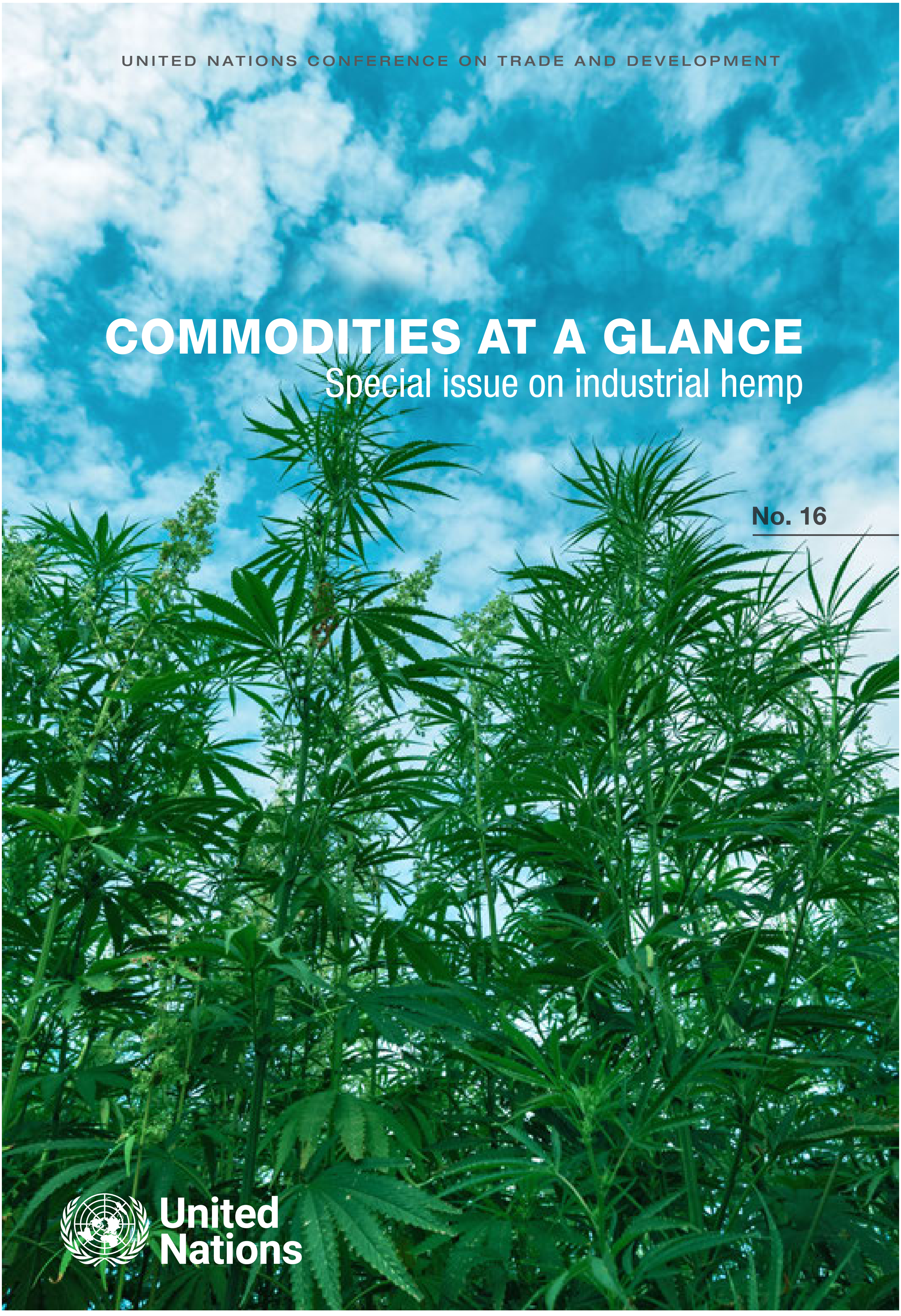
UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

COMMODITIES AT A GLANCE

Special issue on industrial hemp

No. 16



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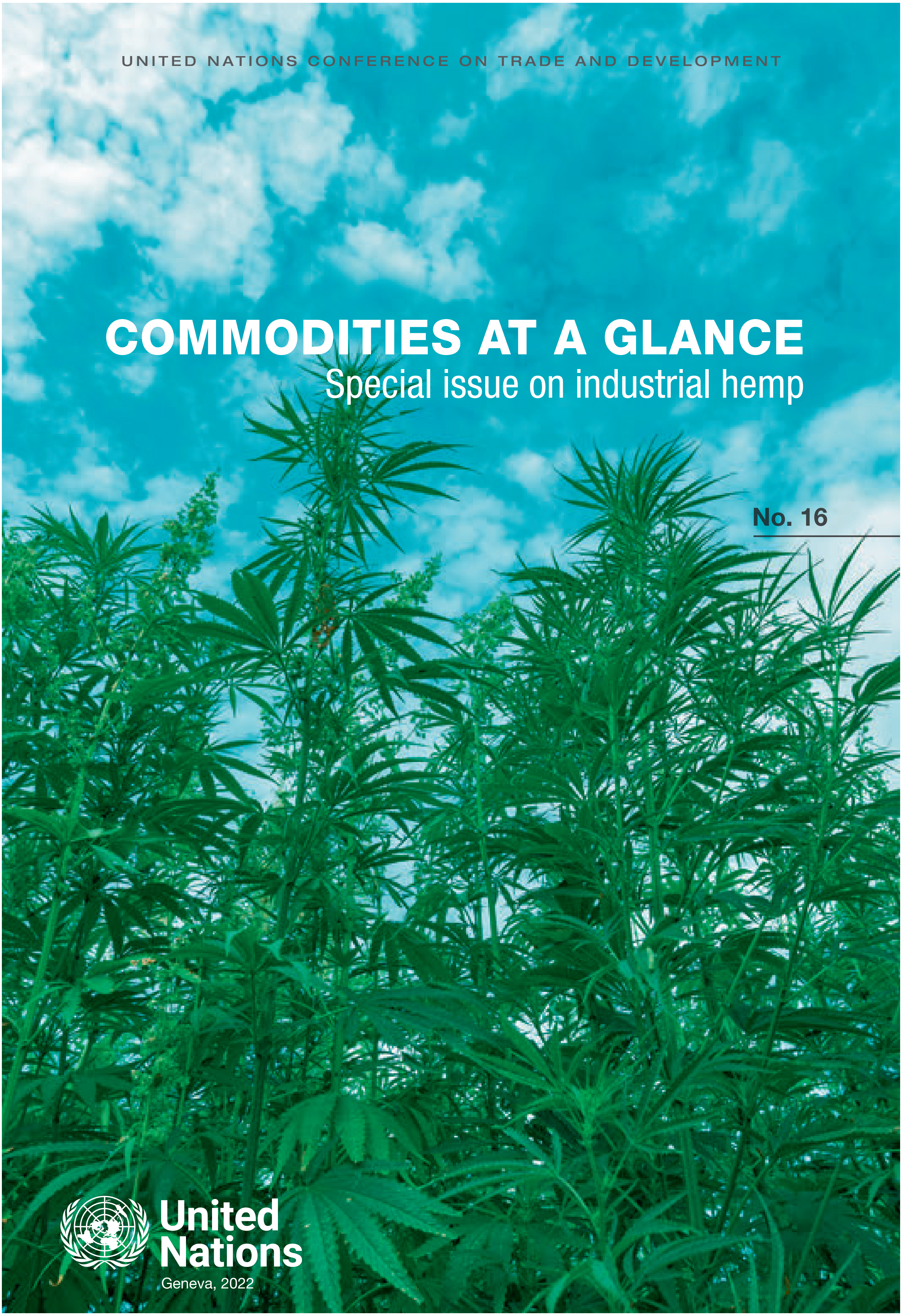

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NOTE

References in the text to the United States are to the United States of America, and those to the United Kingdom are to the United Kingdom of Great Britain and Northern Ireland.

The data for China do not include those for Hong Kong (Special Administrative Region), Macao (Special Administrative Region) and Taiwan Province of China.

Reference to the European Union is to all 27 Member States of the European Union.

The term “dollar” or the $ symbol refers to the United States dollar unless otherwise stated.

The term “billion” signifies 1,000 million; the term “tons” refers to metric tons.

Exports are valued FOB (free on board) and imports CIF (cost, insurance and freight) unless otherwise specified.

Use of an n-dash (–) between years signifies the full period involved, including the initial and final years.

Two dashes in a table indicates that data are not available, or are not separately reported.

ACRONYMS

CBD .... cannabidiol
CBDA .... cannabidiolic acid
CBG .... cannabigerol
CBN .... cannabinodiol
EIHA .... European Industrial Hemp Association
FAO .... Food and Agricultural Organization of the United Nations
ha .... hectare
HS .... Harmonized System (Harmonized Commodity Description and Coding System, in full) (World Customs Organization)
INN .... international non-proprietary name
kg .... kilogram
kWh .... kilowatt-hour
MFN .... most-favoured-nation
NTM .... non-tariff measure
SITC .... Standard International Trade Classification (United Nations)
SPS .... sanitary and phytosanitary (measures)
THC .... tetrahydrocannabinol
UN Comtrade . United Nations Commodity Trade Statistics (database)
UNCTAD .... United Nations Conference on Trade and Development
UNODC .... United Nations Office on Drugs and Crime

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CHAPTER I

Introduction

This report discusses the general uses of industrial hemp, and how they are reflected in international production and trade statistics. Based on current practical experiences and empirical expertise, it also defines the steps that could be taken by developing countries where climate and agronomic characteristics are favourable for its cultivation in order to exploit its economic and social potential.

Industrial hemp does not have intoxicating properties. Nonetheless, it remains a controversial plant, as it is still often mistakenly associated with use as an intoxicant. A negative connotation still prevails despite a history, over several millennia, of its industrial and medicinal applications. Such a connotation is due in part to confusion about the botanical characteristics and chemotype of the plant.

Industrial hemp belongs to the *Cannabis* L. genus. Despite a long history of botanical research, no consensus on its taxonomy has emerged yet. The only consensus reached is about the current existence of a unique species in the genus, namely the *Cannabis sativa* L. species.

From a botanical point of view, industrial hemp does not uniquely correspond to any subspecies of *Cannabis sativa* L. All recognized subspecies encompass several varieties and cultivars, some having intoxicating properties.[1] A clear distinction between intoxicating properties and intoxicant plant varieties should be made, as is done, using a practical approach adopted by the hemp industry. This is also the approach adopted in this report, even though it does not perfectly correspond to any taxonomic or phylogenetic classification.[2]

China has always been the leading producer of industrial hemp, primarily for its fibre. Other important historical producers have been essentially European countries such as France. However, Canada and the United States of America are becoming large producers with a growing influence on international markets. Overall, about 40 other countries currently produce some significant quantities of industrial hemp.

Due to a narrow set of hemp products covered by international trade statistics, recorded trade flows do not fully reflect the true size of the global industrial hemp market. Despite an estimated overall value of about $5 billion in 2020, trade in such products, as reported in international trade datasets, amounted to a mere US42 million. Thus a clear effort is urgently needed to include a more representative set of hemp-related products in international product classifications.

Information about prices of hemp products is also scarce. Currently available sources of information are scattered and are not easily comparable. However, some patterns emerge within the sector. Important price differences exist between raw, semi-processed hemp, hemp yarn and more sophisticated derivative products such as cannabidiol (CBD).

In 2020, the average value of one kilogram (kg) of imported hemp yarn was about $9.1 against $0.94 for semi-processed hemp, and $1.38 for raw hemp. The price of crude CBD hemp oil on the European market reached $931 per kg in November 2021. CBD isolate[3] was sold at $952 per kg and $1,200 per kg in November 2021 on the European and United States markets, respectively. However, a significant fall in prices due to overproduction of hemp-derived CBD-containing products has been observed since the overheating of the market in late 2019 and early 2020 in the United States. This drop in prices rapidly spread to the European market causing some turmoil in overall industrial hemp production.

1 In the taxonomic hierarchy, the genus splits into species, then into subspecies and finally into varieties or cultivars. A variety is a type of plant grown from seed that has the same characteristics as the parent plant. A cultivar is a lithe parent plant. Growing a plant from one of these plant's seeds may not produce the same plant as the parent.

2 Hereafter, non-intoxicant plants are referred to as industrial hemp or hemp. Intoxicant plants are referred to as cannabis with "c" in lower case. References to *C. sativa* L. or *Cannabis*, with "C" in upper case, may or may not have intoxicating properties.

3 CBD isolate is a pure extract that contains only cannabidiol and no other chemical compound naturally present in hemp plants. It can take the form of a crystalline solid or a powder.

In general, trade flows of industrial hemp products face relatively low tariffs compared with other agricultural products. Some tariff escalation can be observed in most importing countries, with hemp yarn facing higher tariffs relative to raw or semi-processed hemp products. However, a full appreciation of prevailing international market access conditions must also take into account the incidence and prevalence of non-tariff measures (NTMs).

Available information reveals that such measures are systematically imposed on imports but may also be imposed on exports. Some of these measures can have a potentially strong restrictive impact on trade flows and can involve some laboratory testing. There is also some escalation in the number of applied measures. For instance, the number of different types of measures imposed worldwide on both exports and imports of hemp yarn is twice as large as that imposed on exports and imports of raw or semi-processed products.

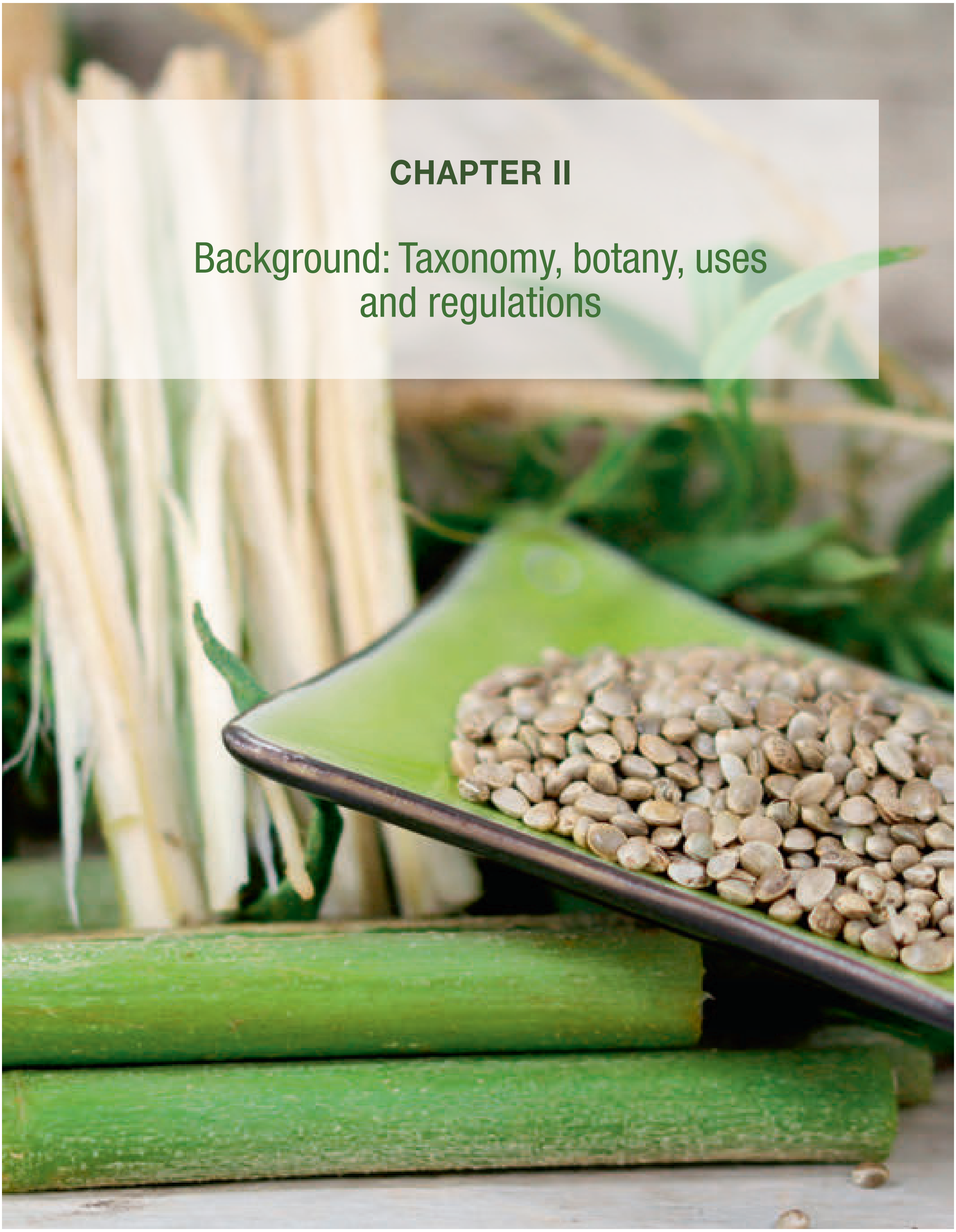
The *C. sativa* L. plant is a versatile, multipurpose crop. Given that its roots, flowers and fruits, stems and leaves have various medical, industrial and nutritional uses, their exploitation could generate significant agricultural benefits. Thus, a so-called whole-plant approach based on the exploitation of all parts of the plant should be at the core of any sectoral development strategy. This approach could facilitate the creation of production chains that are able to contribute to growth in rural areas, in manufacturing and in the food processing industry.

However, to fully exploit the potential of industrial hemp, countries would need to take specific actions. For instance, a clarification of the legal status of hemp as distinct from intoxicant cannabis substances could be the first step taken by governments. A precise understanding of production constraints imposed by regulatory frameworks in destination markets would also be necessary to identify market potential. Regional cooperation to facilitate the establishment of production chains may also be a strategy for developing countries to consider.

The remainder of this report is organized as follows. Chapter 2 presents the definitions and taxonomy related to the *Cannabis* L. genus, followed by a description of its botanical properties and ecological characteristics. Current uses are then reviewed, and the chapter concludes with an assessment of international treaties that regulate industrial hemp production. Chapter 3 discusses the industrial hemp sector value chain. It first describes production options and constraints faced by major growers. It then looks at potential challenges and opportunities for processors. Finally, the chapter considers how consumers' preferences, and their evolution, may affect market trends. Chapter 4 first presents some facts and figures about hemp production, followed by information relating to international trade in hemp products. The last section discusses tariffs and NTMs relating to hemp trade. Chapter 5 discusses prices of industrial hemp products, based on trade unit values and prices that are published by the Food and Agricultural Organization of the United Nations (FAO) and various other sources. Chapter 6, highlights policy issues for consideration by governments for promoting the development of industrial hemp.

CHAPTER II

Background: Taxonomy, botany, uses and regulations



This chapter first reviews the definitions and taxonomy relating to the plants belonging to the *Cannabis* L. genus with specific reference to industrial hemp. It then provides a description of hemp's botanical properties and ecological characteristics. This is followed by a discussion of the multiple uses of the different parts of the plant. International treaties defining the prevailing regulatory framework dealing with intoxicant properties of the *Cannabis* L. genus plants and de facto industrial hemp are also presented.

2.1 DEFINITIONS AND TAXONOMY

Industrial hemp – or simply hemp – is the commonly used term for non-intoxicant plant varieties belonging to the so-called *Cannabis* L. genus. The international hemp sector defines industrial hemp as "a *Cannabis sativa* L. plant – or any part of the plant – in which the concentration of the secondary compound tetrahydrocannabinol (THC) in the flowering tops and leaves is less than the regulated maximum level, as established by authorities having jurisdiction." [4] A clear identification of industrial hemp is necessary to appreciate fully the multiplicity of its industrial, agricultural and agronomic uses.

Industrial hemp, however, does not correspond to any consensual taxonomic or phylogenetic classification, and is instead a reflection of a specific cannabinoid profile, especially in terms of THC content, and the associated legislative restrictions.[5]

The first classification of the botanical genus that encompasses industrial hemp plants, as commonly defined, was first established in 1753 by the botanist, Carolus Linnaeus, and is referred to as the *Cannabis* L. (Linnaeus) genus.[6] Domestication of *Cannabis* L. plants has been so extensive that it has led to the quasi-disappearance of most wild species.[7] However, some endemic varieties (sometimes called "landraces") persist. Moreover, there are countless cultivated varieties that occasionally escape cultivation and grow also in the wild, giving life to forms ("hybrids") that lose some features typical of the cultivated ones. For these reasons, the nomenclature of the *Cannabis* L. genus has imprecise foundations and has been the object of numerous taxonomic treatments.[8]

Nevertheless, there seems to be broad agreement on the recognition of a unique species (i.e. *Cannabis sativa* L.). Divergences across existing taxonomies emerge essentially in the number of subspecies and their respective varieties (e.g. Bouloc, 2013; Small, 2017).

One common trait of all *Cannabis sativa* L. plants is the presence of secondary compounds called "phytocannabinoids" or, more commonly, "cannabinoids". There are over 100 different phytocannabinoids. However, among the various *Cannabis sativa* L. accessions,[9] the profile and quantity of specific phytocannabinoids can vary significantly. To reflect this variation, it has been suggested[10] that *Cannabis sativa* L. strains be classified according to their chemical phenotypes into chemotypes (or chemovars) with distinct cannabinoid profiles.

Of the many compounds in cannabis, the cannabinoids delta-9- tetrahydrocannabinol (Δ9-THC, international non-proprietary name (INN): "dronabinol") and cannabidiol (CBD, INN: "cannabidiol") are the most abundant.

4 See Common-position-of-the-Industrial-Hemp-Sector.pdf (hemptoday.net) for explanationsfor the use of such a definition.

5 See Watts (2006) for a non-technical introduction to taxonomical controversies and common confusions.

6 The *Cannabis* L. genus belongs to the botanical family called Cannabaceae (see, for example,Polio, 2016), which also includes the *Humulus* genus whose most well-known species is hops or Humulus lupulus (Larsson and Lagerås, 2015).

7 Some documented wild species, however, still exist in Asia. See, for instance, Small (2017) for a discussion.

8 See McPartland (2018) for a comprehensive review.

9 According to the FAO (2013) official definition, an accession is defined as a sample of seeds, planting materials or plants representing either a wild population, a landrace, a breeding line or an improved cultivar, which is conserved in a gene bank.

10 See Small (2017) for a detailed discussion.

While the former is the only narcotic and addictive constituent of *Cannabis sativa* L., cannabidiol (CBD) has no narcotic or addictive effects. Both have gained widespread interest among researchers and consumers for their nutraceutical[11] and medicinal purposes.

Small (2015) proposed two possible classifications of *Cannabis sativa* L. The first classification, based on the International Code of Nomenclature for Cultivated Plants (ICNCP), recognized six groups of cultivars.[12] The second classification, first introduced by Small and Cronquist (1976), adopted the taxonomic subdivision of the *Cannabis* L. genus under the International Code of Nomenclature for algae, fungi, and plants (ICNAFP). It follows a biphasic approach,[13] combining morphological and chemical characters (fruit morphology and Δ-THC content). The four varieties, all belonging to the single species *Cannabis sativa* L., which "coexist dynamically by means of natural and artificial selection" are presented in table 1. Varieties belonging to the subspecies, sativa, show a limited intoxicant potential. In contrast, varieties of the subspecies, indica, have a much higher intoxicant potential.

Due to the difficulty of distinguishing the *Cannabis sativa* L. subspecies, either in chemical terms or morphologically, given that *Cannabis sativa* L. (*C. sativa* L.) p resents continuous changes depending on the environment and the conditions in which it is planted, the United Nations Office on Drugs and Crime (UNODC) considers the designation *C. sativa* L. suitable for all plants of the genus. Other species reported for the genus (i.e. *C. sativa* ssp. sativa, *C. sativa* ssp. indica, *C. sativa* ssp. *ruderalis*, *C. sativa* ssp. spontanea, *C. sativa* ssp. *kafiristanca*) are all recognized as subspecies of *C. sativa* L.[14]

Table 1 A practical *Cannabis sativa* L. classification

Genus *Cannabis* L. – Hemp			
Species *Cannabis sativa* L.			
Weak intoxicant Less than 0.3 per cent THC and up to 1 per cent, depending on country legislation		**Strong intoxicant** More than 0.3 per cent THC or 1 per cent, depending on country legislation	
Domesticated	Wild	Domesticated	Wild
Variety *sativa*	Variety *spontanea*	Variety *indica*	Variety *kafiristanica*
Fibre and oil cultivars		Narcotic cultivars	

Source: Small and Cronquist (1976), illustrating the conceptual bases for delimitation, based on Small (2015).

The common definition of industrial hemp, cited above, remains essentially pragmatic, and does not correspond to any officially adopted taxonomic or phylogenetic classification. Instead, it reflects a specific cannabinoid profile, especially in terms of THC content and the associated legislative restrictions.[15]

[11] Nutraceutical refers to a food or part of a food that provides medical or health benefits, including for the prevention and treatment of disease.

[12] Clarke and Merlin (2015) have cautioned that the use of groups needs careful interpretation as it removes some hierarchical classifications which, while simplifying taxonomic issues, obscures deeper evolutionary relationships between genotypes.

[13] Already adopted by Small and Cronquist (1976).

[14] See UNODC (2022) for further details.

[15] For instance, as of today, the Common Catalogue of varieties of agricultural plant species of the European Union encompasses 81 varieties with a THC value in the field (i.e. observed after harvest) of less than 0.2 per cent (https://tinyurl.com/2p8rfww2). Starting from 2023, following the adoption of the new texts of the Common Agricultural Policy (CAP) of the European Union, the maximum threshold of THC forregistration in the European Union catalogue will be reset at 0.3 per cent. This change is likely to entail an increase in the number of European Union registered varieties. The Community Plant Variety Office (CPVO) online registry lists 1,474 results matching the genus "*Cannabis*", 608 of which correspond to "registered varieties" (https://vf.plantvarieties.eu/varieties). Few plant varieties have been granted protection under the International Union for the Protection of New Plant Varieties (UPOV) denomination class "CANNB" for *Cannabis* L. (https://pluto.upov.int/result).

The existence of several taxonomies and societal sensitivity concerning the plant due to the psychotropic effects of some of its variants may also explain a somewhat parsimonious definition of *Cannabis sativa* L. products in international nomenclatures such as the World Customs Organization's Harmonized Commodity Description and Coding System (HS) introduced in 1988[16] and the United Nations' Standard International Trade Classification (SITC) introduced in 1950. In the most recent versions of both nomenclatures only "True hemp"[17] products are considered. The term "True hemp" has been associated with the *Cannabis sativa* L. species in the second edition of the HS nomenclature promulgated in 1996 and in the fourth revision of the SITC nomenclature published in 2006.[18] The HS nomenclature includes only three hemp-related products as shown in table 2. The SITC has only two references: raw or retted true hemp (code 26521), and tow and waste of true hemp (code 26529).

Even though national nomenclatures, used principally to collect tariffs and record trade transactions, include some additional hemp-related products, these are poorly reflected in trade statistics, with no more than 14 entries overall. Table A.1 presents the HS nomenclature national transcription for Canada, the European Union, Japan and the United States. It reveals that both Canada and Japan include *Cannabis sativa* L. products for medical use. These products can be considered as being derived from intoxicant types of *Cannabis sativa* L. plants even though their THC concentration level is not explicitly mentioned.[19]

Table 2 Industrial hemp in the HS international nomenclature

HS 2 digits	HS 4 digits	HS 6 digits	Description
53			Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn
	53.02		True hemp (*Cannabis sativa* L.), raw or processed but not spun; tow and waste of true hemp (including yarn waste and garnetted stock)
		5302.10	Hemp (*Cannabis sativa* L.); raw or retted, but not spun
		5302.90	Hemp (*Cannabis sativa* L.); processed (other than retted) (but not spun), true hemp tow and waste (including yarn waste and garnetted stock)
	53.08		Yarn of other vegetable textile fibres; paper yarn:
		5308.20	Yarn; of hemp (*Cannabis sativa* L.)

Source: World Customs Organization (HS Nomenclature, 2017 edition, extract).

