. The authorities of the US delegate responsibility for drug law and enforcement to the DEA which has refused permits to (would be) industrial hemp growers. Under US Law, the DEA is required to inform congress of any countries producing 'Marihuana' in order for sanctions to be levied. Despite the DEA non-discriminatory approach i.e. between hemp (Cannabis Sativa) and Marihuana (Cannabis Indica), no sanctions have been levied against the EU, India or China in what remains something of a paradox (Roulac, 1997). There is a possibility that USA foreign policy on Cannabis cultivation contravenes UN international law that permits the cultivation of *Cannabis Sativa L.*

activities. In comparison to the problem of climate change this (THC) issue is insignificant given the immediate possibilities for addressing it via modern plant breeding practices or legislative changes.

4.3 Cannabis: Industrial raw material for the 21st Century?

While the answer to this question rests with the degree to which resources are dedicated to achieving this end, the present picture is very promising. Current research has resulted in new advances in Cannabis breeding for fibre yield, quality and seed production (Ranalli, 1999) and technologies are being further developed for the utilisation of biomass in the energy and transport sectors - which Cannabis is perfectly suited to (see section 3.5.0). In addition, because of the range of products that can be synthesised from Cannabis our current reliance on fossil fuels could be reduced still further. The ability to do so exists at present so far from being a future or long-term objective, industrial Cannabis could in fact be utilised for these purposes in the very short-term. In the context of climate change mitigation policy, reducing the use of fossil fuels is of paramount importance but the case for Cannabis appears strong given the overlapping environmental concerns associated with modern production methods that can and should be addressed by coherent environmental policy.

As well as there being several environmental concerns arising from modern agriculture, many of the products currently synthesised from fossil fuels will continue to pollute air, land and water long after their usable life is over. Products made from Cannabis would not have this problem given their greater potential for recycling and for biodegradable product lines (Roulac, 1997). This is an important aspect in the light of international standards set out by the International Organisation for Standardisation such as the ISO 14000 requirements for environmental management. Roulac (1997) points out that the US Department of Energy requires all contractors to register as complying with these (ISO) standards. If all the environmental considerations are taken into account, Cannabis certainly has the *potential* to become a primary industrial feedstock for the 21st Century.

We should, however, learn the lessons of the past where corporate and political interests have been successfully mobilised to prevent the cultivation of this important crop. There remain therefore a plethora of inter-related issues that require serious deliberation – several of which are fundamentally political. Not least is the politico-economic power that today's multi-national (in particular petrochemical and biotech) corporations have over governments – especially in the developing world. Moreover, within the context of climate change and it's associated causes, decisions cannot be left to the market to decide, although as pointed out (in section 4.2) this *will* occur eventually where fossil fuels are concerned. Successful climate change mitigation requires immediate action which in turn requires political ***and*** corporate attention to be focused on the relevant issues.

While these obviously include our obligation and responsibility to implement climate change mitigation as laid out in the UNFCCC it should also include the activities of several multi-national corporations. For example, while the GM food safety issue is of major concern, this technology has the potential to contribute positively in the further development of biofuel crops and land rehabilitation using multipurpose industrial crops. This technology also has a potential role to play in the production of enzymes required for ethanol production from cellulose. Unfortunately, without some political intervention this technology will have greater market viability where food crops are concerned over other, arguably more environmentally sound uses such as climate change mitigation. Alternative technology designed specifically for the energy sector has been making substantial progress. According to Paul Staples, Chairman of HyGen Industries (personal communication, 2000) hydrogen powered fuel cells will enter the market with a sizeable share of domestic, commercial and utility applications within the next ten years.

In addition, there are many companies, such as Iogen Corporation (personal communication, 2000), that are committed to the development of ethanol from cellulosic biomass feedstocks. This process has particular economic and environmental benefits since (see section 3.5) it can use commercially established technology such as the internal combustion engine rather than new (i.e.hydrogen) fuel cells, thus saving the premature devaluation of capital stocks (from oil generated power stations to motor vehicles). Most importantly Cannabis is particularly well suited to this end both practically and logistically.

The cultivation of Cannabis within both conventional and organic agricultural systems, combined with the rehabilitation/reclamation of degraded land could form an important – if not crucial – foundation for a coherent and politically/socially inclusive **World Agricultural Agreement**. By addressing climate change via an environmental approach using Cannabis as a multipurpose industrial feedstock of cellulosic biomass – supported by environmental policy and economics – we have the potential to address many of the land-use and consumption related causes of climate change ***and*** the actual volume of carbon dioxide in the atmosphere. This would be especially the case where cellulosic biomass is used in energy and transportation applications.

5.0 References

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