The United States Department of Agriculture (USDA) is currently working on a method to define more accurately and systematically different *C. sativa* L. cultivars or varieties. Its approach aims at capturing phenotypic data for genetically and geographically diverse plant germplasms across many diverse usage classes and applications. [20]

[16] The HS nomenclature is used by most countries and economies as a basis for their customs tariffs and for the collection of international trade statistics, and often include additional digits for a more refined identification and definition of products.

[17] The adjective "true" was introduced to differentiate "true hemp" (*Cannabis sativa* L.) from other genera commonly called "hemp" in popular culture, such as Bog hemp (Boehmeria cylindrica), Madras hemp (Crotalaria juncea), Manila hemp (Musa textilis) or Sisal hemp (Agave sisalana).

[18] Note that the first revision of the SITC nomenclature included references to yarn and fabrics of true hemp only. However,references to any hemp-related product disappeared in the second revision of 1975. Hemp fibre products were reintroduced in the third revision of 1985.

[19] THC thresholds are referred to in regulations (e.g. sanitary and phytosanitary (SPS) measures and technical barriers to trade (TBT)) imposed on imports and exports of these products. The issue of such NTMs is discussed in chapter 4.

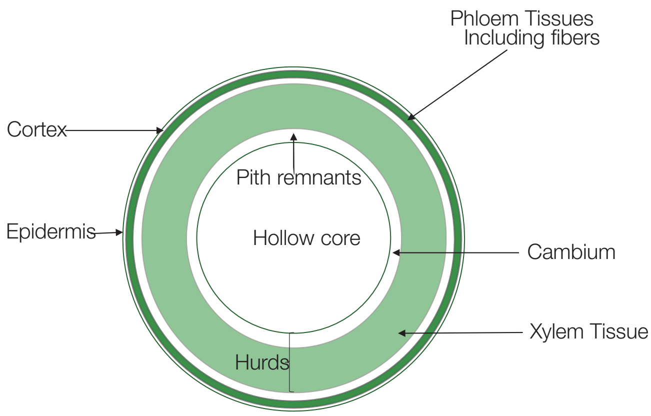
[20] The information gained from these phenotyping efforts will be reported in the USDA Hemp Descriptor and Phenotyping Handbook, and will be digitally stored at https://www.ars.usda.gov/northeast-area/geneva-ny/plant-genetic-resources-unit-pgru/docs/hemp-descriptors/.

2.2 BOTANY/BOTANICAL ASPECTS AND BIOCHEMICAL STRUCTURE

Cannabis sativa L. is an annual,[21] pollinated herbaceous plant. It is naturally either a monoecious species (both male and female unisexual flowers are on the same specimen but not in the same floral structure) found often in tropical climates, or a dioecious species (with the unisexual male and female flowers located on separate specimens) found often in more temperate climatic conditions (Small and Cronquist, 1976; Clarke and Merlin, 2013; Moliterni et al., 2004).[22]

The plants have a branched taproot system, in general growing at a depth of 30–60 centimetres, but it could reach 2.5 metres in loose soils (Farag and Kayser, 2017). The stems are erect, usually angular, furrowed and branched, with a woody interior and sometimes hollow in the internodes. The outer part is generally referred to as "bark" or bast, while the inner material is referred to as hurds (figure 1). The stems' height can vary from 1 to 6 metres. The green, palmate leaves comprise seven lobes. The size and shape of the leaflets can vary noticeably across cultivars with different genetic origins. The lower (abaxial) and upper (adaxial) surfaces of the leaves have scattered resinous trichomes (tiny secretory epidermal glands). Different kinds of glandular or non-glandular epidermal trichomes can occur.

Figure 1 Scaled diagram of a cross section of a mature hemp stem



Source: Small (2015).

From a biochemical perspective, *C. sativa* L. plants contain a complex mixture of secondary metabolites.[23] More than 500 compounds have been reported from these plants, of which around 100 cannabinoids have been isolated and/or identified. These cannabinoids are specific to *C. sativa* L. and are essentially localized in its capitate-stalked glandular trichomes.[24] There is some evidence of cannabinoid production outside the epidermal glands, but only in trace amounts. Furr and Mahlberg (1981) detected cannabinoids in the plants' laticifers.[25] Various studies (e.g. Pacifico et al., 2008) found no production of THC in tissue cultures, suggesting that non-secretory cells do not produce cannabinoids. However, some experiments have demonstrated production of cannabinoids in cell cultures of *C. sativa* L., but in extremely limited amounts.[26]

[21] Note, however, that female plants protected from frost can survive for years even though they gradually lose their vitality (Small, 2017).

[22] Compared to dioecious cultivars, the monoecious cultivars are more uniform in terms of plant height, stem and seed production (e.g. Amaducci et al., 2012; Salentijn et al., 2015; Small, 2015).

[23] Secondary metabolites are organic compounds that are not essential to the growth and life of the producing plant.

[24] Hemp trichomes are classified into bulbous, capitate-sessile, capitate stalked and non-glandular types (Andre et al., 2016).

[25] Laticifers occur in the foliage and stems. These are of an unbranched and non-articulated form, made up of an elongated secretory cell producing a kind of latex.

[26] See Mandolino and Ranalli (1998) for an early review.

Glandular trichomes are found predominantly on the bracts and floral leaves of female plants (Romero et al., 2020), but few, if any, on male plants. Radwan et al. (2021) further group these naturally occurring cannabinoids into 11 phytocannabinoid sub-classes, namely: cannabichromene (CBC), cannabidiol (CBD), cannabielsoin (CBE), cannabigerol (CBG), cannabicyclol (CBL), cannabinol (CBN), cannabinodiol (CBND), cannabitriol (CBT), (Δ8)-D8-trans-tetrahydrocannabinol (D8-THC), (Δ9)-D9-trans-tetrahydrocannabinol (D9-THC/dronabinol),[27] and miscellaneous-type cannabinoids. The very first compound isolated in pure form from the plant was CBN by Wood (1899). The second compound identified was cannabidiol CBD found by Adams et al. (1940) and Mechoulam and Shvo (1963), followed by cannabidiolic acid (CBDA) in the subsequent decade (Krejčí and Šantavý, 1955). Gaoni and Mechoulam (1964) isolated the main narcotic compound D9-THC[28] as well as CBC.

In addition to cannabinoids, more than 400 non-cannabinoid constituents have been isolated and/or identified from the *C. sativa* L. plant. Radwan et al. (2021) classify non-cannabinoid constituents into four major categories: non-cannabinoid phenols, flavonoids, terpenes and alkaloids.

Additional molecules are found in the seed (e.g. Borhade, 2013; Callaway, 2004). The whole seed contains about 25 per cent protein, 30 per cent carbohydrates, 17 per cent insoluble fibre, carotene, phosphorus, potassium, magnesium, sulphur, calcium, iron and zinc, as well as vitamins E, C, B1, B2, B3 and B6.[29] Hemp seed further contains essential fatty acids: omega-3-linolenic acid and omega-6-linoleic acid. It is also a good source of gamma linoleic acid. Phytochemicals are also present in the plants' roots. Kornpointner et al. (2021) identified 20 secondary metabolites, including β-amyrone, glutinol, fucosterol, stigmastanol, stigmasta-3,5-diene, stigmasta-3,5,22-triene and oleamide.

C. sativa L. plants synthesize both CBDA and THCA, which become CBD and THC when heated or aged (decarboxylation) during the harvesting and processing stages. The initial biosynthesis within the plant is due to the same cannabinoid, namely CBGA (Cannabigerolic Acid). Whether THC, CBD, or both, appear, and at what level of concentration, depend on an enzyme that can take one of two forms that are encoded by the same gene. Since each plant gets two gene copies, there are only three available options. It would either get two of the first-encoding genes, one of each of the two encoders, or two second-encoding genes.

The genetic configuration obtained determines how much CBDA and THCA the plant will contain. The plant can end up being CBD-dominant with minimal THC levels, with a 1:1 THC/CBD ratio, or THC-dominant. As both THC and CBD are derived from the same gene, there are strict limits on the possible ratios of either. For THC, the upper limit is around 35 per cent THC by dry weight, with most high-potency strains at 25–30 per cent. The upper limit for CBD, by comparison, is 20–25 per cent. In strains containing significant amounts of both cannabinoids, the limits are even more nuanced. For instance, a strain with 30 per cent THC and 10 per cent CBD is improbable, as is the reverse. However, novel genetic techniques and "synthetic biotechnologies"[30] might enable increased deviations from these traditional phytocannabinoid ratio limitations in a relatively near future.

2.3 GEOGRAPHICAL DISTRIBUTION AND ECOLOGICAL CHARACTERISTICS

The geographical and ecological range of *C. sativa* L. is broader than for most crops. It can be successfully grown on soils where other crops cannot. Industrial hemp can be grown in most parts of the world as it

[27] Recent research has found the presence in trace amounts of the stereochemical variant delta9-cis-tetrahydrocannabinol in *Cannabis* plants (Schafroth et al., 2021).

[28] For a detailed history of chemical research related to the discovery of cannabinoids, see Mechoulam and Hanuš (2000).

[29] A typical proximate composition of seed would be associated with the following ranges: moisture 3–5 per cent, oil 30–35 per cent, protein 20–25 per cent, ash 3–5 percent, fibre 15–20 per cent and carbohydrate 27– 30 per cent.

[30] See UNCTAD (2019a) for a policy-oriented discussion on synthetic biology.

tolerates a variety of climates. Indeed, cultivated varieties/cultivars growing outdoors are found on every continent, except Antarctica, in a wide range of environments, from sub-arctic to temperate to tropical, and from sea level to altitudes of over 3,000 metres in the Himalayas (Clarke and Merlin, 2013). Wild or feral (i.e. domesticated plants that again became wild) populations are also found as far north as the edge of the Arctic Circle in Eurasia. However, as stated by Small and Cronquist (1976), *C. sativa* L. in its wild form grows mostly to the north of latitude 30°N and south of latitude 60°N. The plants usually grow best in rather warm temperatures of 25-30°C (Small, 2017). Soil temperatures must reach a minimum of 8-10°C when hemp seeds are sown. These conditions lead to vigorous vegetative growth, implying a better ability to suppress competitive weeds (Bouloc, 2013). This explains why *C. sativa* L. plants are most commonly found in well-drained soils in temperate continental ecosystems in Eurasia and North America, where tropical populations are absent or rare.

When grown outdoors in the Northern hemisphere, hemp seeds are traditionally sown between March and May and in the beginning of June, which implies plants mature between September and November (Bouloc, 2013; Leggett, 2006). However, due to their exceptionally adaptive phenotypic[31] plasticity, different varieties of *C. sativa* L. respond differently to prevailing climatic conditions, depending on latitude and basic agronomic inputs (Williams and Mundell, 2018). Thus, an outdoor temperature range of 14°C–27°C could be sufficient to ensure decent plant growth.

Even though *C. sativa* L. grows best in fertile loams, it is plastic enough to adapt to a large range of soil conditions. Such plasticity allows the root system to adapt to prevailing hydraulic conditions, including penetrating deep-water sources. The plant grows well in areas that receive rainfall of about 600mm per annum, with an average monthly rainfall of at least 65mm throughout the growing season. The plant foliage prevents the evaporation of soil water. Acidity of the soil mix can also significantly affect the plant's development, as it directly influences the soil's nutrient composition. The best range appears to be between 6 (slightly acidic) and 7.5 (slightly alkaline).[32] *C. sativa* L. plants generally respond to a good supply of soil nutrients, and in particular nitrogen, phosphorus and potassium. However, dwarf plants will grow even in very infertile conditions, characterized by either undesirable or basic levels of acidity that cause a severe shortage of minerals and nutrients, and still produce a few seeds (Leggett, 2006).

2.4 REGULATORY STATUS

The international drug control system comprises three conventions that establish core international regulations related to cannabis and de facto industrial hemp (UNODC, 2013). Indeed, they focus on the distinction between the intoxicant and non-intoxicant properties of the plant.

These conventions have been established to prevent the abuse of narcotic drugs and psychotropic substances, while ensuring their availability for medical and scientific purposes, and other legitimate purposes such as industrial uses. They represent the core of the various regulatory frameworks dealing with *C. sativa* L. implemented at different jurisdictional levels.

The first treaty signed by United Nations Member States in 1961[33] is the Single Convention on Narcotic Drugs, amended by the 1972 Protocol (C-61 or Single Convention). The convention lists narcotic drugs and

[31] Phenology is defined as the study of the timing of recurring biological events, how these recurrences are influenced by seasonal and interannual variations in climate, habitat factors and the interrelations of the same or different species during recurrent events.

[32] Soil acidity is measured as apH value. Soils with pH between 6.5 and 7.5 are neutral; soils with pH over 7.5 are alkaline; soils with pH less than are 6.5 acidic; and soils with pH less than 5.5 are considered strongly acidic.

[33] Certified copies and the status of adherence to the Convention, along with the amendment, are available at https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=VI-18&chapter=6&clang=_en. See also United Nations, 1973; UNODC, 2013.

their preparations in four schedules according to their dependence potential, abuse liability, and therapeutic usefulness. The inclusion in a specific schedule determines the control measures that States Parties are required to apply to the respective substances.[34] Schedule IV represents the strictest levels of mandatory control, followed by Schedule I – "the standard regime under the Single Convention" (United Nations, 1973: 51);[35] Schedules II and III establish lighter subsets of controls. For substances listed in Schedule IV, States Parties are additionally encouraged to adopt any special measures of control they may deem necessary.

The second international treaty signed by United Nations Member States[36] is the Convention on Psychotropic Substances of 1971 (C-71). Psychotropic substances are categorized in four schedules, depending on the risk of abuse, the threat to public health and the therapeutic value associated with them. Substances in Schedule I pose a high risk of abuse and a particularly serious threat to public health, and have very little or no therapeutic value, whereas substances included in Schedule IV pose a risk of abuse and a minor threat to public health and have considerable therapeutic value. Substances in the remaining two groups have intermediate risk characteristics.

The third treaty signed by United Nations Member States[37] is the United Nations Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances of 1988 (C-88). Under this convention, controlled precursors (substances used in the manufacture of narcotic drugs or psychotropic substances) are listed in one of two tables. Substances in Table I are, in principle, of special relevance in international trade. Governments are entitled to request pre-export notifications whenever Table I substances are present.

A clear textual distinction is made, especially in C-61, between *C. sativa* L. plants grown to produce drugs (falling within the scope of the treaties) and exempting those grown for any other purposes. In Article 1-1(c) of C-61, the definition of "Cannabis plant" refers only to *Cannabis* plants used for the "production" and "manufacture" of drugs. Article 28-2 further qualifies distinctive features between drug and non-drug products: "This Convention shall not apply to the cultivation of the *Cannabis* plant exclusively for industrial purposes (fibre and seed) or horticultural purposes". The official Commentary published by the United Nations Secretary-General's office further underlines that "[this] control régime applies only to the cultivation of the *C. sativa* L. plant for the production of cannabis and cannabis resin [i.e. drugs present in the Schedules]" and hence the "cultivation for any other purpose, and not only for the purposes mentioned in paragraph 2 [i.e. "industrial purposes", "horticultural purposes", "fibre and seed"], is consequently exempted from the control regime provided for in article 23 [i.e. falls out of the scope of C61]" (United Nations, 1973: 312).

Both cannabis flowering and fruiting tops without seeds) and cannabis resin were listed in Schedules I and IV of C-61 until December 2020. Since then, following a critical review of *C. sativa* L. by the Expert Committee on Drug Dependence of the World Health Organization (WHO), the Commission on Narcotic Drugs (CND) of the United Nations Economic and Social Council took the decision to delete cannabis and cannabis resin from Schedule IV of C-61 (Riboulet-Zemouli and Krawitz, 2022; UN News, 2020). However, both remain in Schedule I alongside "extracts and tinctures of cannabis" and are thus still subject to all levels of control defined by the convention. The Convention on Psychotropic Substances of 1971 lists in its Schedule I the

[34] Note that no legal classification of drugs is based on science. Drug listing, classification and scheduling therefore do not accurately reflect potential harms and remain discretionary. See Nutt et al. (2007) for a detailed discussion.

[35] See commentary in United Nations (1973: 51) for a detailed interpretation, athttps://www.unodc.org/documents/commissions/CND/Int_Drug_Control_Conventions/Commentaries-OfficialRecords/1961Convention/1961_COMMENTARY_en.pdf.

[36] Certified copy and status of adherence are available at https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=VI-16&chapter=6&clang=_en

[37] Certified copy and status of adherence are available at https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=VI-19&chapter=6&clang=_en

six isomers of tetrahydrocannabinol other than delta-9,[38] and in Schedule II delta-9-tetrahydrocannabinol.[39] So far, these seven isomers of THC are the only official cannabinoid classes to be listed as psychotropic substances. Other cannabinoids are considered to be psychoactive but are not classified as psychotropic or narcotic substances.[40] No *Cannabis*-related substance is listed as a precursor under C-88.

Even though a clear distinction is made between intoxicant and non-intoxicant *C. sativa* L. products in international treaties, the interpretation of the Conventions' scope is still subject to controversy regarding the inclusion or not of the various parts of the plants. The international hemp industry has called for a precise definition of non-intoxicant *C. sativa* L. or hemp.[41] A commonly agreed declaration by most hem associations proposed that the latter should be defined as "a *Cannabis sativa* L. plant – or any part of the plant – in which the concentration of tetrahydrocannabinol (THC) in the flowering or fruiting tops is less than the regulated maximum level, as established by authorities having jurisdiction." The declaration further proposes that "hemp extracts" or "hemp products" should be defined as "products or preparations derived from industrial hemp."

According to the above-cited conventions, the participating countries can prohibit illicit uses of scheduled drugs for other than medical and scientific purposes (e.g. recreational use), but prohibition or criminalization of personal use and possession is not mandatory and "the conventions do not oblige States to adopt punitive responses" (INCB, 2019).[42] Most of the national laws on drugs are shaped by the provisions of these treaties. In some cases, though, laws on drugs, and particularly on *C. sativa* L., preceded the Conventions, and may even have influenced the creation of an international regulatory framework (Kozma, 2011a; Mills, 2016; McAllister, 2000). After the Conventions were adopted, many countries approved drug control laws that made a clear distinction between drug-type and non-intoxicant *C. sativa* L., based on limitations over varieties to be grown, plant parts and THC concentration in the "flowering tops and leaves."

2.5 CURRENT USES

The *C. sativa* L. plant is a versatile, multipurpose crop the properties of which have been explored and exploited for several millennia, as discussed in box 1. All parts of a hemp plant – the roots, flowers and fruits, stem and leaves – can be used for various medical, industrial and nutritional purposes (figure 2).

As described in section 2.4, the legal differentiation between industrial hemp and the intoxicant plant is based almost entirely on the D9-THC content. As cannabinoids are produced by glandular trichomes that are predominantly found on the bracts and floral leaves of female plants, industrial uses involve mainly the stalks and seeds.

[38] These are: delta-6a(10a)-THC, delta-6a(7)-THC, delta-7-THC, delta-8-THC, delta-10-THC, delta-9(11)-THC. All stereoisomers (or enantiomers) of these cannabinoids, both plant-derived and synthetic, are also classified as psychotropic substances under C-71 in Schedule I or II.

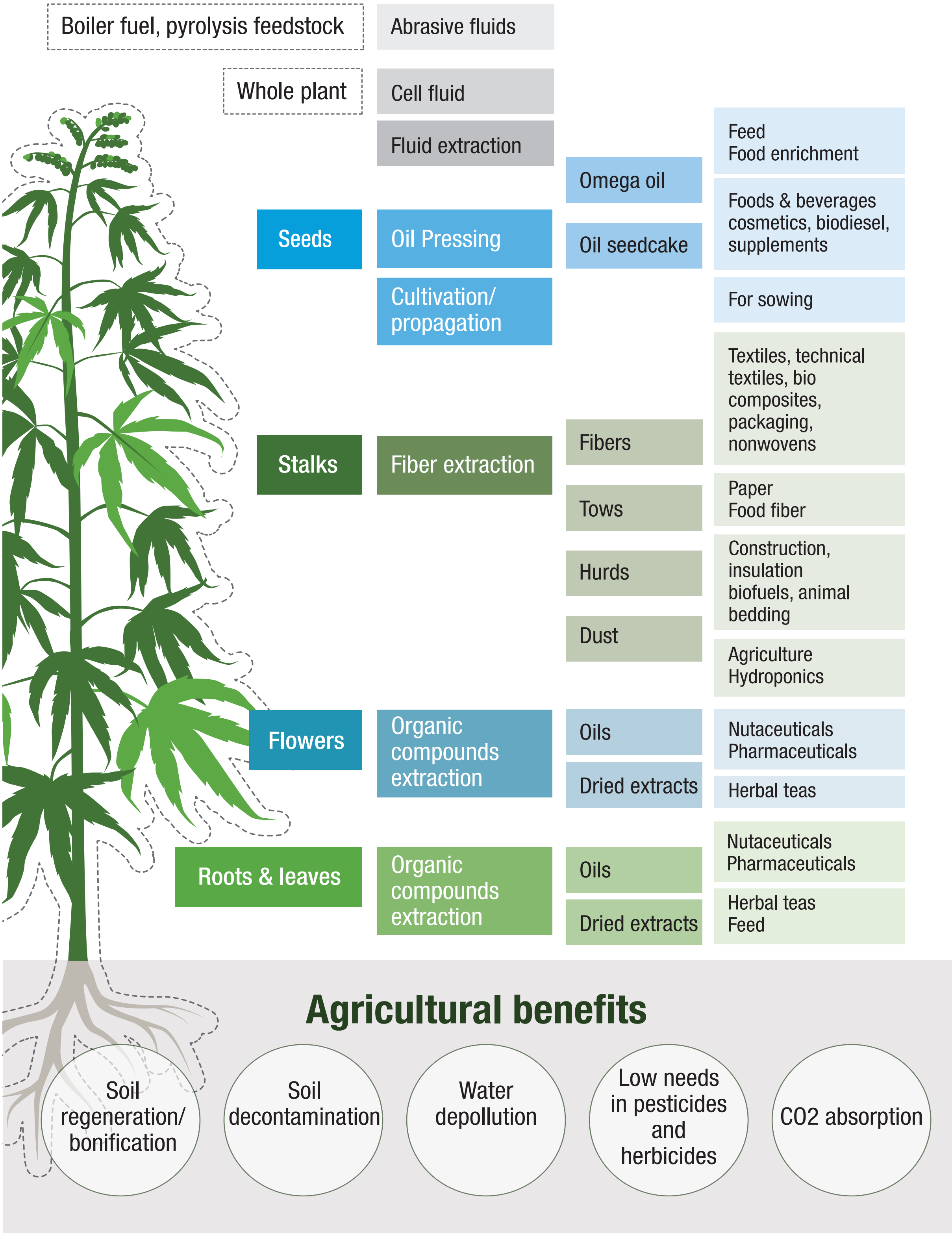
[39] Also referred to as "dronabinol and its stereoisomers"

[40] Psychoactive compounds can have an influence on the central nervous system, however, and, contrary to psychotropic compounds, they do not affect the sensorial perception and do not alter the consciousness of the user (psychotropic/narcotic effects are commonly identified as "intoxication").

[41] A declaration commonly agreed by most hemp associations in the world is accessible at https://www.globenewswire.com/news-release/2020/09/08/2090340/0/en/Hemp-associations-from-all-over-the-world-join-forces-and-speak-out-industrial-hemp-is-an-agricultural-product-not-a-drug.html. A recent declaration by the European Industrial Hemp Association (EIHA) with a focus on regulations prevailing in the European Union market is available at:https://eiha.org/wp-content/uploads/2021/02/PPFFSCBD01022021-1.pdf.

[42] See also a discussion of this flexibility of treaty obligations in the Commentary in United Nations (1973: 111, 402–403, 425–429).

Figure 2 Major uses and agricultural benefits of *C. sativa* L.



Source: Author, based on information derived from http://www.multihemp.eu , http://www.fibrafp7.net and http://www.ihat.org.au.

Box 1 Uses of *Cannabis* L. genus plants: A historical review

Plants belonging to the *Cannabis* L. genus have a very long history of domestication, which led to the breeding of multiple varieties and cultivars. Indeed, they have been used and deliberately cultivated by humankind for at least 6000 years (Fleming and Clarke, 1998). For centuries they have been a source of biomaterials, food, medicines and preparations for recreational and ritual purposes. Many ancient East Asian cultures used every part of the plant. Even the seeds were eaten and used to produce oil.

Cultivation of the plant for its fibre was recorded in greater China as early as 2800 BCE, and seems to have begun during the Copper or Bronze age in Europe (McPartland et al., 2018). Plants were introduced in Chile in the 1500s and a century later in North America (Clarke and Merlin, 2013). They were one of the leading fibre crops of temperate regions from the sixteenth to the eighteenth century, widely used for making rot-resistant, coarse fabrics, such as sailcloth. Indeed, it was the world's leading cordage fibre until the beginning of the nineteenth century. Its fibres were also used for paper production. Since wood was not yet the major raw material for paper production, plants of the *Cannabis* L. genus became one of the paper industry's most important raw materials, due to its high cellulose content, until the nineteenth century (Small, 1979).

As discussed in Small (2015), a combination of developments in the late nineteenth and early twentieth centuries severely undermined the importance of the *Cannabis* L. genus plant's fibre outside Asia. The most important was the development of motorized ships, which dramatically reduced the demand for fibre used for cordage. The second important development was brought about by the Industrial Revolution, which accentuated differences in the cost of fibre production between rich temperate regions and poor tropical and semi-tropical regions. The third development was related to the invention of modern cotton in the late eighteenth century. The development of cotton spinning machines in the nineteenth century increased the efficiency of cotton production and enabled the productionof softer fabrics. The invention and commercialization of synthetic fibres in the twentieth century, starting with acetate in 1924, further contributed to the decline in demand for *Cannabis* L. genus plants.

The last development that helps explain the diminishing role of the *Cannabis* L. genus plants as an industrial crop has been their growing use as an intoxicant substance in Western countries in the early twentieth century. This has provided a reason for some social and industrial interests to push for legislation prohibiting cultivation of any type of *Cannabis* L. genus plants, including industrial hemp. The prohibition started in the early twentieth century in South Africa (Kozma, 2011a; Mills, 2003) and Egypt (Kozma, 2011b; Mills, 2016), soon followed by the United States (Leinwand, 1971; McAllister, 2000; Scheerer, 1997). It was banned in almost every state in the United States by 1935.

In the immediate aftermath of the Second World War large-scale cultivation of industrial hemp ceased almost everywhere. It resumed in the temperate-climate regions of many developed countries in the 1990s. For example, the first crops were established in Australia (Tasmania) in 1990, in the United Kingdom in 1993, in Germany in 1995, and in Canada in 1998. This resurgence was mainly for economic reasons, driven by the general need to find new, profitable crops and natural materials in response to increasing consumer demand for more sustainable products in several developed countries.

C. sativa L. plants can also serve several agronomic functions and may be considered in strategies for environmentally friendly actions. Their processing generates zero waste, as all parts of the plant can be used or further transformed. They help regenerate soils and can significantly improve the advantages derived from crop rotations. Industrial hemp cultivated for fibre creates a large and well-furnished root system that is deeply distributed in the soil, which improves soil porosity and friability, and mends soil structure (Adesina et al., 2020).

The *C. sativa* L. plant is easy to work with compared to other crops. Because of its versatility and its functional characteristics, it is used by the industrial hemp market for a vast array of biobased products, such as non-woven textiles, construction materials, high quality foods and composites for the car industry, to name but a few. Nine submarkets have been identified: agriculture, textiles, recycling, automotive, furniture, food and beverages, paper, construction materials and personal care (Johnson, 2018). Traditionally, industrial hemp has been grown for either its fibre or seeds. Today, it is grown as a dual or triple purpose crop, harvested mainly for its stalks and seeds.

Medical and recreational uses involve essentially the flowering and fruiting tops, seeds and sometimes the roots. An increasing number of clinical studies have investigated anecdotal uses of cannabinoids like CBD to treat various medical conditions.[43] In the 1950s, the first medical application of CBD identified was its antibacterial effect against gram-positive microorganisms (Krejčí and Šantavý, 1955; Mechoulam and Hanuš, 2000). The medical literature has explored several potential therapeutic applications of CBD for various diseases and altered conditions, such as depression, multiple sclerosis, pain, inflammation, and many others. As discussed in the next chapter, the cultivation of hemp for medical purposes is subject to strict regulations and control systems to ensure that required quality standards and particularly phytocannabinoid content are respected.

C. sativa L. plants can also serve several agronomic functions and may be considered in strategies for environmentally friendly actions. Their processing generates zero waste, as all parts of the plant can be used or further transformed. They help regenerate soils and can significantly improve the advantages derived from crop rotations. Industrial hemp cultivated for fibre creates a large and well-furnished root system that is deeply distributed in the soil, which improves soil porosity and friability, and mends soil structure (Adesina et al., 2020).

Research further shows that hemp can decrease parasitic nematodes and reduce the presence of pathogenic fungi in soil (Van der Werf et al., 1995; Kok et al., 1994). Moreover, due to the high density of hemp leaves from the early stages of the plant's development, water loss and soil erosion are reduced.[44] Various studies have shown that hemp cultivation can thus boost other crop yields when included in crop rotation (Gorch et al., 2017; Xiaobing et al., 2012), such as a 10-20 per cent increase in wheat yields (Johnson, 2018). Hemp can also be used with great efficiency in ecological reconstruction and related land reclamation owing to its phytoremediation capacity, meaning the ability to remove heavy metals from the ground. Over time, it can remove heavy metals and other contaminating substances from deeper layers of soil as its root system develops (Wu et al., 2021; Ahmad et al., 2016; Kumar et al., 2017).

In addition, *C. sativa* L. plants can help mitigate the effects of climate change as it captures non-negligible amounts of carbon dioxide (CO2) by storing carbon in both the stems and the roots through photosynthesis.[45] As hemp plants grow rapidly and are deeply rooted into the ground, they have proved to be an ideal carbon sink, capturing more CO2 per hectare (ha) than other commercial crops or even forests (Adesina et al., 2020; Liu et al., 2017). Another potential use of hemp (especially hemp waste) discussed in the scientific literature (e.g. Lehmann et al., 2006; Andreae and Merlet, 2001) is the production of biochar[46] for soil applications that could potentially improve soil carbon sequestration and reduce greenhouse gas emissions.

43 CBD could represent a considerable addition to medicine's "armoury" in the fight against MRSA (Methicillin-resistant Staphylococcus aureus), an infection that is resistant to many antibiotics (Van Klingeren and Ten Ham, 1976; Appendino et al., 2008).

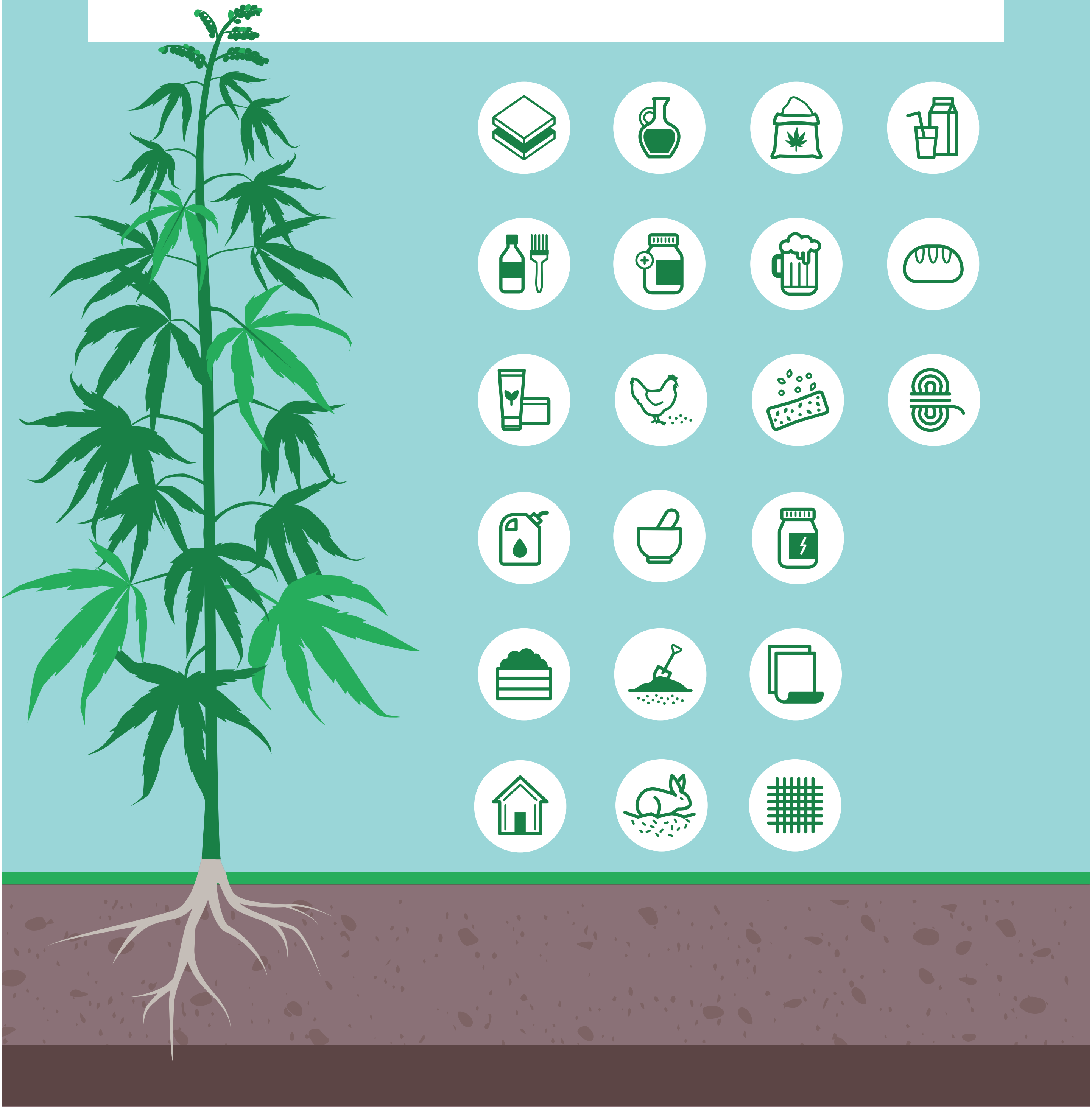
44 For instance, cotton production requires 9,758 litres of water per kilogram (kg), whereas hemp requires only between 2,401 and 3,401 litres of water per kg. This represents a reduction in water utilization of Chappteup to 75 per cent (Cherrett et al., 2005).

45 See, for instance, Lehmann et al. (2006) for a general discussion.

46 Biochar is the carbon rich remains of organic material after pyrolysis (heating process carried out in the absence of air/ oxygen to prevent the material burning).

CHAPTER III

Value chain



As discussed in chapter 2, industrial hemp is best characterized as a multipurpose plant. Constraints, both technical and regulatory, along the production chain become more binding moving from processed or semi-processed industrial hemp products to those intended for the medical, paramedical, nutraceutical, nutritional and cosmetic markets.

Whether the plant is grown for fibre, seeds or for cannabinoid-related uses will affect several parameters in the production process (Hillig and Mahlberg, 2004). Such parameters include the varieties/cultivars of *Cannabis sativa* L. to be grown, the methods used to grow them, and the timing of their harvest. Different cultivars respond differently to differences in latitude and basic agronomic inputs (e.g. Williams and Mundell, 2018). Moreover, quality requirements vary depending on the specific final use of the hemp (Amaducci et al., 2015).

For any of the uses, though, the target of successful crop cultivation is essentially the optimization of either fibre, seed or cannabinoid yield.[47] However, yield optimization is only one necessary component of a successful production strategy along the value chain. A proper appreciation of business opportunities and economic returns at the various production stages would require a precise risk assessment, risk being a combination of the probability of occurrence of an event and the severity of its potential negative effects (Renn, 2008).

Adamovics and Zeverte-Rivza (2015) define a risk assessment methodology for hemp cultivation and processing. They divide the chain into five phases and assess risks in each of them. Six groups of risks are defined and are reflected in 18 specific factors (figure 3).[48] Growers and processors are not exposed to the same sets of risks, even though risks faced exclusively by growers could affect processors' activities. In an integrated production chain, the whole set of risks should be managed and borne by a unique entity. Related issues and opportunities are discussed below.

3.1 GROWERS

There are three methods of growing *C. sativa* L. plants: outdoors, indoors and in greenhouses.[49] The method growers will opt for depends closely on the final use of the plant. Outdoors, which is the most natural method, is strongly – but not exclusively – associated, with fibre and seed production. Indoor and greenhouse methods are preferred for cannabinoids-oriented cultivation in order to have better control of the cannabinoid's potency. The outdoor method could be a relatively viable option, especially in the Southern European type of climate. Indeed, outdoor cultivation requires, for instance, 18 times less energy to produce one gram of dry flowers than indoor cultivation and 13 times less than greenhouse cultivation.[50],[51] Moreover, indoor cultivation produces nearly 25 times more carbon (CO2/gram) than outdoor cultivation (Mills, 2012).

47 The term "biomass" has recently gained usage to refer to various CBD-containing plant parts or fibre as raw products. However, technically speaking, CBD hemp biomass is not proper biomass. Referring to "hemp trim" or to the specific plant parts would avoid confusion with the common definition of "biomass" in ecology ("the weight or total quantity of living organisms of one animal or plant species", as defined in www.britannica.com/science/biomass), or in the field of energy, where it refers to organic matter used as a fuel.

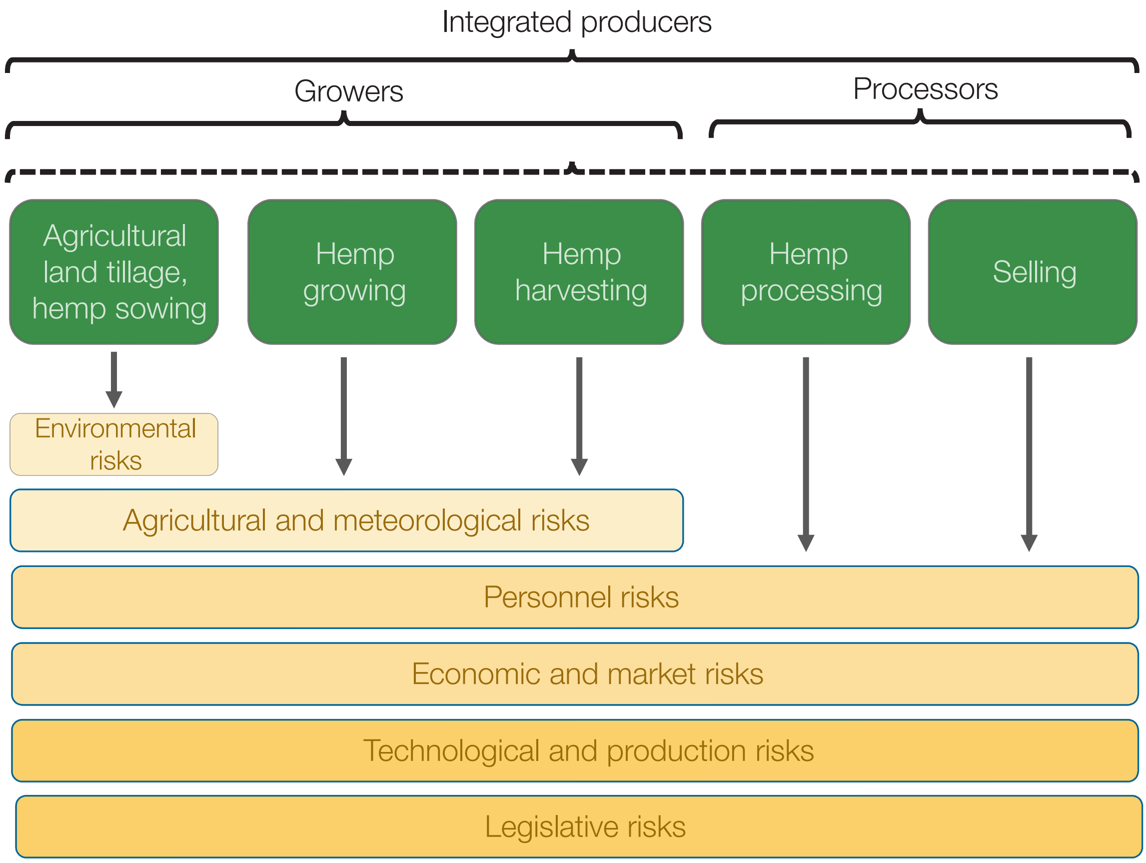
48 Applying their methodology to the Latvian context, Adamovics and Zeverte-Rivza (2015) find that, on average, the risk effects are the highest in agricultural land tillage and hemp sowing, and some very significant risks are specific to the hemp harvesting phase and the processing phase due to a high probability of machinery not being available.

49 See Small (2017) for a detailed description of the scope and constraints relative to each method.

50 Research at New Frontier data (https://newfrontierdata.com) shows that to produce one gram of dried flower of *Cannabis*, outdoor cultivators use 0.07 kilowatt-hours (kWh), greenhouse cultivators use 0.94 kWh and indoor cultivators use 1.27 kWh. See also New Frontier (2018).

51 For a more pragmatic discussion, see Russo blog (2017) "In or Out? Sungrown vs. Indoor *Cannabis* Cultivation"? Available at https://www.projectcbd.org/outdoor-vs-indoor-cannabis-cultivation.

Figure 3 Risk assessments in hemp production and processing



Source: Based on Adamovics and Zeverte-Rivza (2015).

However, in the case of cannabinoid production (i.e. flowering and fruiting tops), while outdoor production may produce more grams per kWh of energy, indoor cultivation produces more grams per square meter. Hemp, when grown outdoors and to some extent in greenhouses, is often presented as a low-input crop, at least in temperate areas. Ideal conditions include well-drained and fertile soils where pH is neutral or slightly below neutral (i.e. slightly acid). Yields and quality will be negatively affected if plants are grown in poorly drained clay soils or soils poor in organic matter, and with structurally low fertility.

Contrary to either indoor or greenhouse cultivation, a major concern with outdoor cultivation could be cross-pollination among different varieties grown for different purposes within a given perimeter. Wind and/or insects could lead to cross-pollination even between relatively distant fields. Besides pollination, wind, hail, drought, pests and other stressors can increase total THC levels in the cultivated plants. This may put producers at risk of violating current laws resulting in fines and destruction of crops, depending on the regulatory sanctions that apply. Such inconveniences do not exist in indoor cultivation, as it allows precise control over all key parameters for growing the plants. It is thus possible to standardize processes and produce the expected quality and flowers characteristics. This explains why cultivation for medical uses geared towards isolating compounds is almost exclusively done indoors.

Nonetheless, traditional and modern herbal medicinal *Cannabis* products may benefit from outdoor cultivation to take advantage of a number of specific soils, environmental and other ecosystem features (Chouvy, 2022; Krawitz, 2018) linked to the balance of minor cannabinoids in the final product exerting jointly different pharmacological effects (Mechoulam and Den-Shabat, 1999; Russo, 2011). An important point is that a large proportion of recent strains have proved to grow better in indoor conditions. Moreover, indoor cultivation provides greater yields than any other type of *Cannabis* cultivation for flowering/fruiting tops – as many as 4–8 per year.

Greenhouse cultivation falls between indoor and outdoor cultivation. It can allow producers to preserve the best features of the other two methods, excluding most of their negative aspects. Although greenhouse cultivation does not enable full control over environmental conditions, it allows control over some key parameters, such as temperature and possible light deprivation. In contrast to indoor cultivation, plants can still benefit from natural sunlight, and produce flowers with characteristics such as aroma comparable to outdoor grown ones. Yields are also expected to be higher than in outdoor cultivation, and two harvests per year are feasible (Potter, 2009). The construction of greenhouses and their equipment are obviously more expensive than growing plants in the field, but much cheaper than adapting any infrastructure for indoor cultivation.

Hemp cultivation techniques, especially outdoors, remain relatively accessible even for small-scale production. They have been refined over several centuries of growing experiences on different continents with varying environmental conditions and specificities. Small fields can be harvested by hand with sickle bar mowers or with hay swathers. However, large-scale industrialized production requires the use of a seed drill or transplanter, and mechanical harvesters, such as combines to cut and collect stalks and grain material, as well as forage harvesters or other specialized machinery (e.g. CBD hemp harvesters designed explicitly for CBD oil production). Moreover, a high level of professional skills and knowledge about respective horticultural practices is also required (Kaiser et al., 2015).

In other words, hemp farming can require substantial agricultural knowledge and practical experience. The equipment needed will depend on the precise approach adopted by growers. This is also the case for indoor and greenhouse cultivation, where, in addition, it has proved more difficult to get rid of possible pathogens and allow strict monitoring of growing conditions such as the amount of CO2 in the air, which can seriously harm the plants.[52] Moreover, the equipment for producing hemp products can be complex.

Technical requirements and growing constraints are briefly reviewed in the remainder of this section in the context of four different production targets: fibre, seeds, cannabinoids and dual purposes.

3.1.1 Fibre production

For fibre production, both male and female hemp plants are used, although males are preferable (e.g. Amaducci et al., 2015). In general, late flowering cultivars are preferred when maximization of stem yield is a priority (Finnan and Styles, 2013; Prade et al., 2011).

Fibre production requires the separation of the fibres from the whole plant. Traditional dew and water retting methods both require extensive manual work. Hence, these processes are not extensively used in developed countries where labour costs are relatively high. Another process for fibre extraction more adapted to large-scale cultivation is the mechanical decortication of green or pre-retted bast fibres. This process, which incorporates beating, scutching and combing, produces short hemp fibres and hemp tow (e.g. Schäfer, 1944; Voegelin and Vetterli, 1962) used for insulation material or fillers in composites. These applications do not require high-quality fibres.

Several chemical and physical degumming methods have been developed to obtain fine single fibres. These methods chemically dissolve and remove the gum substances between the elementary fibres. To enhance their efficiency and to prevent fibre damage, physical means are used, such as steam explosion (Vignon et al., 1996; Kessler et al., 1998) or ultrasound (Zimmer and Kloss, 1995). Because of the high input of chemicals and energy, these methods are economically less attractive. A more promising method for

52 See, for instance, Jordan blog article (2019) for a more general discussion “Indoor vs. Greenhouse vs. Outdoor *Cannabis*: Which Should You Buy”? available at https://www.leafly.com/news/strains-products/what-to-buy-greenhouse-vs-indoor-vs-outdoor-cannabis-growing.

obtaining fine hemp fibres is the controlled biological degumming of decorticated bark in bioreactors using adapted microorganisms and their enzymes (Leupin, 1998).

To obtain fibres of high quality, a homogeneous starting material is needed. Due to the inhomogeneous fibre material obtained after dew retting, the appropriate starting material for degumming is non-retted, green decorticated bark material. Decortication of green bast plants is carried out on fresh or dried stems. Dry decortication is reportedly quicker, and is not restricted to the harvesting season, whereas fresh decortication generally yields fibres of better quality (Jarman et al., 1978).

It has been found that fibre content is stable across environments, but varies largely among genotypes, from 25 per cent to 47 per cent in cultivars bred during the twentieth century (Amaducci and Gusovius, 2010; Westerhuis et al., 2009; De Meijer, 1994). Moreover, as described in Mediavilla et al. (2001), the fibre yield, the stage of maturity and the number of primary and secondary fibre cells depend on the growth stage of the plant.

3.1.2 Seed production

As a seed crop, a female predominant plant population, with a limited number of male plants for pollination, or a monoecious variety, are the preferred options to maximize seed yield (Schluttenhofer and Yuan, 2017). Seed cultivars are usually characterized by short stalks, large seed heads, and higher branch density, as opposed to fibre cultivars, which have long stalks and minimal branching. Different genotypes imply some significant differences in the cultivation processes of hemp grown for the use of seeds and those cultivated for fibre use.

Plants intended for seed production are usually sown with a relatively low density, with a maximum of 2,500 to 4,000 plants per hectare as compared to up to 100,000 plants per hectare for fibre production. Hemp seeds are harvested when 70 per cent of the seed is ripe. Combining seeds after the optimal harvest time leads to lower quality grain and losses due to shattering and bird damage in some circumstances.

Hemp grown for its seeds is generally ready for harvesting 100 to 120 days after the seeds were sown. Harvesting for seeds may be a delicate operation as not all seeds mature at the same time. Hemp seeds start maturing from the bottom up, and harvesting is generally initiated once the seeds located up to the medium height of the plant have matured. Hemp grown for fibre should be harvested before seeds are formed and the dying of the male plants, which typically occurs 90–100 days after sowing (Hall et al., 2012). Traditional harvesting with sickles is possible, in principle, in small-sized farms. However, most commercial farms use specially modified harvesting equipment called combine harvesters. These machines are designed to remove the heads for flower and seed processing and cut the stalks for fibre processing, a process referred to as “threshing”.

Drying the seeds for effective storage is the final essential part of the agricultural cycle of hemp cultivation for seeds. The seeds should be dried to below 12 per cent moisture for storage and at 8 to 10 per cent for long-term storage. Conveyor belts are the most popular equipment used for drying hemp seeds to a moisture content of about 9 per cent. Hopper bins with aeration are considered the best containers for grain storage. Once the seeds have reached an adequately dry state, they are transported to processors for further transformation and packaging.

3.1.3 Cannabinoids

As discussed in chapter 2, among all cannabinoids, CBD has been a leading hemp derivative since 2015. There is, however, an increasing interest in other cannabinoids such as CBG, and in compounds such as terpenes, as the applications developed by small and medium-sized enterprises (SMEs) and innovative delivery solutions developed by larger players expand. In general, for phytocannabinoid production, a pure female population is the most desirable to avoid pollination, which could reduce flower yield (Schluttenhofer and Yuan, 2017).

Hemp for CBD production is cultivated to be small and leafy, staying lower to the ground than its counterpart grown for fibre, and it is less densely grown, with a maximum of around 400 plants per hectare. Growing hemp for CBD production is generally considered more challenging than growing it for fibre (Darby, 2019). Harvest begins after the flowers have fully developed, usually between 100 and 120 days after sowing as is the case for hemp grown for fibre. However, the time for harvesting depends on the variety, planting date and region. As with hemp seed production, the drying stage is crucial for obtaining a high-quality product. Moreover, depending on the system of drying and the processing equipment, there are different harvesting techniques. Plants can be either dried before trimming or processed immediately after harvesting.

Mechanical equipment such as buckers, trimmers and commercial driers can drastically reduce processing time compared with manual harvesting. The end use will determine the level of leaf removal and manicuring required, even with the use of mechanized equipment. In general, labour requirements increase considerably with increased processing.

To achieve a successful cultivation system for medicinal hemp, as well as for industrial hemp for nutraceutical, nutritional, cosmetic and other cannabinoid-reliant purposes, specific technical skills and horticultural practices are needed (Small, 2017). For instance, if the end use is for medicinal purposes, production methods must comply with the Good Agricultural Practices (GAP) defined by the FAO.[53]

3.1.4 Dual purpose

Interest in hemp as a multipurpose crop has been growing steadily worldwide over the past decade. So far, the plant has been cultivated essentially as a dual-purpose crop, for its seeds and fibre. Dual-purpose hemp is harvested when the seeds are close to maturity. From a practical point of view, the seeds can be harvested first, and the stalks cut in a second phase. Combines can be modified to harvest both grain and stalks at the same time.

However, if high stem yields are obtained from late flowering cultivars (Amaducci and Gusovius, 2010), the latter will have low seed yields (Höppner and Menge-Hartmann, 2007). Increasing seed yields would require postponing harvesting time until seed maturity is reached. Harvest postponement could increase stem yield because it allows continuous accumulation of secondary fibre and xylem (Amaducci et al., 2005; Keller et al.,2001), or decrease it because of biological aging (Mediavilla et al., 2001). The effects on fibre content and yield can be positive but would remain modest (Höppner and Menge-Hartmann, 2007). Moreover, an increase in lignified fibre is often observed (Westerhuis et al., 2009; Amaducci et al., 2005), which is undesirable for applications such as textiles. In other words, waiting until the seeds are harvestable could result in poorer quality fibre, which would be acceptable only for lower value uses, such as pulp production (De Meijer and Van der Werf, 1994).

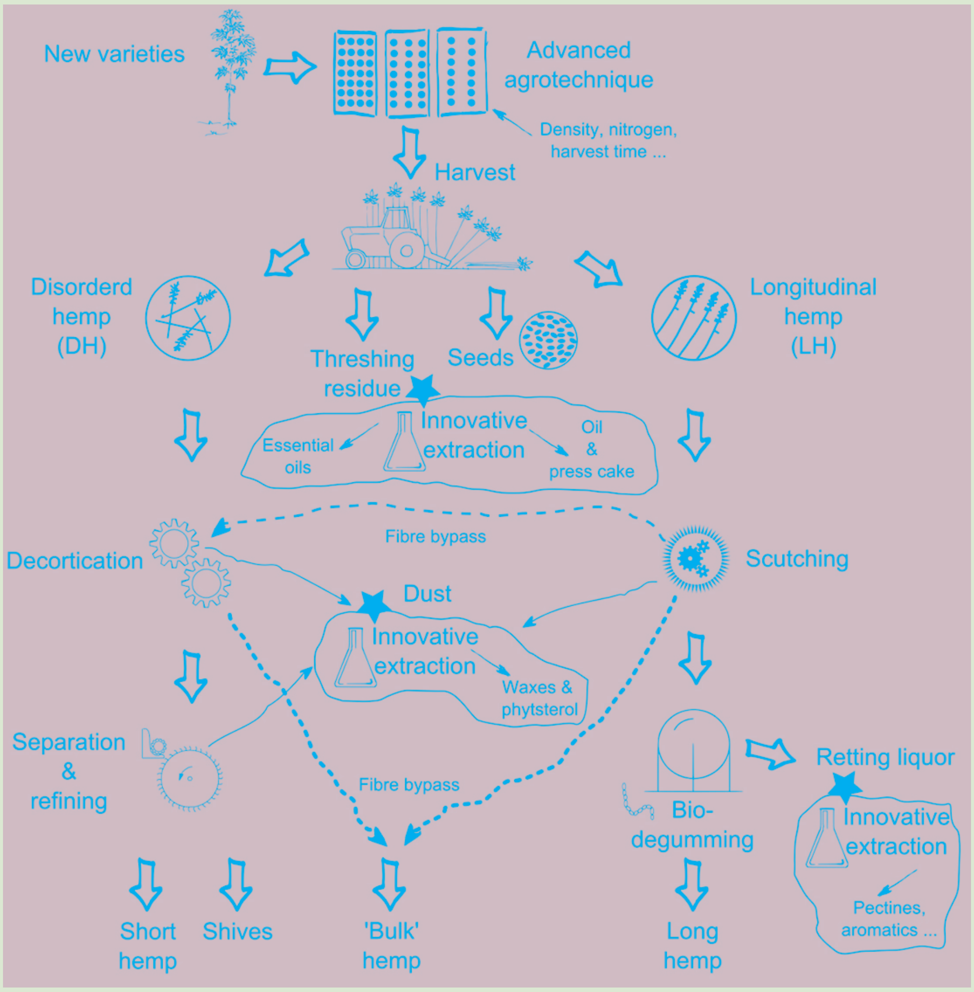
Seed production is extremely complicated when dioecious cultivars are used, as in the case of fully fibre-oriented hemp cultivation. Dioecious cultivars will produce high stem yield due to the large proportion of male plants (Berenji et al., 2013). However, as male plants start to deteriorate rapidly immediately after flowering, this will result in lower yields and an increase in fibre heterogeneity. In this context, hemp breeding has been oriented towards the development of monoecious cultivars that are considered suitable for producing fibre and seed simultaneously (Berenji et al., 2013; Salentijn et al., 2015).

[53] The GAP describe regulations and standards generated by the food industry, producer organizations and governments with the aim of managing agriculture in a responsible way by enhancing economic, environmental and social sustainability, while ensuring the safety and quality of agricultural (both food and non-food) products (FAO, 2017; Small, 2017).

Box 2 A hemp-based biorefinery

The MultiHemp (2017) project's main objective was to develop, with a dual-purpose objective, an integrated hemp-based biorefinery that would combine actual and innovative processing systems. Starting from harvesting, it transforms various hemp plant parts into a spectrum of intermediate and final products to be sold on markets. Hemp processing approaches rely heavily on the chosen harvesting method. Two methods have been used during the past two decades (i.e. the Longitudinal (LH) and the Disordered (DH) method), each with its pros and cons (Amaducci and Gusovius, 2010).

The MultiHemp project implemented an alternative, disordered harvesting system. It consists of cutting the top of the plants containing the seeds separately from the rest of the stem. Moreover, the system allows recuperation of threshing residues for the extraction of valuable chemicals.



Source: MultiHemp (2017).

Note: Large arrows indicate raw material flow along the production chain; stars highlight innovative processing to upgrade by-products into high value added end uses.

The production of long bast fibre for textiles and high-quality composites can be considered in conjunction with the production of short bast fibre for injection in moulded bio-composites and insulation products, as well as for shives for low carbon construction materials. The valorization of seeds allows the production of oil for health and personal care applications, protein for food and animal feed, and high value chemicals such as phytosterols, waxes and essential oils. Innovative applications have also been developed for the by-products from processing. They include dust from fibre processing, retting liquor from fibre degumming, flour (or cake) from oil extraction, and threshing residues from seed harvesting.

Based on a seminal large field experiment, Tang et al. (2016) tested the fibre and seed productivity of 14 commercial cultivars in four contrasting European environments. Their results show that when harvesting was postponed from full flowering to seed maturity, the stem yield of monoecious cultivars significantly increased, but in dioecious cultivars it decreased in all but one of the test sites. Their results also suggest that the relationship between fibre and seed yields is likely to remain negative even with monoecious cultivars. Among the 14 tested cultivars, none combined the highest stem with the highest seed yield. This indicates that strategies to develop cultivars and cropping practices for dual-purpose hemp production still need to be refined, possibly with the help of further developments in hemp breeding resulting from advances in understanding hemp plant genetics. Such development and its possible implications for a sustainable and viable dual approach are at the core of the MultiHemp project[54] funded by the European Union (see box 2).[55]

The set of dual-purpose cultivation combinations could also be extended as, in theory, hemp growers for seeds and those for fibres could also exploit the flowering/fruiting tops and leaves of their plants for extraction purposes. However, in practice, cultivars best adapted for the former two types of cultivations do not generate high enough concentrations of cannabinoids to cover any extra costs linked to the necessary additional care and specific operations discussed previously. An alternative dual-purpose cultivation, possibly more suitable to some climatic and environmental conditions, is hemp grown for both fibres and for its flowering and fruiting tops.

3.2 PROCESSORS AND VALUE ADDITION

As mentioned earlier, hemp components and compounds derived from every part of the plant, from the roots to the leaves, are used in multiple applications (figure 2). Over 25,000 of hemp-based products have been identified globally.[56] Value addition can thus be boosted by the plant's potential to produce different products: food, animal feed, cosmetics, biomaterials and energy, while achieving positive environmental externalities with this one rotational crop.

The value-chain approach used in MultiHemp (2017) is reproduced in figure 4. A distinction is made between processes applying to grown raw materials and those applying to semi-processed hemp inputs. The system level is usually handled by growers as defined in the previous section, and the product level is usually handled by specialized processing firms. Both entities may belong to a single economic conglomerate.[57]

All final product applications require specific transformation processes involving different combinations of labour, capital and skills, and different technological practices.[58] Note that the harvesting and processing methods also depend on the intended final use, implying that system and product levels are closely linked. The processing equipment needed will vary with the projected end-product. Moreover, processes at the product level often require highly skilled workers, ideally in proximity to the cultivation facilities in order to preserve the integrity and quality of the primary inputs produced at the system level.

54 Project details and deliverables are available at http://multihemp.eu .

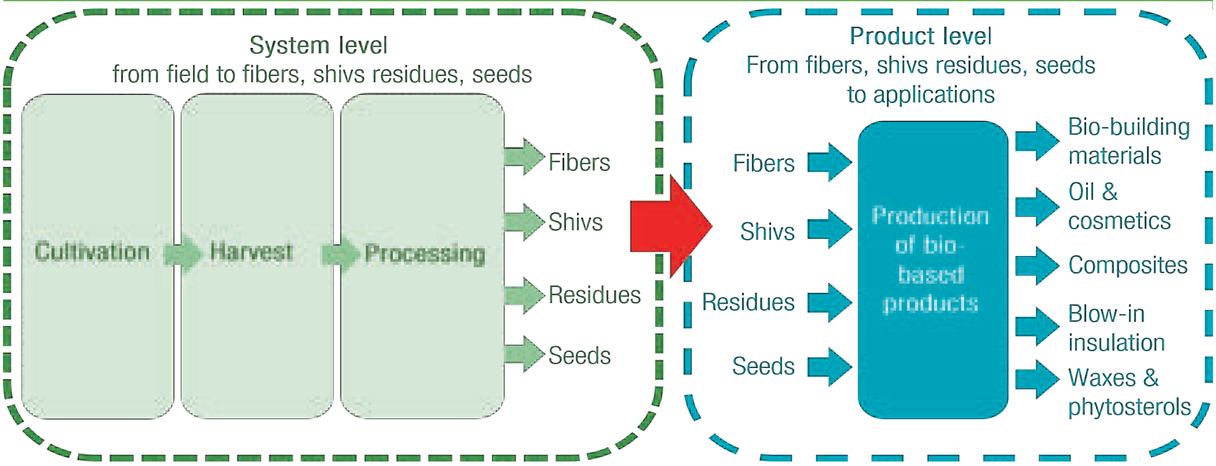
55 Grant agreement no 311849 of the European Union's Seventh Framework Programme for research, technological development, and demonstration.

56 See a Forbes article for an extensive discussion, available at https://www.forbes.com/sites/davidcarpenter/2018/12/20/legal-hemp-in-2019-may-be-a-boon-for-stressed-out-american-farmers/?sh=462a49f98f3b.

57 For instance, Charlotte's Web and CV Sciences are two major vertically integrated businesses operating in the hemp-derived North American CBD market. Signature Products is one of the leading vertically integrated hemp suppliers in Europe. It produces and trades hemp raw materials, such as hemp seeds, but also hemp proteins and extracts.

58 See Garcia and Duran (2022) for a comprehensive technical discussion.

Figure 4 System and product levels in the hemp value chain



Source: MultiHemp (2017).

3.2.1 Products derived from hemp fibres

In the case of hemp yarn confection, processes at the system level are crucial for determining the quality of fibres. During the wet spinning process, for instance, to produce a better, finer yarn, the fibres are thoroughly soaked in a small trough of water, known as wet spinning. Fibres can also be dry spun, which often results in a coarser yarn. The processes used to produce other fabrics, such as cotton fabrics, are also used to produce hemp fabric (Riddlestone et al., 1995)

The long fibre locks need to be further separated in a process called hackling or combing. Just before hackling the bast fibre is led through a set of ribbed rolls, or softening emulsion can be applied to further soften the relatively coarse hemp fibres. During hackling, the fibres are repeatedly pulled through fine pins which separate the fine long fibres and parallelize them for further processing. Hemp tow can be combed as well, especially if it is intended for cottonization and dry spinning.

Once it is processed into fabric, long fibre hemp has a similar texture to linen, while cottonized short fibre resembles cotton. In contrast to some other fabrics, only one major variety of hemp fabric exists. Only the quality, feel and texture of hemp yarn may vary from one manufacturer to another. Indeed, the quality of the fabric is highly dependent on the processing method adopted. Producing hemp fabric does not inherently cost more than producing cotton fabric. However, due to a smaller scale of production and to some price premium due to hemp's niche-product image, the price of hemp fabric remains relatively high compared with that of cotton.[59]

Short fibre is also used to make high-quality papers. Most hemp paper is used for cigarette papers and other specific applications. It may also be used more widely as heavy-duty cardboard, food packaging, sanitary and other absorbent products, as well as for filtration. Hemp paper is particularly durable and tear-resistant compared to wood-based types of paper. It can be recycled more often (7–8 times versus 3–5 times) and requires less cultivation area than wood.

Most non-woven processing lines can support natural fibres, including hemp fibre, without major adjustments. However, mixing with viscose or other more malleable fibres might be needed to achieve the expected properties of the final product.

[59] As an illustration, prices may be consulted at https://naturesfabrics.com/ . Cotton jersey would cost about $ 9.15 per meter, while hemp jersey would cost at least 50 per cent more for the same quantity.

Hurds separated from fibre during the retting process are principally used as animal bedding or mulch. However, recent technological advances have dramatically expanded their use. For instance, material derived from hurds can be found in the production of carbon nanosheets, plastics and fibreglass alternatives used by the automotive and aviation industries, 3D-printer filaments, oil absorbent materials, insulant materials and construction concrete. The latter, also called hempcrete, which is a mixture of hemp hurds and lime products, is of particular interest due to its high insulation properties and its simplicity of fabrication.

3.2.2 Products derived from seeds

Hemp seeds are technically nuts and feature similar characteristics. They contain approximately 30 per cent protein, 25 per cent starch and 30 per cent oil (e.g. Deferne and Pate, 1996). Consequently, hemp seeds have numerous possible uses, some of the more common being as ingredients in cooking oils, milk and dairy products in general, and flour. Hemp seeds are perfectly balanced nutrition wise and provide a reliable alternative source of protein as an ingredient in food products and in animal feed (e.g. Callaway, 2004).

Processors utilize a range of techniques for cleaning, including mechanical screening (sieving), grading and gravity separation. Cultivated as inputs in food products, hemp seeds also undergo a process of manual or mechanical removal of the seeds' outer shells, known as "dehulling". Producers work carefully to minimize damage to the inner seeds in order to maintain their quality and integrity. Next, hemp oil can be extracted mainly by mechanical pressing. As plants grown for oilseed are marketed according to the purity of their inner product, any mixing with other genotypes due to cross-pollination could degrade the value of the crop.

Cold-pressed hemp seeds contain carbohydrates, alimentary fibre, vitamins and trace elements. Given their perfect balance of amino acids, oils and fatty acids, they may be considered a superfood. The seeds' proteins are used to create antibodies and help maximize nutrient absorption, maintain organs, and even build muscle. Hemp seeds release an oil that contains more than 90 per cent of polyunsaturated fatty acids, with a desirable ratio of omega-6 to omega-3 lipids, which makes it a valuable addition to human and animal diets. The oil from crushed hemp seeds is also used in soaps, shampoos, lotions, bath gels and cosmetics. In addition, it can be used in fuels. The preparation of seeds as pharmaceutical ingredients relies upon roughly similar processing techniques to the ones used for food production.

A residual by-product known as hemp cake, or hemp meal, can also be exploited to produce hemp protein powder. It can be used in the production of protein-rich animal feed or powdered food supplements added to bread and even beer. Hemp protein powder is usually milled before screening to separate the fine powder substance from its coarser fibre counterparts.

3.2.3 CBD products

As suggested by existing information on prices (see chapter 5), production of the same quantity of stalks is likely to be more profitable if the targeted end-use is CBD extraction rather than fibre production. Implicit prices per hectare[60] cultivated obtained from CBD extraction are higher than those obtained from fibre, or even seed oil, production. Of course, the production scale may be different, especially if greenhouse or indoor cultivation methods are adopted for CBD extraction.

There are different degrees of transformation in the process of CBD extraction. To make CBD for use in food or medicine, hemp must be cultivated, harvested, dried, processed, extracted, refined and purified using specialized equipment and processes, the technicality of which increases with the degree of refinement of the final product. The most refined product is called CBD isolate.

The process to produce CBD isolate is clearly highly specialized and technical, and requires pharmaceutical grade equipment, facilities and training. The number of steps implies loss of yield across the entire CBD

[60] Given by Total value of harvest (in $)/harvested area (in ha).

production and isolation process. The selection of input material to produce high-quality hemp for CBD is crucial. This implies that risks (as represented in figure 2) are best managed by means of an integrated approach by considering the whole production chain independently of the number of intervening productive entities along that chain.

In theory, several products can be derived in the process of manufacturing CBD isolate. The first one would be a dried decarboxylated hemp material with, ideally, about 10 per cent CBD content. This product is marketed to be vaporized, smoked, cooked or infused. From the same material, CBD oil can also be extracted, and has about 50 per cent CBD content.

With some refinement to remove contaminants, the CBD content would increase up to 60 per cent. This product can be used for different purposes. When refined CBD oil is distilled to concentrate CBD (up to 80 per cent), the resulting CBD distillate is usually used by the cosmetics industry.

Further processing leads to CBD isolate. Chromatography[61] is used to purify CBD obtained from distillate (CBD content is close to 99 per cent). An additional transformation to further purify the CBD isolate is crystallisation.[62] CBD isolate is a popular component of *Cannabis*-derived medicines and is increasingly used as an active ingredient in pharmaceutical products (e.g. Epidiolex) and other health and wellness products.

The versatility of hemp, which enables all parts of the plant to be exploited in various product applications, suggests that value addition could be maximized through a whole-plant approach.[63] Such a production strategy may not be easily implemented by a single firm, but could be promoted at the industry level.

3.2.4 A whole-plant approach

A successful whole-plant industrial strategy could guarantee the supply of top-quality inputs to processors. Moreover, it would facilitate an integrated management of risks along the whole production chain. From a practical point of view, the whole-plant approach is the standard in inter-tropical regions, due to botanical, environmental and prevailing favourable climatic conditions. In more temperate climates, as in Europe and North America, a whole-plant approach is also feasible if regulations allow all parts of the plant to be used.

Constraints presented in previous sections should be taken into consideration for the approach to be successfully implemented. For instance, the choice of the plant variety influences the feasibility of the whole-plant approach. So far, varieties developed in Europe are intended to fulfil only one purpose. However, when processed, all parts could be used.

Regarding cannabinoids, processors' production choices are defined by the competitiveness of the products on the market. Today, synthetic and isolate cannabinoids imported from North America are far cheaper than full-spectrum extracts produced in Europe. Moreover, legislations tend to favour zero THC products. This has a major impact on feasibility of adopting a genuinely whole-plant approach.

Research on different varieties is likely to enhance the performance of the whole-plant approach of hemp, as demonstrated by the MultiHemp project (MultiHemp, 2017). However, its implementation in the field would require some additional flexibility, especially with respect to observing regulatory limits on THC content. Reliance on traditional multipurpose Cannabis plant varieties is likely to increase in this respect. This suggests the need for access and benefit-sharing strategies to ensure that breeders, researchers and farmers, who are custodians of traditional varieties and cultivation knowledge, obtain a fair share of the monetary and non-monetary benefits from exploitation of those plants.

61 Except for so-called supercritical CO2 chromatography, all methods introduce toxic solvents such as pentane or hexane to isolate CBD.

62 This removes THC, terpenes and other impurities. However, it involves the use of strong solvents.

63 See Mirizzi and Wilson (2018) for a general discussion.

Because processing techniques can always enable control of the final cannabinoid content in any given hemp product, regulations that favour the whole-plant approach should focus on THC and cannabinoid content in hemp-based products, rather than in hemp plants and crops. Currently very few standards apply to hemp-based products, and quality can vary significantly across manufacturers. Some sector-specific certification schemes have been developed recently by standardization agencies such as ASTM,[64] but also by farmer unions like Sun+Earth.[65]

Several developments suggest that such certification might be introduced soon for hemp-based products. The first is the persistence of traditional hemp products and associated varieties, and cultivation or processing techniques, in what can be described as cannabis and hemp “terroirs” (Chouvy, 2022; Krawitz, 2018). The second is the creation in January 2022 of local-level appellations of origin for cannabis products in the state of California in the United States.[66] Another development is the recent entry into force of a treaty on Appellations of Origin and Geographical Indications,[67] which has been ratified by a number of traditional producing countries and the European Union.

3.3 USERS

A survey in 2019 indicates that more than one third of Americans have already purchased CBD products.[68]

Even though global awareness amongst final consumers about hemp products has been increasing over the past five years,[69] most hemp-related final goods markets remain small. Hemp product markets can still be considered niche markets. This characteristic is associated with specific market dynamics that may affect price evolution significantly.[70]

Small markets may develop because of changes in preferences, and eventually demand, or because of changes in supply due to some technological innovation, the conception of a new product, or new use of an established product. Two major interrelated issues may arise in such markets. First, oversupply may occur more easily than in more developed and mature markets. Second, product quality may be either low with respect to potentially competing products or vary across manufacturers.

Oversupply may be the result of either supply-side shocks, demand-side shocks, or both. A supply-side shock may occur with the creation of a new product by some innovative firms that elicits a positive demand response. The creation of a new market may attract additional investors and lead to a significant increase in supply if early firms are unable to contain the entry of new suppliers. A consequence could be a drop in prices leading to the exit of the least efficient producers. Prices may stabilize once expectations on both the supply and demand sides converge after the rationalization phase.

A demand shock may be the consequence of changes in consumer preferences due, for instance, to greater awareness of some specific product’s existence and properties, or to some evolution in the prevailing regulatory environment. An increase in demand for some product would lead to an increase in production and eventually translate into oversupply. Rationalization could still occur because of a fall in prices, again pushing the least efficient producers out of the market. Some adjustment can also occur on the demand

64 See https://www.astm.org/.

65 Available at: https://sunandearth.org/wp-content/uploads/2021/07/Sun_Earth_Certified_Standards_Final_05_31_2019.pdf.

66 Information available at https://cdfa.ca.gov/oefi/cap.

67 Geneva Act of the Lisbon Agreement on Appellations of Origin and Geographical Indications, available at https://wipolex.wipo.int/en/treaties/textdetails/15625 ; see additional information at https://www.wipo.int/lisbon/en/; and status of ratification at https://www.wipo.int/export/sites/www/treaties/en/documents/pdf/lisbon.pdf.

68 See CBA (2019) for details.

69 See Kolodinsky et al. (2020) for a case study on consumer preferences.

70 See USDA (2000) for an analysis of three agricultural niche markets: for poinsettias, emus and mesclun.

side in both situations of oversupply due to either poor overall quality or variations in quality.

Preferences would react to both situations leading to a decline in demand growth. The degree of overreaction in supply with respect to a situation characterized by stable price conditions will vary depending on the availability of secondary markets towards which part of the production may be redirected. In the case of hemp, secondary markets are more likely to exist for relatively less processed hemp products. Hurds may be more easily redirected than CBD isolate or even hemp seeds. In addition, where more specialized machinery is used in production processes, it is less likely for the process to be adapted to secondary market products.

An illustration of the above dynamics may be provided by CBD topicals (e.g. salves, balms, ointments and lotions). The demand for such products has been on the rise recently, as benefits were scientifically investigated and publicized. For instance, Pavlovic et al. (2018) specifically showed the benefits of CBD topicals for inflammation and pain. According to the Brightfield Group (2021), in the United States alone, the hemp-derived CBD market was expected to reach $4.7 billion in retail sales in 2021, an increase of 2.5 per cent compared with 2020 sales. This demand shock led to an increase in the production of CBD refined inputs such as CBD distillates.

However, as mentioned in Canxchange (2021), this demand-driven increase in supply has led to an oversupply with prices falling towards a historical low of €300/kg. In other words, hemp farmers who reoriented their production towards hemp grown for CBD may not have been able to generate the anticipated returns because of oversupply in the CBD market, resulting in the weakest possibly being pushed out of the market.

With rationalization of production, the price of CBD isolate is expected to rise and remain at about €500/kg on the European market. Sales are expected to reach €12 billion by 2026, driven by accelerated growth of secondary markets such as ingestibles like drinks, as well as larger mainstream distribution channels such as grocery stores. Moreover, technological innovations have helped to rationalize processing and harvesting, leading to a fall in production costs and a subsequent increase in production margins.

As mentioned previously, however, competition from biotechnologies, synthetic biology, such as cultured cannabinoids and dysbiosynthesis (see Plamondon, 2021; Riboulet-Zemouli, 2020; UNCTAD, 2019a) and fully chemical synthetic CBD has become fiercer and represents a real threat to natural CDB derivatives. Moreover, the subsector still faces issues of compliance with quality standards, which are important obstacles to meeting demand expectations.

While CBD offers patients the promise of controlling their own health with natural products, due to the character of the substance, consumers may have unrealistic expectations. For instance, respondents to the CBA (2019) survey who had purchased CBD reported doing so to alleviate cancer symptoms, treat effects of a neurological disorder, improve heart health or enhance bone health. None of these properties has been backed by peer-reviewed empirical evidence so far. This raises consumer protection issues.

The only officially approved use of CBD by the United States Food and Drug Administration (USFDA) so far is for the treatment of epilepsy through a drug called Epidiolex. As mentioned previously, other properties may be confirmed by some reliable empirical evidence and clinical testing. The proliferation of CBD products clearly points to the need for developing regulations based on rigorous science for the benefit of consumers' health. While a major issue in the United States market is to establish a uniform set of regulations,[71] the European approach based on the concept of novel food[72] appears to be relatively conservative, resulting in possibly prohibitive costs to producers.[73]

[71] There are currently about 140 different state bills for CBD products and hemp derivatives.

[72] Novel food is defined as food that had not been used for human consumption to a significant degree in the European Union before 15 May 1997, as defined by Regulation (EU) 2015/2283(see https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32015R2283).

[73] See EIHA for an extensive discussion, at https://eiha.org/eiha-novel-food-consortium/.

The hemp industry, and especially the CBD industry, also decries the lack of global standards, whether public or private, to protect consumers. Strong coordination efforts are under way towards recognition of existing international standards that guide the sectors and product categories in which they operate.[74]

[74] In Europe, the EIHA is constantly examining issues of safety for the consumer and quality in CBD for the industry in the context of developments in laws and regulations within the European Union.

CHAPTER IV

Supply and demand

As observed in chapter 2, industrial hemp is a multipurpose crop. It can be used to produce food, animal feed cosmetics, biomaterials and energy, and is able to create positive environmental externalities. However, data with an extensive country coverage are available only for hemp products obtained from the plant's stalks. Some information about seed production is also available, but there is scant data on trade in seeds and derivative products It is available only for some countries with highly disaggregated national tariff schedules.

Moreover, since legal requirements vary by country, the product coverage of individual tariff lines is not the same in different national nomenclatures. Comparable information is only available at a level of disaggregation that does not include hemp seeds or hemp seed oils as separate products. In addition, informal trade in hemp products, including transborder trade in some instances, is widespread in many of the least developed countries (e.g. Alcock, 2015; Laudati, 2014; Lowitt, 2020) not to mention the prevalence of illicit trade in *Cannabis* for many decades.

Data on the production of illegal intoxicant *C. sativa* L. are missing. However, trends can be inferred from information collected by UNODC about seizures. As reported in UNODC (2021), 3,779 tons of illegal *Cannabis* herb and 1,395 tons of its resin were seized worldwide in 2019. While the quantities of illegal *Cannabis* herb seized have been declining since 2017, those of its resin have been rising steadily since 2015. Public information about trade in illegal *Cannabis* remains mainly qualitative. UNODC (2021) indicates that trafficking in the herb remains mostly intraregional, and trafficking in the resin mostly originates in a limited number of countries.

Some, evidence, albeit scarce, points to the prominent role played by women in traditional illicit *Cannabis* and hemp cultivation (Afsahi and Darwich, 2016; Afsahi, 2015; Kay et al., 2020; Clarke, 2007, 2010). The existence of informal exchanges of hemp and hemp products, even if they cannot be properly and systematically quantified, needs to be taken into account when framing policy intervention plans. The gender dimension, in particular, may be an important consideration in defining the criteria for the success of policies.

This chapter first presents some facts and figures about hemp production, followed by information on international trade in hemp products. The last section discusses tariffs and NTMs relating to the hemp trade.

4.1 HEMP PRODUCTION

Statistics compiled by the FAO remain the most extensive repository of information about hemp production. Available information in the FAO database includes harvested areas and production,[75] and it covers both hemp fibres and seeds. There are currently about 40 countries producing raw/semi-processed industrial hemp. Until the end of the 1980s the number of hemp-producing countries reported in the FAO statistical database fluctuated between 20 and 23. It then jumped to 31 in 1995 and stabilized at 30 between 2006 and 2007. In 2018, it rose to 34, and to 36 in 2019. The new additions are Switzerland and Uruguay.

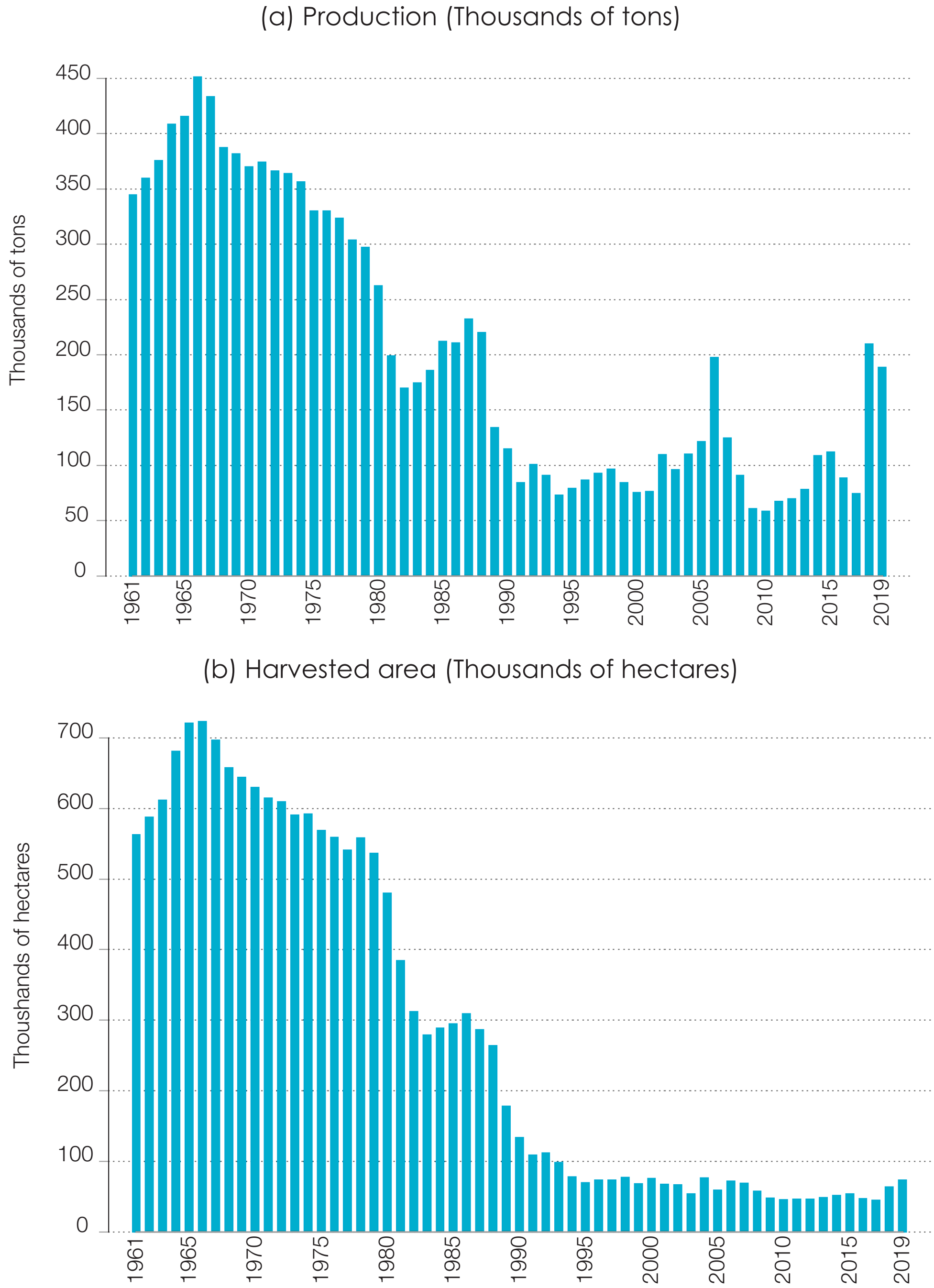
4.1.1 Hemp fibre

Both harvested areas and production of hemp fibre were considerably greater in the 1960s and 1970s than during the past 30 years (figure 5). Production was about 300,000 tons at the onset of the 1970s after

[75] Note that for the European Union Member States, only hemp surfaces for which direct payments are requested by growers in the context of the European Union's Common Agricultural Policy (CAP) are covered by official statistics as reported by the FAO. All other growing areas are not included in the calculation. This implies that European Union figures may be seen as lower bounds of effectively cultivated areas.

reaching a peak of about 450,000 tons in 1965. At the beginning of the 1990s, production dropped to less than 100,000 tons. It is only in 2018 that it rose to more than 200,000 tons, thus more than doubling from 2017.[76]

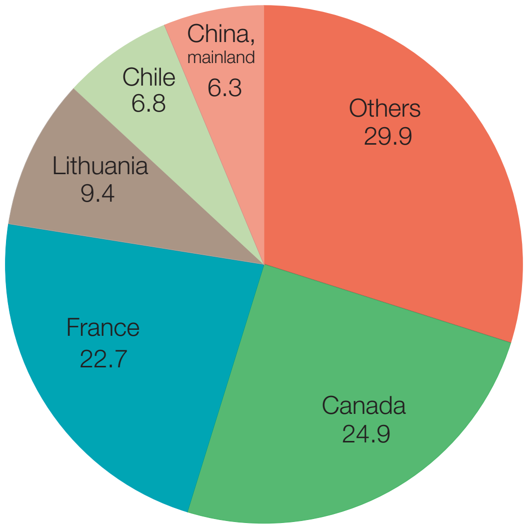
Figure 5 Hemp fibre: Total production and harvested area, 1961–2019



Source: FAO statistics. https://www.fao.org/faostat/en/#data/QCL

76 This exponential increase is the consequence of France reporting a production of about 120,000 tons in 2018 and of 80,000 tons in 2019, as shown in the upper panel of annex figureA.1.

Figure 6 Share of selected countries in total area cultivated for hemp fibre, 2019
(Percentage)



Source: FAO statistics https://www.fao.org/faostat/en/#data/QCL and Statistics Canada https://www150.statcan.gc.ca/n1/en/subjects/agriculture_and_food.
Note: Countries with cultivated areas of less than 4,000 ha are included in the "Others" group.

Data for countries such as Canada and the United States are not included in the production data reported by the FAO. However, Statistics Canada released data on harvested area for hemp fibres for 2019.[77] Information about harvested areas in the United States was also released. [78] Available information for selected countries for 2019 is shown in figure 6. The largest area was found in Canada (15,937 ha), followed by France (14,550 ha), Lithuania (6,000 ha), Chile (4,381 ha), China (4,015 ha)[79] and the Russian Federation (3,600 ha).[80]

In 2019, world production of hemp fibres was approximately 275,000 tons if Canadian production is included.[81] The surge in the figures for France observed in 2018 and 2019 is due to the revision of official figures, rather than being estimates or imputed values.[82]

Figure 7 shows the respective shares in total hemp fibre production of the major producing countries in 2019.

77 Hemp production data are officially produced by Statistics Canada and can be retrieved from the Field Crop Reporting Series available at https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3401.

78 The United States National Agricultural Statistics Service (NASS) mailed its first Hemp Acreage and Production Survey to 20,500 producers across the United States in October 2021. According to a private group estimate (Brightfield Group, 2021), 115,000 hectares (ha) of industrial hemp were planted in the United States in 2020, with 300,000 ha projected to be planted in 2021 and 930,000 ha by 2023.

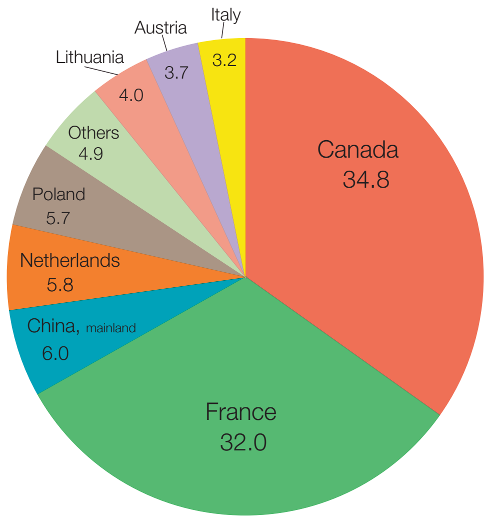
79 Various observers (see for instance Mirizzi and Jablonski, 2020) suggest that FAO figures for China may not reflect precisely the true current situation. USDA (2020) reports industry estimates of China's hemp planted area at around 66,700 ha in 2019, among which over 50 per cent is fibre hemp.

80 Data generated by the FAO based on an imputation methodology would suggest that the country with the largest area harvested for hemp fibres is the Democratic People's Republic of Korea with 21,496 ha in 2019. The information is only reported in a footnote as the total absence of trade data for the country does not allow any crosschecking to assess the consistency of FAO information. Moreover, no official information has ever been reported in the FAO database.

81 The harvested area in Canada is 10 per cent larger than that in France, implying that overall production may be inflated by some additional 8, 000 tons if it is assumed that yields in Canada and France are comparable.

82 Official data were not published between 2003 and 2017. The latest official figure corresponded to a harvested area of 200 hectares, which may explain the "gap" observed between the 2017 estimate and the official data for 2018.

Figure 7 Share of selected countries in total production of hemp fibre, 2019
(Percentage)



Source: FAO statistics and authors' estimates. https://www.fao.org/faostat/en/#data/QCL
Note: Countries with a production level lower than 5,000 tons are included in the "Others" group.

The average yield increased steadily during the period 1961–2019 and then sharply in the 1980s. During the first two decades, from 1961 to the beginning of the 1980s, the average yield rose from 0.8 tons/ha to 1 ton/ha and then up to almost 3 tons/ha in 2018. The latest available FAO's figure is about 2.7 tons/ha. A noticeable drop occurred in 2007, when the average yield was only 2.3 tons/ha compared with 2.8 tons/ha in 2006 – a decrease of about 18 per cent. In 2018 and 2019, the highest yields were observed for France, Italy, the Netherlands and Poland, varying between 5.4 tons/ha and 8.5 tons/ha. The latter, which was Italy's yield in 2019, is also the third highest yield ever observed in the FAO statistics. The Netherlands registered the highest ever yields for four years in a row, from 2004 to 2007.

4.1.2 Hemp seeds

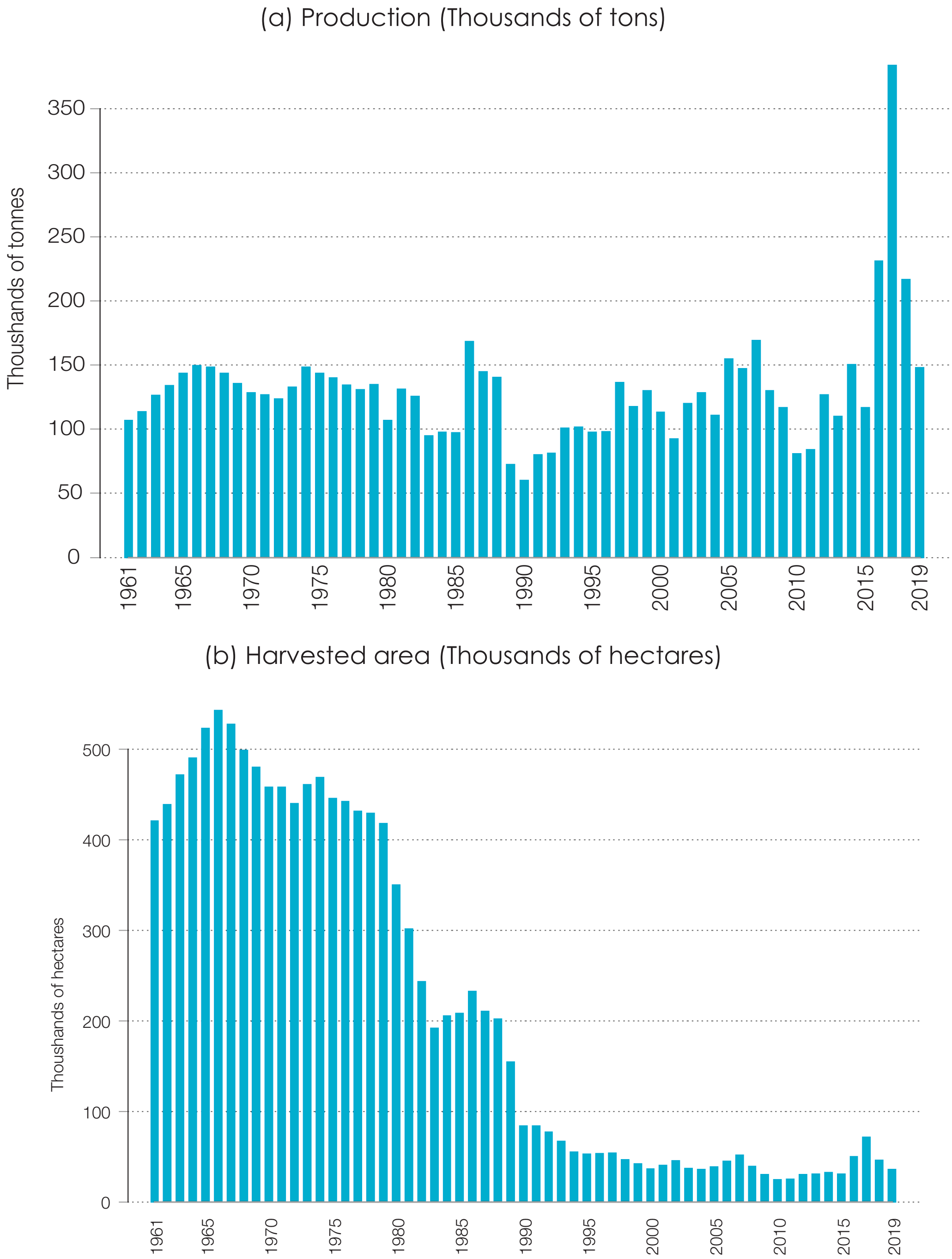
The number of hemp seed-producing countries (14 to16) appears to be about half the number producing hemp fibres (28 to 30). The evolution of hemp seed production since 1961 differs significantly from that of hemp fibre production (figure 8 (a)). While world production of Hemp fibre collapsed at the beginning of the 1980s, world production of hemp seeds fluctuated between 100,000 and 150,000 tons, with historical lows below 70,000 tons during the 1989–1992 and 2010–2011 periods.

The evolution of the total harvested area for hemp seeds was similar to that for hemp fibres. The harvested area for hemp seeds started to shrink from the end of the 1970s (figure 8 (b)), due, principally, to a decline of harvested area in China.

FAO information for 2019 does not include either Canada or France. The last available figure for France dates back to 2017 when it was about 18,000 ha. According to Statistics Canada, the harvested area in Canada in 2019 was about 25,000 ha. If it is assumed that the harvested area remained constant in France between 2017 and 2019, then China will have had the second largest cultivated area with about 19,000 ha (figure 9).

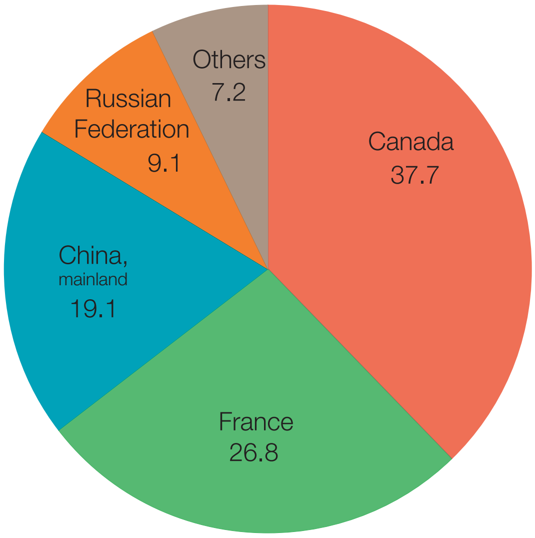
Most recently, the largest producers of hemp seeds, according to FAO data, have been, by far, France (130,000 tons in 2017) and China (125,000 tons in 2017). However, applying the yield observed in 2017 to the harvested area declared in 2019 would suggest that Canada reached production levels up to 40 per cent higher in 2019 than those observed in France in 2017 (see figure 10).

Figure 8 Hemp seeds: Total production and harvested area, 1961–2019



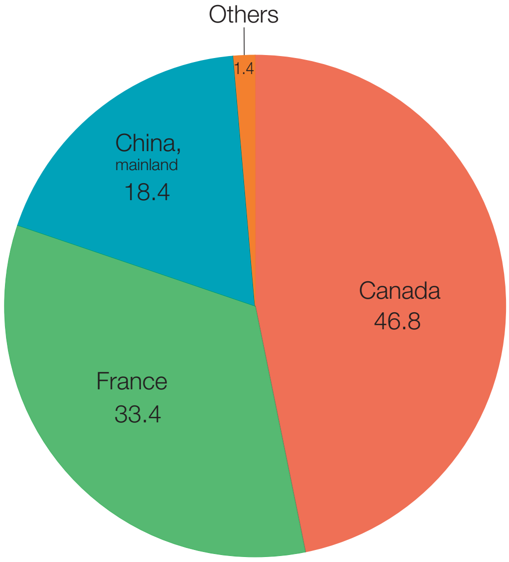
Source: FAO statistics. https://www.fao.org/faostat/en/#data/QCL

Figure 9 Share of selected countries in total area cultivated for hemp seeds, 2019
(Percentage)



Source: Source: FAO statistics https://www.fao.org/faostat/en/#data/QCL and Statistics Canada https://www150.statcan.gc.ca/n1/en/subjects/agriculture_and_food.
Note: France's share is based on the value observed in 2017. Countries with cultivated areas of less than 4 000 hectares are included in the "Others" group.

Figure 10 Share of selected countries in total production of hemp seeds, 2019
(Percentage)



Source: FAO statistics https://www.fao.org/faostat/en/#data/QCL and Statistics Canada https://www150.statcan.gc.ca/n1/en/subjects/agriculture_and_food.
Note: France's share is based on the value observed in 2017. Countries with production of less than 1,000 tons are included in the "Others" group.

If both estimates for France and Canada were added, production based on the most recently published data would more than double the total production, as reported in figure 8, to between 310,000 tons and 320,000 tons.

4.2 HEMP TRADE

The main source of information used in this section is the United Nations Comtrade database. The database covers three hemp-related products at the six-digit level of the Harmonized System (HS) classification. The products are raw or retted (but not spun) hemp, semi-processed hemp (fibres) and hemp yarn. There is some degree of correspondence between production and trade information, but it is not necessarily fully consistent, as discussed in box 3. For instance, it is impossible to identify trade in hemp seeds and hemp seed oil. This implies that a potentially large proportion of trade in hemp products remains unaccounted for in international product classifications. Hence, national sources were also explored to identify the reference to hemp products beyond six digits.[83] However, national classifications do not necessarily adopt the same product definitions and descriptions beyond the standardized international six-digit level. This renders comparison and aggregation difficult.

Box 3 Consistency in trade and production data

Trade and production figures can, in principle, be relatively easily merged, as there is strict correspondence of product definition in production and trade data. In the case of hemp, only raw or semi-processed products are found in both data sources. Production in hemp fibres (FAO item code 777) corresponds to aggregated trade in HS 5302.10 and HS 5302.90 (See https://www.fao.org/faostat/en/#definitions for product correspondences). It should therefore be possible to calculate trade-to-production ratios. However, such calculations can generate inconsistent results with ratios far beyond unity, which, by definition, should be the maximum value observable. This is the case for the following countries: France, Hungary, Japan, the Netherlands, Poland, Spain and Turkey. Inconsistent export-to-production ratios are mostly observed when production information is not systematically retrieved from official sources but is estimated by the FAO. However, production and trade data for 2019 appear to be consistent, as all ratios are below one. This does not mean, however, that they are fully accurate, as production data are still estimated for some countries. Moreover, the sample includes only 18 countries due to the limited country coverage of FAO production statistics. Export-to-production ratios obtained for 2019 vary between 0.1 per cent (Austria) and 48.7 per cent (Hungary). The average value is 11.4 per cent and the median value is 5.6 per cent. Only three countries export more than 25 per cent of their production. These statistics suggest that the producing country is likely to engage in primary and secondary processing.

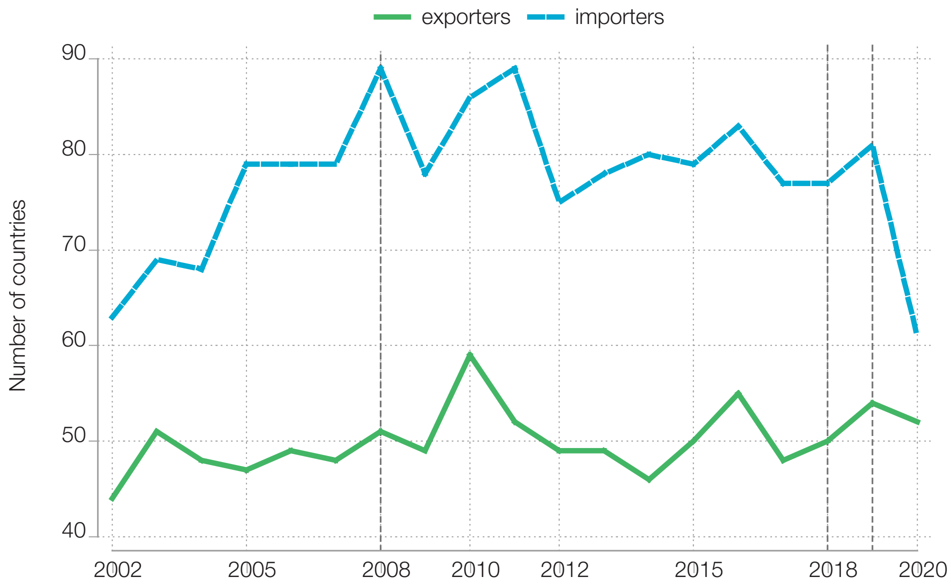
4.2.1 International statistics

Since 2002, 50 countries have exported some of the three HS six-digit products (figure 11). The number of importing countries is much larger, averaging 77 during the period 2002–2020.

The increase in both the number of exporting and importing countries observed between 2018 and 2019 may be the consequence of more permissive laws passed in Canada and the United States in 2018. This is confirmed by trade values and volumes shown in figures 12 and 13. On aggregate, world imports of hemp products, as reported in the HS classification, amounted to about $42 million in 2020, which is about twice as much as their value in 2018.

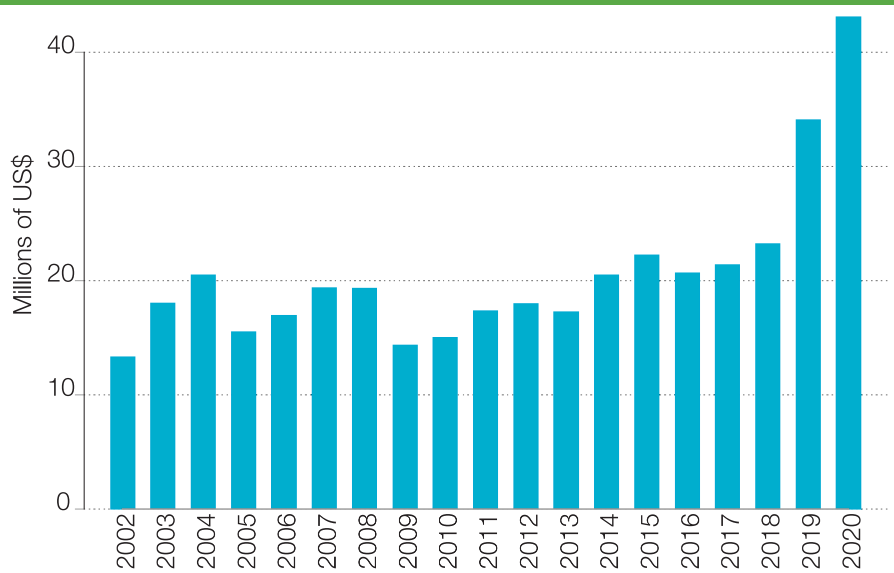
[83] National statistical sources are, in most cases, more disaggregated, and may contain product definitions of up to 10–12 digits.

Figure 11 Number of countries importing and exporting hemp products (HS classification), 2002–2020



Source: Authors' calculations based on UN Comtrade information in World Integrated Trade Solutions (WITS). The number of importers and exporters is based on import information, which is considered to be more exhaustive and precise than export information.

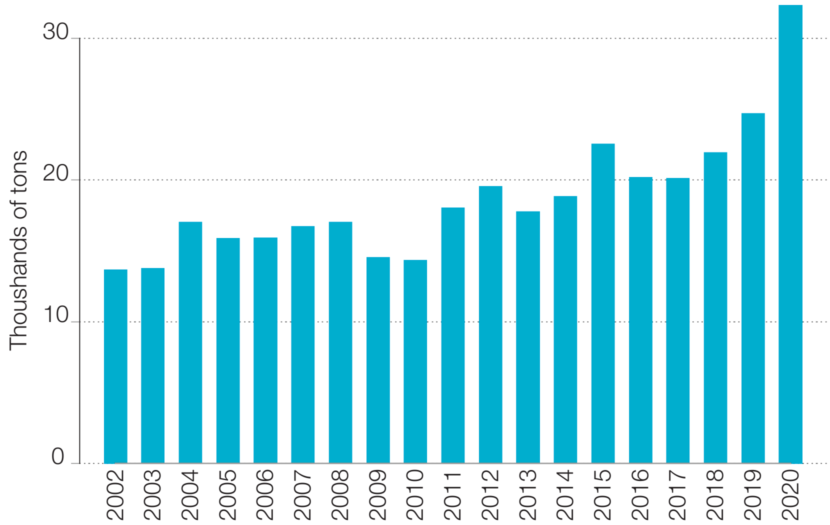
Figure 12 Total value of imports of hemp products (HS classification), 2002–2020
(Millions of United States dollars)



Source: Authors' calculations based on UN Comtrade information in WITS.

In volume terms, the increase observed between 2018 and 2020 was close to 40 per cent. In 2020, the total volume of hemp imports was about 32,300 tons. In terms of both value and volume, the increase recorded between 2018 and 2020 is extraordinary, especially considering that 2020 was strongly negatively affected by the coronavirus pandemic. The boost created by changes in regulations in North America are likely to explain most of this strong rise, even though the absolute amount remains relatively small.

Figure 13 Total volume of imports of hemp products (HS classification), 2002–2020
(Thousands of tons)

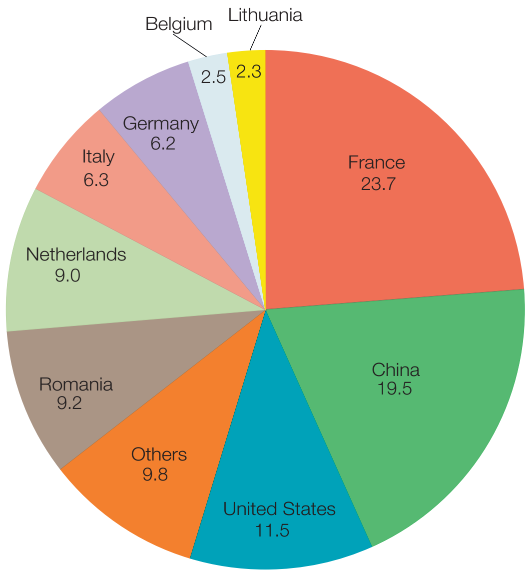


Source: Authors' calculations based on UN Comtrade information in WITS.

Less than two years after the re-legalization of industrial hemp, the United States became its third largest exporter, in value, behind France (ranked number 1 in both value and volume over the past two decades) and China (see figure 14).[84]

On the import side, the three largest markets in 2020 were Spain, Switzerland and the United States (figure 15). Countries such as Nigeria, the Republic of Korea and Turkey featured at least once among the top five importers in either value or volume between 2002 and 2020 (see annex table A.2).

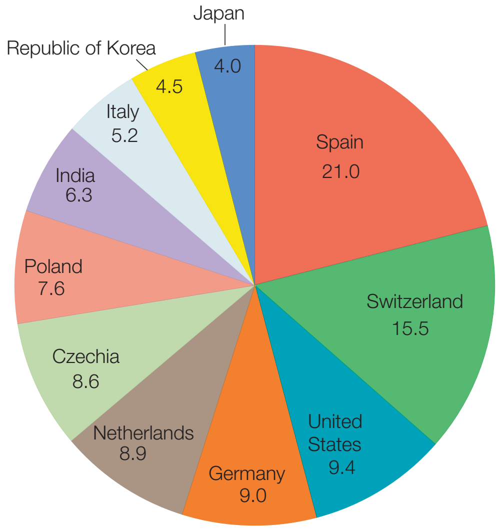
Figure 14 Major exporters of hemp products (HS classification): Countrie's share in total, 2020
(Percentage)



Source: Authors' calculations based on UN Comtrade information in WITS.

[84] Note that Japan ranked fifth in terms of export value in 2002. The United Kingdom and Belgium ranked respectively fourth and fifth in terms of export volume in 2010 (see annex table A.3).

Figure 15 Major importers of hemp products (HS classification): Countries' share in total, 2020
(Percentage)



Source: Authors' calculations based on UN Comtrade information in WITS.

The major product, in value terms, reported in the HS classification was semi-processed hemp (HS 5302.90), especially in 2019 and 2020. In 2020, imports of that product accounted for more than 50 per cent of total hemp imports. The other two products, namely raw or retted hemp (HS 5302.10) and hemp yarn (HS 5308.20), amounted to one fourth of total hemp imports each.

With respect to volume, the dominant product is still semi-processed hemp. In 2020 slightly more than 23,000 tons were traded. The second most traded product was raw or retted hemp with about 8,000 tons traded in 2020. Only 1,100 tons of hemp yarn were traded that same year.

Regarding trade, in value terms, between regions and in some major single markets, intra-European Union trade constituted the bulk of international trade in raw or retted, and and semi-processed hemp (table 3). Trade flows among its 27 Member States represented 27 per cent of world trade in raw or retted hemp in 2002. If European Union trade with other European and Central Asian countries is included, the total share increases to 79 per cent. Moreover, the intra-European Union trade share in total trade increased to 85 per cent in 2019.

For semi-processed hemp, intra-European Union trade accounted for 66 per cent and 69 per cent of total trade in 2002 and 2019 respectively. Trends are more nuanced for hemp yarn. While the intra- European Union trade share in total trade increased from 23 per cent to 33 per cent between 2002 and 2011, it fell to 12 per cent in 2019. Exports from China to the European Union market increased significantly in absolute terms between 2011 and 2019 despite a relatively moderate increase in relative terms. China became the main exporter of hemp yarn during the 2011–2019 period, clearly displacing European Union exports. China's exports were more than half of total exports in 2019, compared with one third for European Union exports. China's main destination markets are in Eastern and Southern Asia. The United States was the largest destination market for European Union exports in 2019, surpassing intra-European Union trade.

Table 3 Interregional and bilateral trade in hemp and hemp products, 2002, 2011 and 2019

Product	Year	Importer	Exporter	Value (US$)	Share in total (Percentage)
Raw or retted hemp (HS 5302.10)	2002	Europe and Central Asia	European Union	1,459,466	52
		European Union	European Union	768,995	27
		European Union	Middle East and North Africa	399,545	14
		European Union	United Kingdom	46,351	2
		East Asia and the Pacific	China	38,757	1
	2011	European Union	European Union	2,138,293	77
		European Union	Middle East and North Africa	173,914	6
		East Asia and the Pacific	China	148,357	5
		Europe and Central Asia	European Union	61,300	2
		East Asia and the Pacific	Latin America and the Caribbean	34,873	1
	2019	European Union	European Union	8,105,790	85
		European Union	Europe and Central Asia	351,209	4
		United States	European Union	316,519	3
		Europe and Central Asia	European Union	154,718	2
		United Kingdom	Europe and Central Asia	110,844	1
Semi-processed hemp (HS 5302.90)	2002	European Union	European Union	3,532,023	66
		European Union	Europe and Central Asia	396,856	7
		Europe and Central Asia	European Union	285,663	5
		European Union	United Kingdom	198,451	4
		East Asia and the Pacific	China	182,190	3
	2011	European Union	European Union	6,759,176	67
		European Union	United Kingdom	648,649	6
		East Asia and the Pacific	China	634,116	6
		United Kingdom	European Union	401,163	4
		Europe and Central Asia	European Union	287,207	3
	2019	European Union	European Union	11,400,000	69
		European Union	United Kingdom	994,947	6
		Europe and Central Asia	European Union	461,084	3
		East Asia and the Pacific	China	453,948	3
		South Asia	China	424,033	3

Product	Year	Importer	Exporter	Value (US$)	Share in total (Percentage)
Hemp yarn (HS 5308.20)	2002	European Union	European Union	1,176,107	23
		China	East Asia and the Pacific	1,050,105	20
		East Asia and the Pacific	China	654,362	13
		European Union	China	546,589	11
		European Union	Others	416,870	8
	2011	European Union	European Union	1,488,123	33
		East Asia and the Pacific	China	775,864	17
		European Union	China	574,395	13
		United States	China	441,370	10
		European Union	East Asia and the Pacific	265,442	6
	2019	South Asia	China	1,564,733	19
		East Asia and the Pacific	China	1339,157	17
		European Union	China	1297450	16
		United States	European Union	992,282	12
		European Union	European Union	959,016	12

Source: Authors' calculations based on UN Comtrade data on imports in WITS.

As discussed in the previous chapter, the HS classification in its international version covers the hemp crop's diversity only partially. It does not cover major products such as seeds, seed oil and CBD products. Information on some of these missing items can be obtained from national tariff schedules, many of which offer more disaggregated and more specific product data.

4.2.2 National statistics

As noted above, national statistics provide additional information when applied product classifications go beyond HS 6-digit product definitions. Such information is shown in annex table A.4 for a selection of countries and regions. It is mainly based on Trade Map of the International Trade Centre (ITC), which collects information from domestic sources and from the UN Comtrade database.

European Union

The European Union's tariff schedule includes three additional hemp-related products.

The first product is hemp seeds, excluding sowing as a final use, for which both exports and imports are recorded, and show a mostly positive trade balance overall. However, between 2016 and 2020, trade was mostly within the European Union. In 2020, $ 75.8 million worth of hemp seeds were exported, the largest amount recorded between 2016 and 2020. During this period, except for Cyprus, all European Union Members exported some, even small, amounts of hemp seeds.

The largest exporters were the Netherlands (40 per cent of total), Spain (20 per cent) and France (11 per cent),[85] and the largest destination markets were Germany, the Netherlands, Spain, Italy and the United Kingdom. Two thirds of Poland's exports ($1.2 million) went to the United States. The latter is also an important destination market for both Lithuanian and Romanian exports.

[85] Considering that France is the largest producer of hemp seeds, export data suggest that a large share of its production is retained for the domestic market.

The value of hemp seed imports in 2020 amounted to about $54.3 million. Between 2016 and 2020, their value peaked in 2017 at slightly more than $56 million. All European Union Member countries, except Denmark, reported some imports between 1996 and 2020. The largest importers were the Netherlands ($19.2 million) followed by Spain ($10.1 million), Austria ($4.2 million) and Romania ($3.8 million). The major source markets were the European Union, China and Canada, especially after 2018.

The other two products relate to hemp yarn. Their distinction is based on whether the product is for retail sale or for other purposes. As in the case of hemp seeds, both imports and exports were recorded between 2016 and 2020. Amounts reported were much smaller than those of the trade in hemp seeds. Imports of hemp yarn for retail sale amounted to $2.5 million, and exports to $846,000 in 2020. Corresponding figures for hemp yarn not for retail sale were $758,000 and $749,000 respectively. This implies that for both products the trade balance was negative.

The European Union is a net importer of hemp yarn whether used for retail sale or other purposes. In 2020, 53 per cent of its total hemp yarn for retail sale was exported, and 77 per cent of its imported hemp yarn was for retail sale. About half of total exports of hemp yarn were sourced from Italy in 2020. Italy's share was close to 60 per cent in 2016 and 2017. Other major exporters were Romania, the Netherlands and Germany. Apart from Japan and Tunisia, major destinations for the European Union's hemp yarn exports are intraregional, in particular Belgium and Lithuania, though some is also exported to China and the United States.

The largest exporter of hemp yarn is also the largest importer. Italy's imports accounted for 30 per cent of total European Union hemp yarn imports in 2020. Its major source markets were China and Tunisia. Other large importers were Portugal (which also accounted for about 30 per cent of total European Union imports), followed by the Netherlands, Belgium and Lithuania. Again, China was the main source of hemp yarn imports into Portugal, Belgium and Lithuania.

Canada

The Canadian tariff schedule includes 11 additional products to the international HS classification. There is a clear distinction between hemp-related and cannabis-related products.

Trade flows of hemp seeds are recorded either as used for sowing (HS 1207.99.00.11) or for other purposes (HS 1207.99.00.19). Canada did not report exports of any types of hemp seeds, at least until 2020, the last year for which data are available. The country's imports of seeds for sowing peaked at about $850,000 in 2019. In 2020 the corresponding import value was not even a quarter of that amount. In quantity terms, 27 tons of seeds for sowing were imported in 2019 against 13.5 tons a year later. Italy, the United States and the Netherlands were the largest exporters to Canada.

Regarding seed imports for other purposes, the peak was reached in 2017, with about 190 tons imported mostly from Lithuania and the United States and worth $1.1 million. In 2020, imports were about 115 tons, worth $560,000. The United States became the largest exporter to Canada followed by Ethiopia. Lithuania's exports were interrupted in 2019 and 2020, most probably replaced by Canadian domestic production.

Information about *Cannabis* seeds for sowing (HS 1209.99.10.29) is also provided. Canada recorded no exports until 2020. However, during that same year 182 tons, worth $1.3 million, were imported. In terms of quantity, the leading exporter to Canada was the United States, followed by China, Paraguay and Uruguay. In value terms, the Netherlands appears to have been the leading exporter.

Some information is also provided for cannabis plant parts, including seeds used for pharmaceutical purposes (HS 1211.90.90.50). No exports were recorded until 2020. Imports started timidly in 2018 ($35,000) but rose dramatically in 2019 ($1.3 million) before collapsing in 2020 ($20,000). The United States was the largest exporter in 2019, with earnings of$1.16 million.

Trade flows of cannabis lac, natural gums, resins, gum-resins and oleoresins are also recorded (HS 1301.90.00.10). No exports were recorded until 2020. Imports were either zero or insignificant until 2020 when they amounted to $15,000, originating mainly from India.

A similar situation is observed for *Cannabis* oil, extracts and tinctures (HS 1302.19.00.10). Imports reached $729,000 in 2018 and originated mainly from Italy. After collapsing in 2019, they amounted to $136,000 in 2020, with the United States being the major exporter to Canada.

Trade flows in hemp oil are also included in the Canadian classification (HS 1515.90.00.10). No exports were registered until 2020. Imports, mainly from Portugal started in 2017. In 2020, Canada imported 144 tons of hemp oil for a total value of $473,000. Italy, the United States, China and France were the largest exporters to Canada. A large proportion of re-imports (Canadian hemp oil first exported and then re-imported under the same product code) is also observed for 2020 and is probably explained by some transformation occurring across the border in the United States.

Some imports of medicines containing *Cannabis* or cannabinoids (HS 3004.90.00.21) for retail were also reported, but no exports were recorded. Imports were first recorded in 2018 amounting to $24,000, jumping to $108,000 the following, before falling to $19,000 in 2020. Spain was the largest source country in 2018, but only Belgium and the United States exported to the Canadian market in 2020.

The last product category (HS 5702.99.10.00) identified in the Canadian classification referring to hemp includes carpets and other textile floor coverings made of straw, hemp, flax tow or jute, so it is not an exclusively hemp category. In 2020, the total imported value of this category was about $3.4 million, with exports from India accounting for more than 70 per cent of the total, followed by the Netherlands (18 per cent) and Bangladesh (4.7 per cent).

Japan

Japan's tariff schedule adds five products to the international HS classification, which relate to either hemp or cannabis. They are identified at the 9-digit level.

Insignificant trade was recorded for cannabis plant (HS 1211.90.600). Hemp seeds (HS 1207.99.010) are included, but with no reference to their final use. Japan imports only hemp seeds, and no exports were reported until 2020. Imports reached $2.36 million in 2015 (about 800 tons) and fell significantly thereafter before recovering to $2.1 million (about 650 tons) in 2020. China has been the main exporter for the last two decades, followed by Canada whose share started increasing significantly after 2015.

Some information about trade in extracts or tincture of cannabis and crude cocaine (HS 1302.19.220) is available. Only imports have been observed since 2020. However, figures may not refer exclusively to cannabis products. Imports in 2020 were lower than the previous year, falling from $443,000 to $240,000. Slovenia has been the largest exporter since 2018, the two other major exporters being the United States and the Netherlands.

Regarding cannabis plants and parts of plants, which are used primarily in perfumery or for insecticides, fungicides or similar purposes, imports oscillated around $40 million during the period 2015–2020. Belgium was the largest exporter to Japan, accounting for about half of the country's total imports during that period. Other exporters were Spain, Italy and the United States.

Medicaments of narcotics, cannabis or awakening-amines (HS 3004.90.010) are also included in Japan's classification. Again, this is not an exclusive cannabis product group. About $40.5 million worth of this group was imported in 2020, with more than half originating from Belgium. Other major exporters were Spain, Italy and the United States whose exports more than tripled during the five reported years.

Another mixed category refers to woven fabrics of true hemp or paper yarn (HS 5311.00.020), of which the bulk of Japan's imports were from China and varied between $732,000 in 2013 and $260,000 in 2020.

The United States

The United States national tariff schedule includes information about hemp-related products, but there is no reference to products incorporating intoxicant cannabinoids, even though exports of such products are recorded in some destination markets such as Canada and Japan. Trade in hemp seeds is reported. However, a distinction by use – for sowing versus other uses – has been introduced only recently; thus available information so far does not include such a distinction.

In 2020, hemp seeds were both imported and exported. While total imports amounted to almost $80 million (5,635 tons), exports were close to $800,000 (110 tons). Canada is both the major origin of those imports and the main export destination. Before 2020, there were only imports, and there is a long history of such flows. Besides Canada, hemp seeds were exported to Germany and the Republic of Korea. China, Lithuania, Poland and Romania have been the major sources of imports in recent years.

Hemp oil (HS 1515.90.8010) has been imported since 2002, but no exports have been recorded as of 2020, the latest year for which information is available. The highest imports by value, were observed in 2018 ($14.2 million) and 2019 ($13 million), but fell by one third in 2020, to $8.6 million.

Oilcake and other solid residues of hemp seeds (HS 2306.90.0130) are also included in the classification. Imports were first recorded in 2008 and hit their highest value in 2015, at $16.2 million, falling to $10 million and $8.1 million, respectively, in 2020. During the period 2002–2020 Canada was the main exporter to the United States.

The last product group represented is woven fabrics of true hemp fibres (HS 5311.00.4010). Only imports were recorded until 2020. The period 2002–2020 was marked by significant fluctuations, with a minimum value of $768,000 observed in 2016 and a maximum of $7.08 million in 2018. Historical exporters were China and India. However, most recently more than half of imports have originated from the Dominican Republic. In 2020, a total of $3.06 million worth of the products was imported, of which $2.3 million worth came from the Dominican Republic.

4.2.3 Underestimated trade values

Relatively low values for international trade in industrial hemp, reported previously, are largely due to the narrow coverage of hemp products in international product classifications. If trade information as reported in national statistics (reviewed above) were to be included, the value of imports would jump from $42 million to about $291 million (table 4). But even this could be considered an underestimation. The figures would further increase manifold if trade in CBD hemp products were to be included. Indeed, recent estimates (Grand View Research, 2021) suggest that the global CBD market size was valued at $2.8 billion in 2020, and it is expected to expand at a compound annual growth rate of 21.2 per cent from 2021 to 2028.

Table 4 Imports of hemp products in 2019: Selected national and regional statistics
(Millions of United States dollars)

Total HS products (6 digits)	United States	Canada	European Union	Japan	Total
42	100	8	58	83	291

Source: Author, based on UN Comtrade and Trade Map data.
Note: National/regional figures do not include imports of HS products reported in the first column.

4.3 TARIFFS AND NON-TARIFF MEASURES

Access to international markets is determined by several elements, such as transportation costs, market structure and distribution costs at destination, but also by trade policy instruments. This subsection provides some descriptive statistics about tariff levels and the incidence and prevalence of non-tariff measures (NTMs) across countries. The main source of information is UNCTAD's Trade Analysis Information System (TRAINS).[86]

4.3.1 Tariffs

Figure 16 shows world averages of MFN applied tariffs for hemp products in the HS classification between 2002 and 2020. MFN applied rates were significantly lower than levels observed for other agricultural goods, and even lower than average levels observed for industrial products.[87] Moreover, there was a high prevalence of zero duty rates. About 60 per cent of the countries in the sample reported a zero most-favoured-nation (MFN) applied rate.

Non-zero MFN applied tariff rates were mostly found in countries that do not import any hemp products. Tariff differences between products with different processing intensity suggest some sort of tariff escalation (i.e. it costs more to export yarn than raw products).

Tariff rates on imports of both raw or retted, and semi-processed hemp products (i.e. HS 5302.10, HS 5302.90) were similar, and fell from about 3.5 per cent in 2002 to about 2.2 per cent in 2020. The two highest rates in 2020 were 25 and 30 per cent, imposed by Bangladesh and India, respectively.

Tariffs on hemp yarn howed a similar downward trend. The average tariff fell from about 7 per cent in 2002–2003 to a historical minimum, at slightly less than 5.1 per cent in 2012–2013, recovering slightly to 5.2 per cent in 2020.

Even though there is some evidence of tariff escalation, the maximum tariff rate imposed on hemp yarn was 20 per cent in 2020. A 20 per cent rate was imposed by Argentina, Bhutan, Brazil and the Bolivarian Republic of Venezuela. Tariff rates on yarn imposed by Bangladesh and India would even suggest reverse escalation. Both countries imposed a 10 per cent duty on hemp yarn imports, which was lower than that imposed on raw or retted hemp.

A full appreciation of any possible escalation schemes would require some additional analysis starting with effectively applied rates (figure 17).[88] Those rates account for preferences granted, if at all. Not surprisingly, effectively applied rates fell below MFN applied rates during the period 2002–2020. Moreover, access to international markets appeared to be free of trade duties for raw or retted hemp, which is not the case for the other two HS products. Some tariff escalation pattern emerges, even though the highest tariff rates stayed well below overall average rates for both agricultural and industrial products.

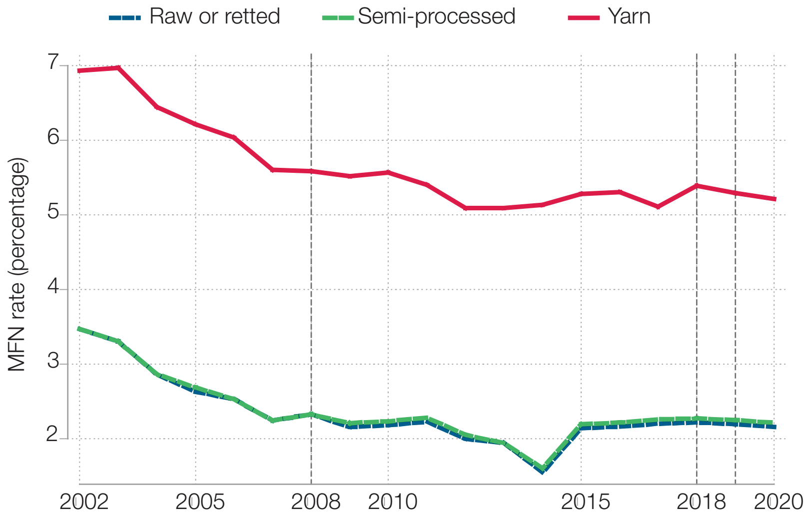
In 2020, the incidence of zero duty was 100 per cent for raw or retted hemp and almost 80 per cent for semi-processed hemp. A country-level analysis reveals that, again, Bangladesh and India imposed the highest rates for raw or retted and semi-processed hemp.

[86] See https://trainsonline.unctad.org/home for information on NTMs , and UNCTAD-TRAINS in WITS at https://wits.worldbank.org for tariff information.

[87] See WTO,UNCTAD, and ITC (2021) for a comprehensive analysis.

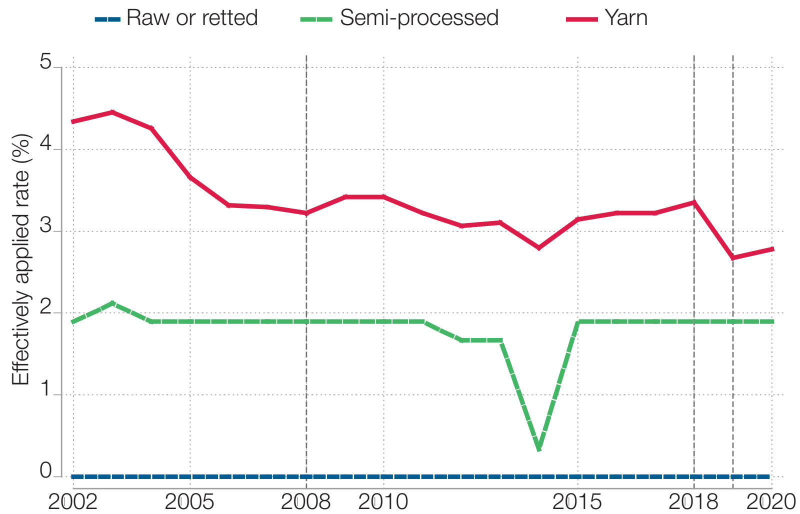
[88] Effectively applied tariffs (AHS variable in the World Integrated Trade System) are only available for products for which some positive trade is recorded.

Figure 16 MFN tariff rates, world average, 2002-2020
(Percentage)



Source: Authors' calculations based on UNCTAD-TRAINS in WITS.

Figure 17 Effectively applied tariff rates, world average, 2002-2020
(World average)



Source: Authors' calculations based on UNCTAD-TRAINS in WITS.

Regarding hemp yarn, the largest rate in the sample was 18 per cent, imposed by Brazil. In Bangladesh, the effectively applied rate fell to 6.5 per cent and that of India to 10 per cent. A pattern of reverse escalation is confirmed for these two countries. As in the case of MFN applied rates, the incidence of duty-free imports was smaller for hemp yarn compared with raw or retted, and semi-processed hemp. Only one third of the countries in the sample reported a zero effectively applied rate.

Annex table A.4 reports MFN and preferential tariffs applied in the major national markets (defined earlier). All HS hemp-related products referred to in national tariff schedules are included. Some information about special tariff rates is also provided for the United States. Special rates applied to imports of some specific products from Cuba and the Democratic People's Republic of Korea. Revealed patterns are comparable to those discussed previously.

Most products in most markets were free of any import duty. Positive rates were found for most processed products, except for live plants imported by Canada. All tariffs were ad valorem except for those applied by the United States on oil cake from hemp seeds (HS 2306.90.01.30). In the latter case, a specific tariff was imposed. Such a tariff was also imposed on raw or retted and semi-processed hemp (HS 5302.10 and HS 5302.90) imported from Cuba and the Democratic People's Republic of Korea.

The figures above suggest that in terms of tariffs, hemp products enjoyed relatively favourable market access conditions. Both international and national statistics indicate that hemp products did not face very high tariff rates compared to other agricultural products. Moreover, tariff escalation, when observed, remained within relatively low tariff ranges. However, a full appreciation of market access conditions requires a close analysis of prevailing NTMs. Indeed, some measures may have been as constraining as prohibitive tariff rates.

4.3.2 Non-tariff measures

Imposition of NTMS is generally the exclusive prerogative of governments. Private standards can also be part of conditions to access some specific markets or export to some specific firms, but they are not a legal obligation per se. Trade in plants may require particular attention because of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).[89]

Although this convention does not apply to *C. sativa* L. varieties, the plant's genetic material could fall under dispositions such as those related to the Convention on Biological Diversity and its Nagoya Protocol. These were agreed in response to the high risk of biopiracy, which constitutes a threat to local control of the national heritage in many countries and presents a possible barrier to their future development (Chouvy, 2022; Duvall, 2016; Riboulet-Zemouli, 2021; Wyse and Luria, 2021).

Likewise, subsequent product applications and derivatives might be subject to specific intellectual property dispositions, as, possibly, in Thailand, where there are restrictions on patent applications,[90] or in India which requires the inscription in its national Traditional Knowledge Database Library. In recent years, there have been proposals for amendments to the Nice classification of trademarks,[91] to better reflect cannabis and hemp classes of products and services, echoing the growing number of applications for trademarks that include the word "hemp" (Zimmerman, 2020).

In the following discussion, only public NTMs, as defined in the internationally recognized classification of such measures (UNCTAD, 2019b), are considered. As in the case of tariffs, information about NTMs has been drawn from both the UNCTAD-TRAINS database and National sources for the countries considered previously.

UNCTAD-TRAINS data are based on the international HS classification at 6-digit disaggregation. The reference sample covers 46 countries that applied some NTMs either on imports or exports, or on both, during the 2012–2020 period. Of the different types of NTMs, 72 have been identified.[92] Some information may be missing, as not all countries' NTM schedules are up to date. Moreover, not all countries reporting either some imports or exports of hemp products, or both, are represented in the sample. Hence, the evaluation of the incidence of NTMs is only partial. Nevertheless, major markets, such as Canada, the United States and Europe, are covered.

[89] CITES is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species.

[90] For details, seehttps://www.reuters.com/article/us-thailand-cannabis-idUSKCN1PM1FU.

[91] See Nice Agreement Concerning the International Classification of Goods and Services for the Purposes of the Registration of Marks at https://wipo.int/treaties/en/classification/nice.

[92] See annex table A.1 for an exhaustive list of these measures, with a short description of their specific scope.

Country analysis

As shown in table 5, 18 countries imposed some NTMs on raw or retted hemp, with 17 of them applying some NTMs on imports, 8 on exports and 7 on both. On average, raw or retted hemp faced 10 different types of NTMs when imported in the reference country markets, whereas its exports were subject to half that number.[93] The largest number of measures applied to imports was 37 and was imposed by Ecuador. The corresponding figure for exports was 24, imposed by the Bolivarian Republic of Venezuela.

Some NTMs on semi-processed hemp were imposed by 40 countries, of which 35 applied some NTMs on imports, 18 on exports and 13 on both. On average, semi-processed hemp faced 5 different types of NTMs when imported in the reference country markets. Exported semi processed hemp was, on average, subject to 2 different types of measures. The highest number of measures applied to its imports was 20, again imposed by Ecuador. The corresponding figure for exports was 5, imposed by Jamaica.

Some NTMs on hemp yarn were imposed by 20 countries, 16 of which applied some NTMs on hemp yarn imports, 9 on exports and 5 on both. On average, hemp yarn faced 6 different types of NTMs when imported in the reference country markets. When exported, hemp yarn was subject to 4 types of NTMs. The highest number of measures applied to hemp yarn imports was 24, imposed by the Bolivarian Republic of Venezuela, which also imposed 22 NTMs, the highest number, on exports.

Table 5 Incidence of NTMs (latest available year)

	Trade flows	Raw or retted (HS 5302.10)	Semi-processed (HS 5302.90)	Yarn (HS 5308.20)
Number of countries imposing NTMs-	Imports	17	35	16
	Exports	8	18	9
	Imports-exports	7	13	5
Number of measure types	Imports	10	5	6
	Exports	5	2	4

Source: Author's calculations based on UNCTAD-TRAINS data.

Despite the large number of possibly applied NTMs, it is not clear whether trade in semi-processed hemp is more restricted than trade in raw or retted hemp. Indeed, the information above points to a small number of measures applied at the country level for semi-processed hemp. There are clear variations across markets, but not necessarily more restrictive regulations.

Analysis of measures[94]

Contrary to tariffs, there was no obvious escalation in the application of NTMs. All hemp products, independently of their level of processing, were affected by NTMs, with potentially equally restrictive effects.

Aggregate statistics reveal that in the case of raw or retted hemp the most extensively used measures related to licensing for economic reasons (E1) on the import side and to prohibitions on the export side (P31). In the latter case there was also extensive use of authorization and permit requirements for technical reasons (P11). On average, 7 different measures of this type were imposed. The maximum number observed was 12. This suggests that governments tend to strictly regulate exports of raw or retted hemp. Not surprisingly, an extensively regulated approach was also adopted for imports in most of the selected countries, with widespread imposition on practices related to fumigation (A53) and quarantine (A86). Imports of raw or

[93] Note that differences in types of measures affecting imports and exports may be the consequence in differences in the classification of SPS and TBT measures across trade flows. A larger number of SPS measures and TBTs apply to imports as compared to exports.

[94] NTMs types are reported into brackets and refer to the international classification presented in UNCTAD (2019b).

retted hemp often requires specific import authorization (A14) and can be subject to strict inspection requirements (A14).

Regarding semi-processed hemp (HS 5302.90), the most extensively used measures also related to licensing for economic reasons (E1) for imports, and to export formalities for exports (P29). On average, imports were subject to 4 different types of E1 measures with an observed maximum of 15. Exports were subject to 3 different P29 types of measures in all countries applying such measures. As in the case of raw and retted hemp, governments tend to strictly regulate exports of semi-processed hemp. Not surprisingly, a restrictive regulatory approach was also adopted for its imports in most countries. An extensive use of measures relation to fumigation (A53) and quarantine (A86) practices was found for raw and retted hemp. Imports of semi-processed hemp face a systems approach (A13) that combines two or more independent SPS measures on a given product. These products can also be required to pass through a specified port at customs (C3).

When considering hemp yarn (HS 5302.10), the most extensively used measures are related to licensing for economic reasons (E1) for imports, and to authorization or permit requirements, for technical reasons, for exports (P11). On average, imports were subject to 13 different measures (which is also the rounded minimum number) of E1 type, with an observed maximum of 15. Exports were subject to 7 different measures of P11 type, on average, with an observed maximum of 13.

As in the case of other hemp products, governments tended to impose strict regulations on exports of hemp yarn. A restrictive regulatory approach was also adopted for its imports in most countries. An intensive use of fumigation-related (A53) practices was found for hemp yarn, but also some financial measures (G39) were imposed in a limited number of countries. The numbers of different types of NTMs applied to either exports or imports of hemp yarn were akin to those obtained for raw or retted hemp.

The number of different types of NTMs affecting trade flows is a good indicator of the incidence of NTMs. While relatively good market access conditions were observed when considering tariffs, the discussion above suggests that trade in hemp products is subject to potentially strict regulations, particularly in terms of NTMs.

It is, however, misleading to draw any conclusion from the analysis about the stringency of NTMs. Indeed, few measures can be as restrictive as a larger set if they involve testing procedures rather than purely administrative obligations. For instance, a single measure imposing some tolerance limits of some substance (i.e. A21 or B21) can be as restrictive as 10 measures related to fumigation. Another example would relate to certification requirements (i.e. A83 or B83). The latter are likely to involve some testing by laboratories recognized and approved by the importing country. This could act as a prohibition if such laboratories are not easily accessible or if they impose excessively high testing costs. A precise appreciation of the stringency of any specific measure and its eventual cost implications requires an in-depth analysis that is beyond the scope of this report.

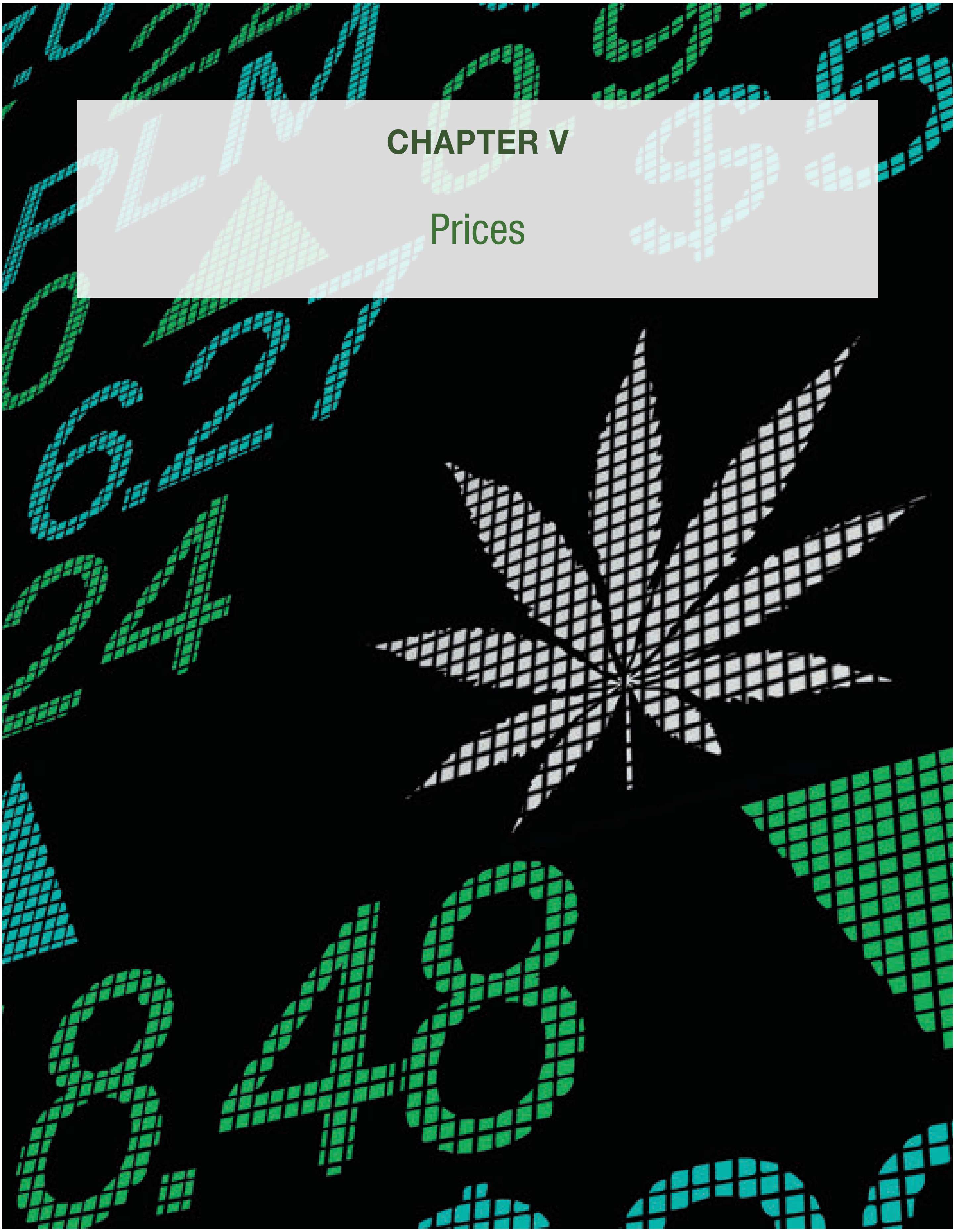
Hemp-related information, whether about production or trade, remains scattered, and its granularity (i.e. level of details) varies considerably across nomenclatures. Consequently, it is difficult to assess precisely and consistently the contribution and market value potential of the hemp sector. By simply aggregating international and some national information sources, the value of world trade in hemp products is multiplied by a factor of about seven.[95]

Tariff data would suggest that trade in hemp products is relatively free, though there is some evidence of escalation in some markets. However, information about the prevalence of NTMs, and especially SPS measures, indicates potentially restrictive market access conditions in the more advanced countries. This may represent dissuasive hurdles to firms operating in less developed markets. A strategy to effectively address those hurdles may consist of organizing production chains at the regional level, with value addition as a specific objective.

95 As a comparison, the figure is close to the value of total exports of durum wheat by France in 2021.

CHAPTER V

Prices



Price information remains scattered, and sources may not necessarily be easily comparable. For the European Union, there is no price information on hemp in the Eurostat database even though hemp is considered a full crop (Eurostat, 2020). The most comprehensive source in terms of country coverage is the UN Comtrade database, but since this is limited to information about trade flows, only unit values are reported. These can, at best, be seen as a proxy for international prices, as they result from calculations based on quantities traded, which are not always accurate.

Another source of information is the FAO database on agricultural prices.[96] However, this reports production prices, and only for a very limited number of countries.

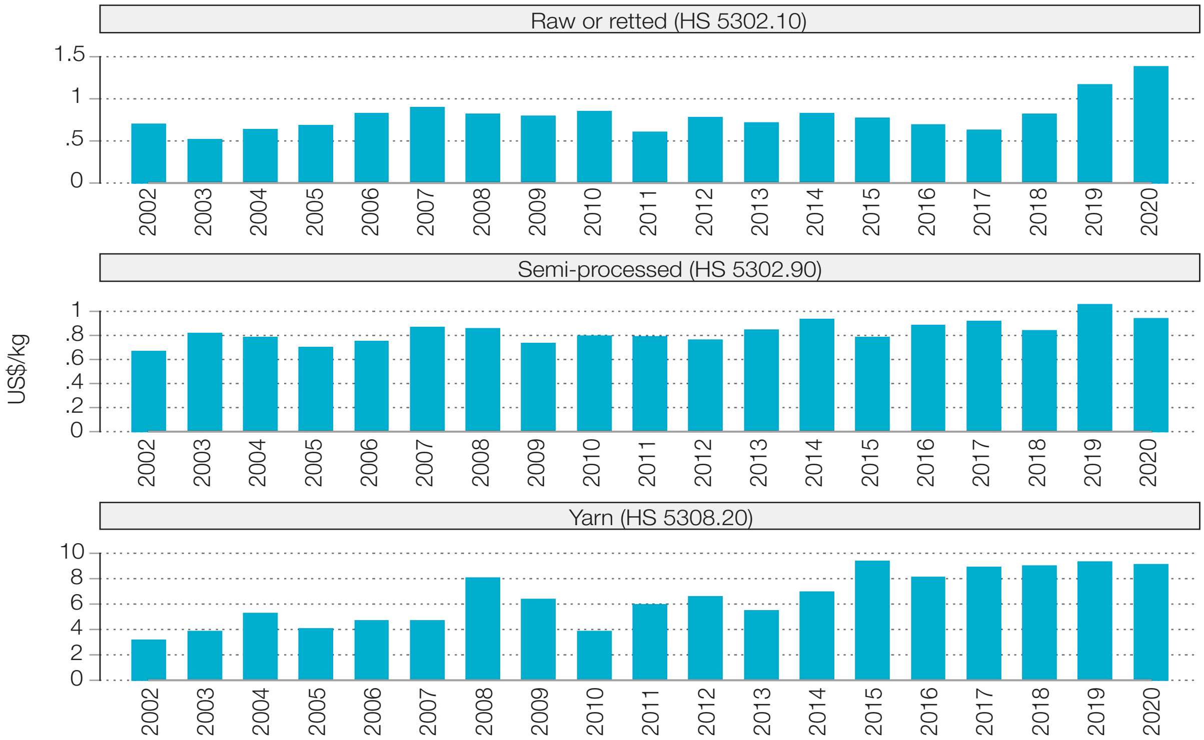
Finally, information can be obtained from specific industry data and reports produced by private entities such as economic consultancy firms. Market analysis may provide information about a larger spectrum of products beyond fibres and seeds, but often it focuses on a specific country market. Hence, it is not always possible to make comparisons across markets due to likely coherence and consistency issues.

This chapter starts with a discussion of trade unit values. It then presents prices, as published by the FAO, followed by prices collected from various other sources, and covering an extended set of hemp products.

5.1 TRADE UNIT VALUES

Not surprisingly, the unit values of hemp yarn were higher than those of raw or retted, and semi-processed hemp during the period 2002–2020 (figure 18).

Figure 18 Import unit values by HS product, 2002–2020
(United States dollars/kg)



Source: Authors' calculations, based on UN Comtrade in WITS.

[96] Available at https://www.fao.org/faostat/en/#data/PP

In 2020, the value of 1kg of hemp yarn imports was about $9.1, compared with $0.94 for semi-processed hemp and $1.38 for raw or retted hemp. Between 2002 and 2020, the unit value of hemp yarn increased almost threefold. The unit value of imports of semi-processed hemp increased by about 40 per cent during that same period, compared with about 50 per cent for raw or retted hemp.

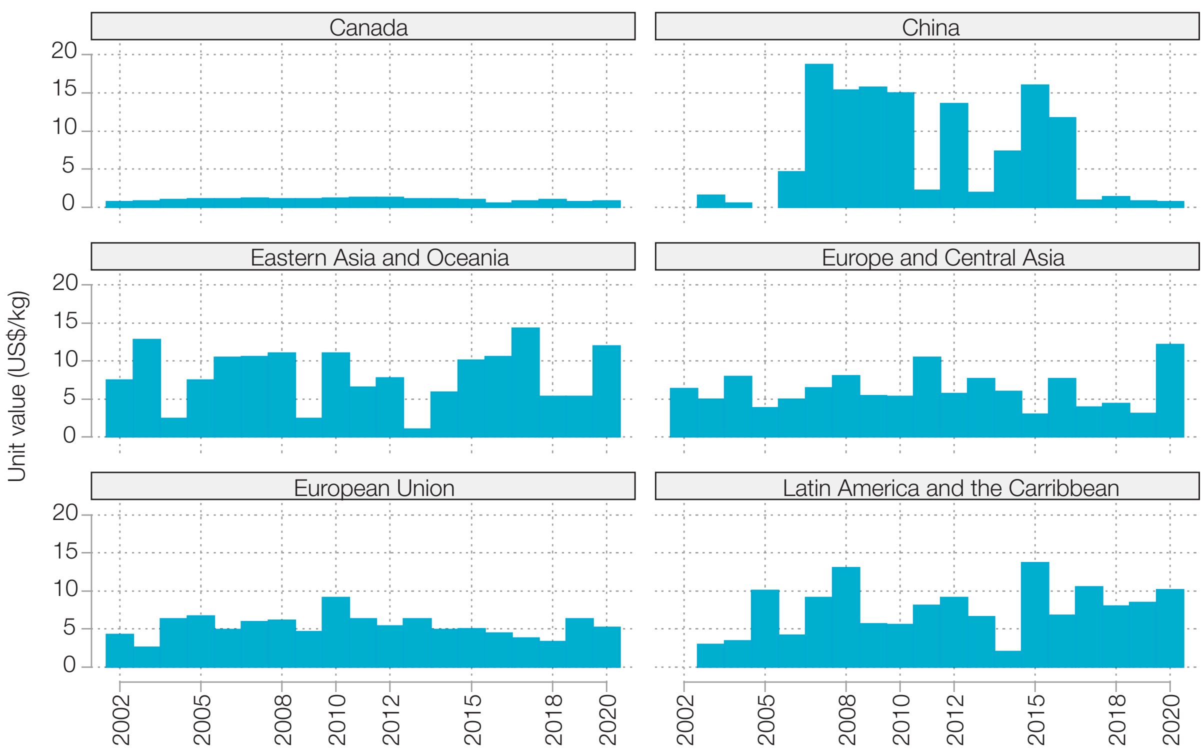
The world unit value of raw or retted hemp has risen sharply, by more than117 per cent in three years since 2017, the year when it registered the third lowest value of the last two decades. However, it should be pointed out that import unit values include the cost of insurance and freight, which may be higher for hemp yarn than for raw or retted, and semi-processed hemp. These costs would not feature in export unit values. In fact, due to differences in reporting standards, export information for most countries is unreliable.

Generally, there was a high degree of variation in average unit values of imports, not only across markets but also across time, as well as within countries and country groups during the period 2002–2020.

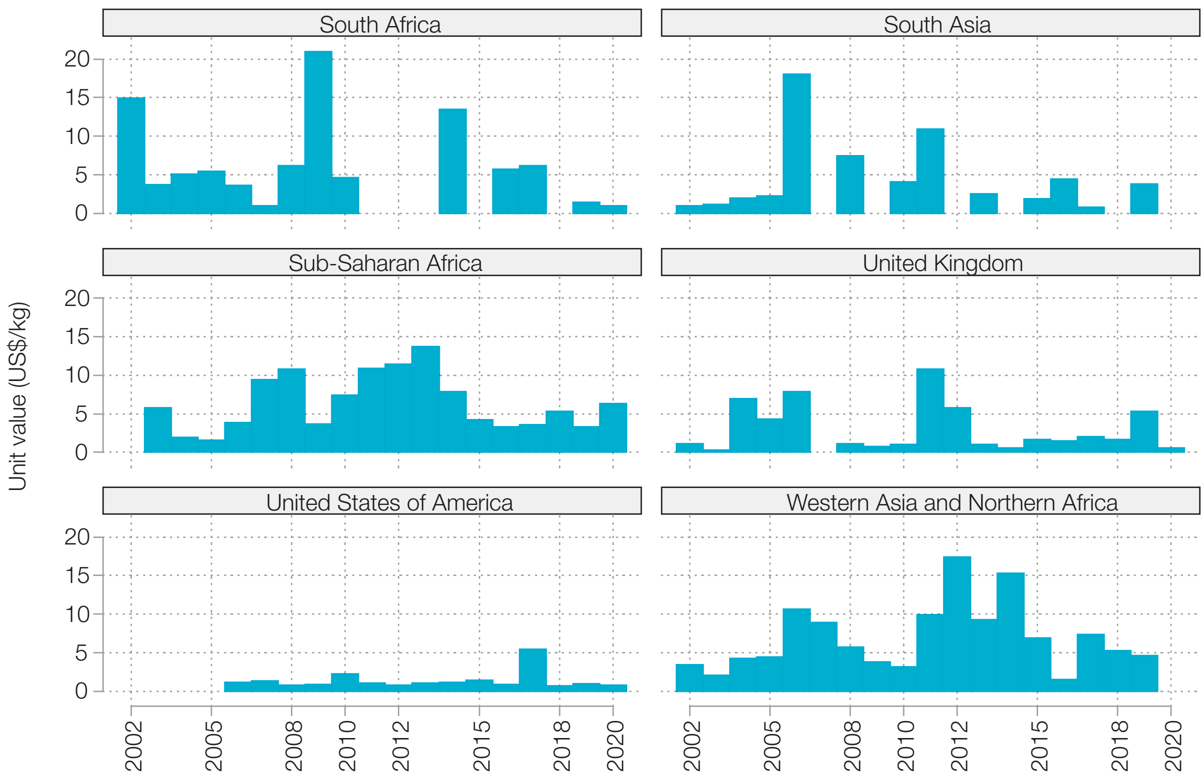
Concerning raw or retted hemp, the lowest import unit values were observed in the Canadian and United States markets (figure 19 (a)) during the whole period under consideration. Unit values of imports into the European Union market evolved following an inverted U-shape trajectory, with a rebound in 2019 and 2020. The unit value of imports from China collapsed after 2017 due to the interruption of exports from countries with the highest unit values, such as the Netherlands. New partners emerged in 2018 and 2019, which had relatively low unit values.

Figure 19 Import unit values by HS product and by country/regions, 2002–2020
(Unites States dollars/kg)

(a) Raw or ratted (HS 5302.10)

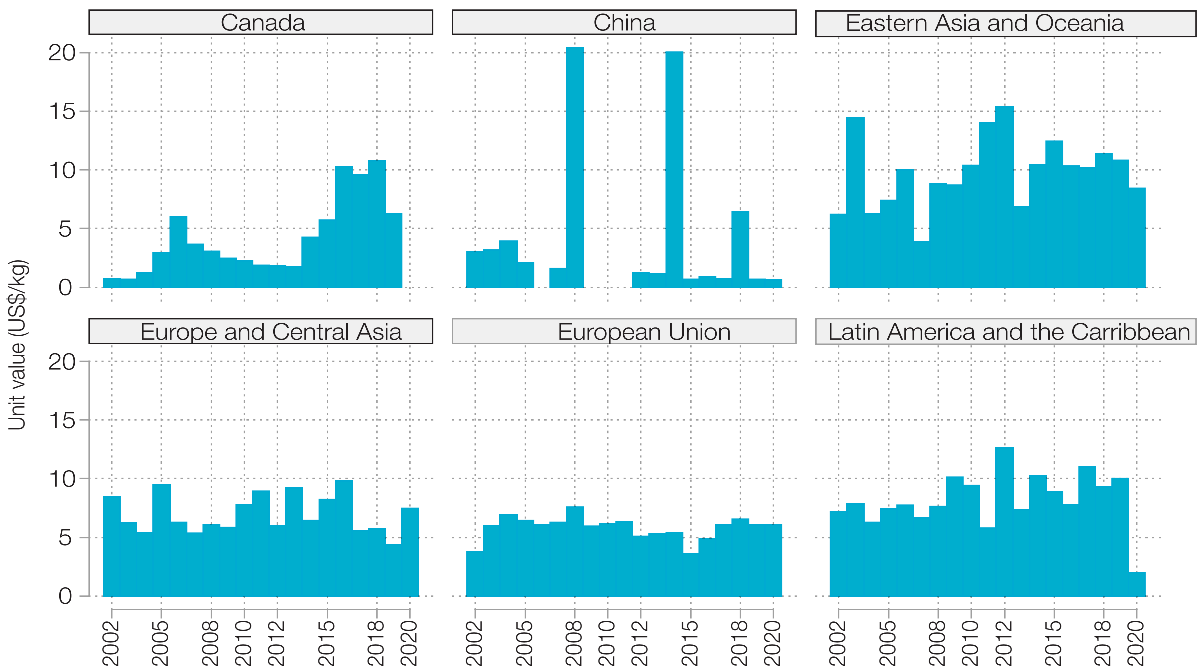


(a) Raw or ratted (HS 5302.10)

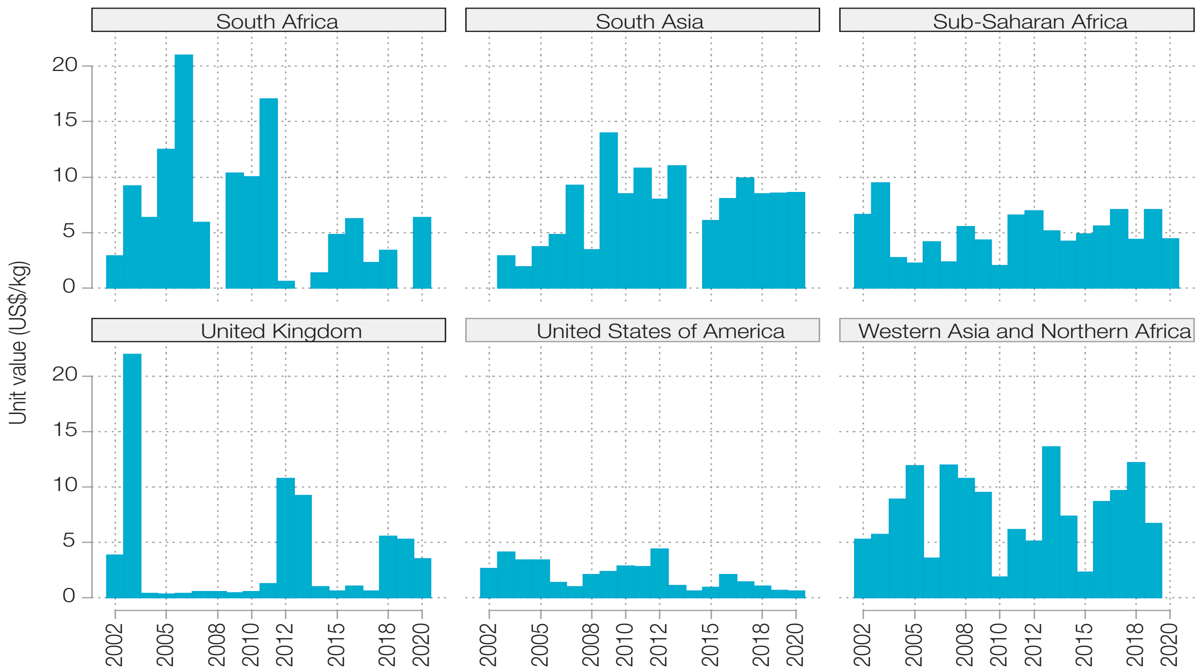


A similar analysis, both from a quantitative and qualitative point of view, applies to semi-processed hemp, with a major difference in unit values observed in Canada that were comparable to levels observed for the European Union (figure 19, panel (b)).

(b) Semi-processed (HS 5302.90)

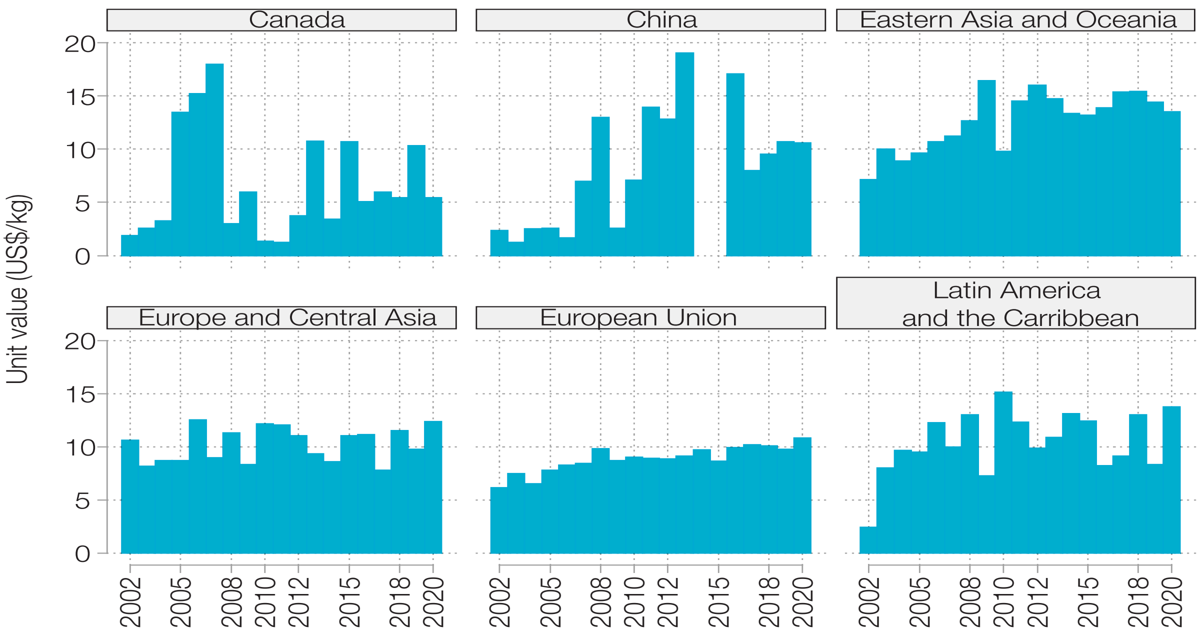


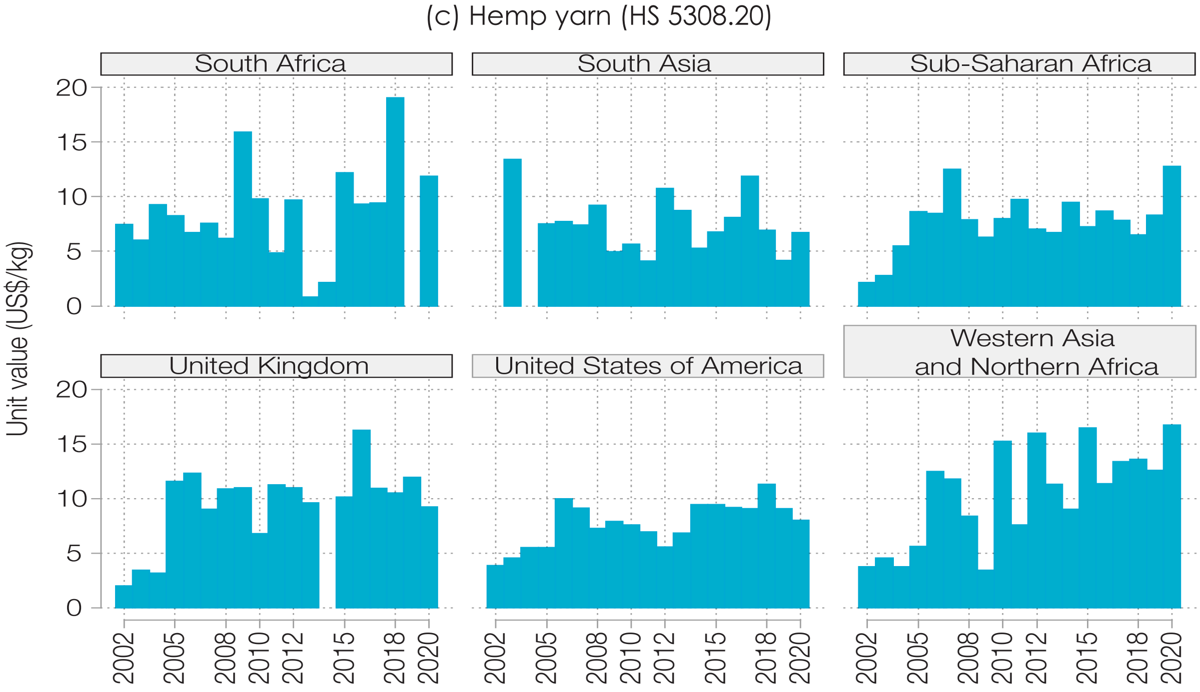
(b) Semi-processed (HS 5302.90)



The unit values of hemp yarn computed for the different markets were higher than those obtained for the previous two products, reflecting earlier findings (figure 19, panel (c)). There was also less variability across both time and markets, suggesting that hemp yarn may be considered a more homogeneous product. The Canadian and South Asian markets displayed the lowest unit values. Only the European Union market showed an upward trend in unit values between 2002 and 2020. In other markets the evolution was more contrasted, even though a slight upward trend can be identified for markets in the East Asia and Pacific region, and in the Middle East and North Africa region.

(c) Hemp yarn (HS 5308.20)

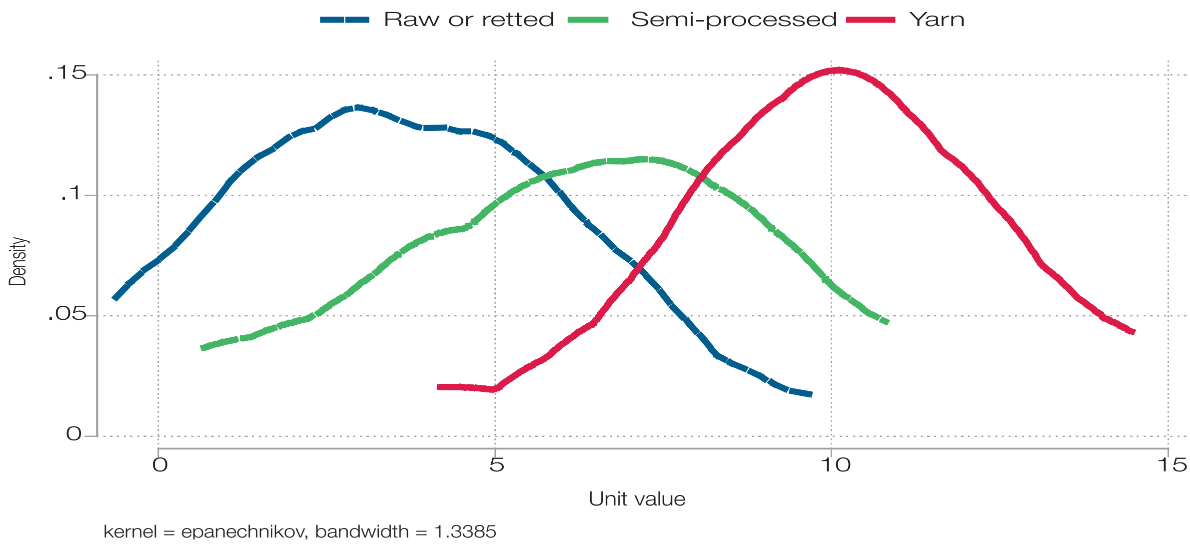




Source: Authors' calculations based on UN Comtrade in WITS.

The variation in unit values is illustrated in figure 20. The reference year is 2019 to avoid any possible contamination from the COVID-19 shock, even though no clear pattern has emerged from the data shown so far. The three distribution curves represented confirm the escalation in unit values. More processed products were characterized by relatively higher average prices located around the hump of each curve. There were also substantial differences between the two least processed products, possibly indicating a high degree of variation within each product group. This may be due to either differences in quality or distinctive characteristics of products sharing the same HS category.

Figure 20 Distribution of country import unit values by HS product, 2019
(Unites States dollars/kg)



Source: Authors, based on UN Comtrade in WITS.

5.2 FAO PRICES

Information compiled by the FAO is relatively sparse. As mentioned previously, its country coverage is extremely limited, and the last year for which information is available is 2018. Major markets such as the European Union are not covered. Information was made comparable across markets by normalizing price series taking a three-year country average as the reference value.

For hemp fibres, the evolution of prices slightly differed across countries. It took a sinusoidal shape in Hungary, with a decreasing tendency that started in 2015. In the Russian Federation, after a 15-year period characterized by an increase of about 400 per cent, prices dropped significantly between 2015 and 2017, only to rise again sharply in 2018.

Prices in Ukraine showed an exponential pattern, rising from an index value of 25 in 2000 to a value of 156 in 2018 – an increase of 525 per cent in less than two decades. Hemp seed prices followed a trajectory similar to that of hemp fibres in both the Russian Federation and Ukraine. In China, prices more than doubled between 2000 and 2015, and thereafter remained somewhat constant. All in all, the Ukrainian market for hemp raw products and seeds appears to have been the most dynamic between 2000 and 2018.

5.3 OTHER PRICES

Other databases listing prices are more specific in terms of either the reference geographical unit or the product considered, or both. Moreover, they are often produced by private entities, non-governmental organizations, or producer associations (regional, national or subnational). The fact that price information, even for major hemp products, is still scarce and scattered does not allow the definition of a precise reference price, either at the national or international level.

The recent evolution of regulations in several countries, and especially the adoption of the 2018 Farm Bill in the United States – which legalized hemp – sparked producers' and investors' interest in CBD hemp production because of its significant economic potential. Consequently, information about CBD-related products has also been generated in recent years. Table 6 reports some of these data, though the reference period varies depending on availability of the relevant data.

Data providers are essentially private entities selling their information to producers and potential investors. As shown in table 6 there is a high degree of variability for similar products across trading platforms. This points to possible differences in the quality of some hemp products, which renders any direct comparisons difficult. As long as markets for hemp products are not closely integrated and information at least partially centralized, prices will not be fully comparable.

Despite high variability across data sources, some general trends have recently emerged in CBD hemp markets.[97] With the passage of the United States Farm Bill in December 2018, the United States has now gone from being the world's biggest importer of CBD to being the leading global exporter. This development has had dramatic effects on the nascent CBD sector in the United States. There has been a sharp drop in prices due to overproduction of hemp-derived CBD-containing products that are in storage and without buyers, particularly since the overheating of the market in late 2019 and early 2020 in the United States. This drop in prices rapidly spread to the European market, causing some rationalization in production, with the weakest growers forced to either drop out or switch to producing other crops.

[97] See, for instance, https://www.hempbenchmarks.com/hemp-market-insider/hemp-industry-2021-review/.

Table 6 CBD hemp products: Prices, selected data sources and periods

	Data Sources				
	Hempbenchmarks.com	Kush.com	Whatishemp.com	Cannyx Markets	Canxchange.eu
Reference Market	United States	United States	United States	United States	European Union
Period	June 2020	Nov 2019-May2020	June 2020	Nov. 2021	Nov. 2021
Crude CBD Hemp Oil	$339/kg	--	$1,737 US$/kg	--	$931/kg
Refined CBD Hemp Oil	$1,549/kg	$9,520/kg	$4,973/kg	--	--
CBD “Biomass” (various parts)	$1.54 per percentage point of CBD/kg	$15–88/kg	$7 per percentage point of CBD/kg	$3.53 per percentage point of CBD/kg	$3.3 per percentage point of CBD/kg
CBD flower (bulk)	$318/kg	--	$802/kg	--	$640/kg(o), $795/kg(i), $1,020/kg(g) *
CBD isolate	$1,964/kg	--	--	$1 200/kg	$952/kg
CBD distillate	--	$1,360/kg	--	$3 300/kg	--
Seeds (non-cultivation)	$7.25/kg	--	$24/kg	--	$1.32/kg
Seeds (cultivation)	--	$1,274/kg	--	--	--

Note: Hempbenchmarks.com and Whatishemp.com information is based on average wholesale prices observed on different trading markets. Other sources are trading platforms operating principally either in the United States or the European Union.
All data have been converted into $ per kg and expressed in per kilogram units.
* (o) = outdoors (i) = indoors, (g) = greenhouse.
The price of the CBD-rich industrial hemp flower (bulk) is usually based on dollars per (percentage) point of CBD oil per pound.

CHAPTER VI

Policy recommendations

The global hemp market, by value, is projected to grow fourfold in the coming years, from $4.7 billion in 2020 to $18.6 billion by 2027 (Krungsri Research Intelligence, 2021).

As described in chapter 2, evolving legislations at the national, regional and international levels may provide new market and new products opportunities for agricultural producers around the world, and particularly in developing countries, including commodity-dependent developing countries.

Hemp value chains can boost growth in rural areas and contribute to both manufacturing and food-processing industries. However, to fully exploit such potentialities, countries may have to take specific actions. A clarification of the legal status of hemp with respect to that of intoxicant cannabis substances would be the first step needed by governments. This would help minimize financial risks for domestic producers associated with possible legal actions. A precise understanding of production constraints imposed by regulatory frameworks in potential destination markets would also be necessary in order to identify opportunities. In addition, regional cooperation may be a strategy for developing countries with a view to establishing viable and sustainable value chains.

Four policy areas deserve particular attention: information, a regulatory framework, sustainability and industrial strategy, as discussed below.

6.1 INFORMATION

At the international level, there is a clear need to improve availability and accessibility of information. Public data about hemp production are limited to standard products (i.e. mainly fibre and seeds), and country coverage remains incomplete. Efforts should be devoted to improving the current state of information about all aspects of this commodity. Hemp cultivated for cannabinoids (other than THC) should be explicitly identified, and its production estimated. Compounds such as CBD have never been classified as narcotic drugs, psychotropic substances, or precursors in any international treaty concluded under the auspices of the UNODC (C-61, C-71 and C-88). International trade statistics provide an even narrower product coverage, as only raw hemp, hemp fibres and yarn of hemp are included in international product classifications such as the HS or SITC nomenclatures. Therefore, as a first important and urgent step, additional categories need to be included to cover, for instance, hemp seeds, hemp seed oil, hemp seed products, hemp oleoresins and essential oils. Country-specific classifications can be used to define such categories, as discussed in chapters 2 and 3. The most comprehensive product schedule, so far, has been implemented by Canada, and may offer a useful benchmark for further development of international classifications.

Public information also lacks adequate coverage of the price dimension. FAO country and product coverage remains extremely narrow, and as noted above, unit values computed using trade information are not necessarily reliable. Some additional resources need to be devoted to the systematic collection and systemic treatment of such information by international organizations in the context of a coordinated action plan.

6.2 REGULATORY FRAMEWORK

The distinction between intoxicant and non-intoxicant hemp cultivars is still subject to controversy in most political arenas at all levels: country, regional and international. Arguments on both sides are often not corroborated by existing empirical evidence and scientific knowledge. Therefore, legislations in vigour in most countries, even the most permissive ones, do not allow a full exploitation of the hemp plant's potential in its many uses, as discussed in chapters 2 and 3.

Cultivation of non-intoxicant *C. sativa* L. cultivars should be permitted in all countries even though it may require strict governmental control. Moreover, an approach favouring THC threshold in final products, rather than in the field, should be adopted to incentivize a whole-plant approach and uses. THC levels can be easily modified in semi-processed inputs, whereas the control of THC contents in cultivated plants can require a large set of agronomic techniques and competences.

Alternatively, raising the THC thresholds in crops up to levels scientifically recognized as non-intoxicant could be envisaged by legislators. This would allow increasing the pool of varieties useable in hemp production chains, thus de facto increasing the possibility to cultivate cultivars best adapted to specific environmental conditions and characteristics. Indeed, field studies have shown that THC thresholds in crops are climate-sensitive, especially in countries in inter-tropical areas (e.g. Wimalasiri et al.,2021; Baldini et al., 2020)).

Regulatory reform may also help contain the trafficking of illegal *Cannabis* products, as discussed in UNODC (2021) with reference to the decline in seizures in North America.

6.3 SUSTAINABILITY

Several dimensions of sustainability can be considered in relation to hemp.[98] The environmental and societal dimensions involved the plant's exploitation, and their interconnections are core to the success of any hemp-related policy.[99] For instance, the development and implementation of hemp-related laws, regulations and practices should thus take into account this multidimensionality in order to ensure a sustainable hemp sector globally (Riboulet-Zemouli, 2021).

The focus should then be on issues of access to, and utilization of, natural resources and associated knowledge. It would also be necessary to consider the threat to development and future trade posed by biopiracy or unsustainable bioprospecting and intellectual property rights practices. This could represent a threat to the control of national heritage and natural resources in countries where there is a traditional use (and therefore knowledge) of local endemic plant varieties (Duvall, 2016; Wyse and Luria, 2021).

As discussed in chapter 2, *C. sativa* L. is a multipurpose plant that offers several agricultural benefits such as soil and water decontamination, and CO2 absorption (Pervaiz and Sain, 2003). In terms of CO2 absorption, hemp can be more efficient than any other crop, even trees. Vosper (2011) estimates that about 1.65 tons of CO2 can be absorbed per ton of hemp. On a land-use basis, assuming a yield average of 5.5 to 8 tons/ha, this can represent between 9 and 13 tons of CO2 absorption per hectare harvested. In comparison, forests typically capture between 4.5 tons/ha (i.e. conifer forests in boreal regions) and 40.7 tons/ha (i.e. eucalyptus forests in humid zones) of CO2 per year during the first 20 years of tree growth.[100]

Moreover, hemp farming requires very low or no inputs, and has a positive effect on soil and biodiversity, while its processing produces zero waste, as all parts of the plant can be used or further transformed, depending on prevailing legislation. In other words, hemp farming can offer environmental benefits that can be considered in policies aimed at mitigating the effects of climate change and restoring healthy ecosystems. Moreover, as hemp cultivation may help concretely to maximize the use of land, it may also contribute to increasing incomes of farmers and rural communities.[101]

98 Because "not all commercial use of biological resources is sustainable," UNCTAD developed the following seven BioTrade Principles: Conservation of biodiversity; Sustainable use of biodiversity; Fair and equitable sharing of benefits derived from the use of biodiversity; Socio-economic sustainability (productive, financial and market management); Compliance with national and international regulations; Respect for the rights of actors involved in bioTrade activities; Clarity about land tenure, use and access to natural resources and knowledge.

99 See Riboulet-Zemouli et al. (2019) and Riboulet-Zemouli (2021) for a detailed discussion.

100 See https://winrock.org/flr-calculator/ for details.

101 See Mirizzi and Wilson (2018) for an extensive discussion in the European Union context.

6.4 INDUSTRIAL POLICY

Due to its versatility, given the possibility to use all parts of the plant, hemp appears to be a natural candidate for the establishment of national or regional value chains. The diversity of products that can be made using various parts of the hemp plant, and the differences in the degree of sophistication of their respective production processes, as discussed in chapters 2 and 3, are potentially attractive features. Moreover, hemp cultivation could be further monetized by integrating some carbon compensation schemes on a voluntary basis.

Diversity in final uses also implies flexibility in setting up a sectoral policy framework. Owing to its botanical characteristics, a whole-plant approach should be considered as a first-best strategy in most parts of the world.[102] This is all the more desirable because of the still relatively small size of hemp markets and the economic constraints inherent in such markets, as discussed in chapter 4. A whole-plant approach allows the identification of both primary and secondary markets. An appropriate strategy would first consider the development of production processes that are easily transferable to reduce the risk of low returns due to negative market developments such as oversupply. A whole-plant approach could only be implemented if a conducive regulatory framework is in place. This implies that, initially, some legal reform may need to be considered.

Policy actions may then be identified and acted upon to help select the best cultivation strategy that facilitates the choice of cultivars and the cultivation method. Such choices would be driven by the main final use that is targeted. For instance, from an environmental point of view, outdoor cultivation should be the norm for non-medical uses of *Cannabis*. As discussed in chapters 4 and 5, there is currently strong demand for hemp oils for use in cosmetics and personal care products, hemp seeds for human consumption as a “super food”, and CBD oil for therapeutic use.

However, those markets are possibly in a situation of oversupply, implying high price volatility (as discussed in chapter 5) and a large turnover of producers. The development of hempcrete production chains may be a reasonable profitable and sustainable target. Hempcrete could be easily adopted in urban development plans in most developing countries due to its low cost of production within a local hemp value chain and its large set of environmental benefits. Due to the plant’s characteristics, the policy plan of action should be, in most cases, based on a local network of operators, capable of providing the harvest and first processing, globally connected to a community having the necessary technology and knowledge.

As discussed in chapter 4, regional cooperation could also be envisaged with a view to adding value to raw hemp materials as well as strategically organizing access to international markets that are often constrained by NTMs. As discussed in UNCTAD (2021), hemp production and processing in Malawi and South Africa (Lowitt, 2020; Alcock, 2015) are good examples of such cooperation. While Malawi, which has recently legalized industrial hemp production, has a clear comparative advantage in production, South Africa has excess and unused capacity in almost all downstream processing activities. In areas where existing capacity does not exist, South Africa has an intensive research and development (R&D) and technology development programme under way for numerous industrial and consumer products based on industrial hemp inputs. The value chain complementarity between Malawi and South Africa is de facto strong. Moreover, as both these countries are members of the Southern African Development Community (SADC), the establishment of an intraregional production and supply chain could be facilitated.

As discussed in chapters 3 and 4, the definition and adoption of quality standards may ease access to international markets, on the one hand, and promote the production of quality products, even for domestic markets, on the other. Appellations of origin and geographical indicators could help promote further use of endemic hemp varieties, especially those from developing countries where traditional farming, knowledge and *Cannabis* plant biodiversity are “at risk of cultural and genetic erosion” (Chouvy, 2022). This would also

[102] See Wimalasiri et al. (2021) for a detailed discussion in the context of tropical areas.

align with boosting sustainable rural development and environmental policies.

A properly framed industrial policy could also be implemented to formalize existing informal hemp production and trade. This would have a potentially positive impact on social sustainability. As mentioned in chapter 4, because informal trade has been regularly associated with illicit *Cannabis* trade for many decades, the transition to the licit hemp sector of farmers and other actors involved in informal cultivation and trade activities deserves specific attention (Riboulet-Zemouli, 2021). A continued reliance on alternative development programmes, including the replacement of drug crops by licit crops (see Alimi, 2018; Brombacher and David, 2020; Jelsma et al., 2021) to favour a transition to the licit market and good cultivation practices, should be prioritized. As mentioned in chapter 4, women have played a prominent role in traditional illicit *Cannabis* and hemp cultivation, both in its harvesting and processing (Afsahi and Darwish, 2016; Afsahi, 2015; Kay et al., 2020; Clarke 2007, 2010). This points to the need for policy approaches that are sensitive to gender issues and to the specific needs of women and vulnerable groups.[103] Industrial policies aimed at formalizing informal activities may consider the creation of cooperatives that would group all small, informal producers.

[103] See UNCTAD's Borderline project at https://unctad.org/project/informal-cross-border-trade-empowerment-women-economic-development-and-regional-integration.

References

Adamovics A and Zeverte-Rivza S (2015). Productivity and risk assessment in hemp production. Proceedings of the Nordic View to Sustainable Rural Development Congress 2015.

Adams R, Hunt M and Clark JH (1940). Structure of cannabidiol, a product isolated from the marihuana extract of Minnesota wild hemp. *Journal of the American Chemical Society.* 62: 196–200.

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

Afsahi K (2015). Pas de culture de cannabis sans les femmes : Le cas du Rif au Maroc. *Déviance et Société*. 39: 73–97.

Afsahi K and Darwich S (2016). Hashish in Morocco and Lebanon: A comparative study. *International Journal of Drug Policy.* 31:190–198.

Ahmad R, Tehsin Z, Malik ST, Asad SA, Shahzad M, Bilal M, Shah MM and Khan SA (2016). Phytoremediation potential of hemp (*Cannabis sativa* L.): Identification and characterization of heavy metals responsive genes. *Clean Soil Air Water.* 44: 195–201.

Alcock GG (2015). KasiNomics: African Informal Economies and the People who Inhabit Them. Tracey McDonald Publishers. Gauteng.

Alimi D (2018). Drogues et développement: vers de nouvelles perspectives? *Drogues Enjeux Internationaux*. 11. Available at https://www.ofdt.fr/index.php?cID=1055.

Amaducci S, Scordia D, Liu FH, Zhang Q, Guod H, Testa G and Cosentino SL (2015). Key cultivation techniques for hemp in Europe and China. *Industrial Crops and Products Review*. 68: 2–16.

Amaducci S, Colauzzi M, Bellocchi G, Cosentino SL, Pahkala K, Stomph T, Westerhuis W, Zatta A and Venturi G (2012). Evaluation of a phenological model for strategic decisions for hemp (*Cannabis Sativa* L.) biomass production across European sites. *Industrial Crops Production*. 37: 100–110.

Amaducci S, Pelatti F and Bonatti PM (2005). Fibre development in hemp, (*Cannabis sativa* L.) as affected by agrotechnique: Preliminary results of a microscopic study. *Journal of Industrial Hemp.* 10: 31–48.

Amaducci S and Gusovius HJ (2010). Hemp-cultivation, extraction and processing. In: Müssig J, ed. *Industrial Applications of Natural Fibres: Structure, Properties and Technical Applications*. John Wiley & Sons Ltd. Hoboken: 109-134.

Andre CM, Hausman J-F and Guerriero G (2016). *Cannabis sativa*: The plant of the thousand and one molecules. *Frontiers in Plant Science*. 7.

Andreae MO, Merlet P (2001). Emission of trace gases and aerosols from biomass burning. *Global Biogeochemical Cycles*. 15: 955–966.

Appendino G, Gibbons S, Giana A, Pagani A, Grassi G, Stavri M, Smith E and Rahman MM (2008). Antibacterial cannabinoids from Cannabis sativa: A structure-activity study. *Journal of Natural Products*. 71(8):1427-30.

Baldini M, Ferfuia C, Zuliani F, Danuso F (2020). Suitability assessment of different hemp (*Cannabis sativa* L.) varieties to the cultivation environment. *Industrial Crops and Products.* 43:111860.

Berenji J, Sikora V, Fournier G, Beherec O, Bouloc P, Allegret S and Arnaud L (2013). Genetics and selection of hemp. In: Bouloc P, ed. *Hemp: industrial production and uses*. CABI Publishing. :48-71.

Borhade S (2013). Chemical composition and characterization of hemp (cannabis sativa) seed oil and essential fatty acids by HPLC method. *Archives of Applied Science Research*. 5(1):5–8.

Bouloc P (2013). *Hemp: Industrial Production and Uses*. CABI Publishing. London.

Brightfield Group (2021). *US CBD Market Industry Update*. Brightfield Group. Chicago.

Brombacher D and David S (2020). From alternative development to development-oriented drug policies. *International Development Policy*. 12:64–78. Available at https://library.oapen.org/bitstream/handle/20.500.12657/42548/9789004440494.pdf?sequence=1#page=87.

Callaway JC (2004). Hempseed as a nutritional resource: An overview. *Euphytica*. 140:65–72.

Canxchange (2021). *November Benchmark Report*. Canxchange Ltd. London.

CBA (Consumers Brands Association) (2019). The Urgent Need for CBD Clarity: How confusion and lack of regulation threaten consumer safety and trust. Available at https://consumerbrandsassociation.org/wp-content/uploads/2019/11/ConsumerBrands_CBD_Clarity.pdf.

Cherrett N, Barrett J, Clemett A, Chadwick M and Chadwick MJ (2005). *Ecological Footprint and Water Analysis of Cotton, Hemp and Polyester*. Report prepared for and reviewed by BioRegional Development Group and World Wide Fund for Nature – Cymru. Stockholm Environment Institute.

Chouvy PA (2022). Why the concept of terroir matters for drug cannabis production. *GeoJournal*. See https://link.springer.com/article/10.1007/s10708-022-10591-x.

Clarke RC (2007). Traditional cannabis cultivation in Darchula District, Nepal – Seed, resin and textiles. *Journal of Industrial Hemp*. 12(2): 19-42.

Clarke RC (2010). Traditional fiber hemp (Cannabis) production, processing, yarn making, and weaving strategies—Functional constraints and regional responses. *Journal of Natural Fibers*. 7(2):118–153.

Clarke RC and Merlin MD (2013). *Cannabis – Evolution and Ethnobotany*. Meise Botanic Garden and Royal Botanical Society of Belgium.

Clarke RC and Merlin MD (2015). Evolution and classification of Cannabis sativa (marijuana, hemp) in relation to human utilization. *Botanical Review*. 81(3): 189–294.

Darby H (2019). Industrial hemp for flower production: A guide to basic techniques. Northwest Crops and Soils Program, Cooperative Extension, The University of Vermont. Available at https://www.uvm.edu/extension/nwcrops/industrial-hemp.

Deferne JL and Pate DW (1996). Hemp seed oil: A source of valuable essential fatty acids. *Journal International Hemp Association*. 3(1): 1–7.

De Meijer EPM, (1994). Variation of Cannabis with reference to stem quality for paper pulp production. *Industrial Crops Production.* 3:201–211.

De Meijer EPM and Van der Werf HMG (1994). Evaluation of current methods to estimate pulp yield of hemp. *Industrial Crops Production*. 2:111–120.

Duvall CS, (2016). Drug laws, bioprospecting and the agricultural heritage of Cannabis in Africa. *Space and Polity*. 20(1):10–25.

Eurostat (2020). *InteMsterdamgrated Farm Statistics Manual*. The European Union. Brussels.

FAO (2013). Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rome.

FAO (2017). The Future of Food and Agriculture – Trends and Challenges. Rome.

Farag S and Kayser O (2017). The Cannabis plant: Botanical aspects. In: Preedy VR, ed. *Handbook of Cannabis and Related Pathologies*. Academic Press. San Diego: 3-12.

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

Fleming M P and Clarke R C. (1998). Physical evidence for the antiquity of *Cannabis sativa* L. (Cannabaceae). *Journal of the International Hemp Association*. 5(2): 80-92.

Furr M and Mahlberg P (1981). Histochemical analysis of laticifers and glandular trichomes in Cannabis saliva L. (Cannabaceae). *Journal of Natural Products*. 44: 153–159.

Gaoni Y and Mechoulam R (1964). Isolation, structure, and partial synthesis of an active constituent of hashish. *Journal of the American Chemical Society*. 86(8):1646–1647.

Garcia I and Duran V (2022). Current Applications, Approaches and Potential Perspectives for Hemp Crop Management, Industrial Usages, and Functional Purposes. Elsevier. Amsterdam.

Gorch G, Lloveras J, Serrano L and Cela S (2017). Hemp yields and its rotation effects on wheat under rainfed Mediterranean conditions. *Agronomy*. 109(4): 1551–1560.

Grand View Research (2021). *Cannabidiol Market Growth Analysis Report 2021 –2028*. Available at https://www.grandviewresearch.com/industry-analysis/cannabidiol-cbd-market/toc.

Hall J, Bhattarai SP and Midmore DJ (2012). Review of flowering control in industrial hemp. *Journal of Natural Fibers*. 9(1): 23–36.

Hillig KW and Mahlberg PG (2004). A chemotaxonomic analysis of cannabinoid variation in *Cannabis* (Cannabaceae). *American Journal of Botany*. 91(6): 966–975.

Höppner F and Menge-Hartmann U (2007). Yield and quality of fibre and oil of fourteen hemp cultivars in Northern Germany at two harvest dates. *Landbauforsch Volk*. 57:219–232.

INCB (2019). *Report of the International Narcotics Control Board*. E/INCB/2019/1 (United Nations publication Sales No. E.20.XI.4). Available at https://www.incb.org/incb/en/publications/annual-reports/annual-report-2019.html.

Jarman CG, Canning AJ and Mykoluk S (1978). Cultivation, extraction and processing of ramie fibre: A review. *Tropical Science*. 20(1):91–116.

Jelsma M, Blickman T, Kay S, Metaal P, Martínez N and Putri D (2021). A Sustainable Future for Cannabis Farmers: 'Alternative Development' Opportunities in the Legal Cannabis Market. Transnational Institute, Amsterdam.

Johnson R (2018). Hemp as an agricultural commodity. CRS Report RL32725. Congressional Research Service. Available at https://fas.org/sgp/crs/misc/RL32725.pdf.

Kaiser C, Cassady C and Ernst M (2015). Industrial Hemp Production. *Center for Crop Diversification Crop Profile*. University of Kentucky. www.uky.edu.ccd/files/hempproduction.pdf

Kay S, Jelsma M and Bewley-Taylor D (2020). Fair Trade cannabis: A road map for meeting the socio-economic needs and interests of small and traditional growers. *Journal of Fair Trade*. 2(1): 27–34.

Keller A, Leupin M, Mediavilla V, Wintermantel E (2001). Influence of the growth stage of industrial hemp on chemical and physical properties of the fibres. *Industrial Crops and Products.* 13(1): 35–48.

Kessler RW, Becker U, Kohler R and Goth B (1998). Steam explosion of flax – A superior technique for upgrading fibre value. *Biomass and Bioenergy.* 14(3): 237–249.

Kok CJ, Coenen GCM and de Heij A (1994). The effect of fibre hemp (*Cannabis sativa* L.) on selected soilborne pathogens. *Journal of the International Hemp Association*. 1:6–9.

Kolodinsky J, Lacasse H and Gallagher K (2020). Making hemp choices: Evidence from Vermont. *Sustainability*. 12(15): 6287.

Kornpointner C, Sainz Martinez A, Marinovic S, Haselmair-Gosch C, Jamnik P, Schröder K, Löfked C and Halbwirth H (2021). Chemical composition and antioxidant potential of *Cannabis sativa* L. roots. *Industrial Crops and Products*.165: 113422.

Kozma, L (2011a). The League of Nations and the debate over cannabis prohibition. History Compass. 9(1):61-70.

Kozma, L (2011b). Cannabis Prohibition in Egypt, 1880–1939: From local ban to League of Nations Diplomacy. *Middle Eastern Studies*. 47(3):443–460.

Krawitz, MA (2018). The importance of appellations of origin to the successful therapeutic model of whole plant cannabis. Appellations paper submitted to the WHO by a coalition of Civil Society

Organizations: Veterans for Medical Cannabis Access, Mendocino Appellations Project, International Cannabis Farmers Association, and FAAAT think & do tank. Geneva. Available at https://www.icfa.farm/the_importance_of_appellations_of_origin_to_the_successful_therapeutic_model_of_whole_plant_cannabis_follow_up_on_civil_society_cannabis

Krejčí Z, Šantavý F (1955). Isolace dalších làtek z listí indického konopí *Cannabis sativa* L. (Isolation of other substances from the leaves of the Indian Hemp Cannabis sativa L). *Acta Univ. Olomuc. Fac. Med.* 6: 59–66.

Krungsri Research Intelligence (2021). Hemp: A new cash crop that brings both challenges and opportunities. Bank of Ayudhya Public Company Limited. Bangkok. Available at https://www.krungsri.com/en/research/research-intelligence/hemp-2021.

Kumar S, Singh R, Kumar V, Rani A and Jain R (2017). Cannabis sativa: A plant suitable for phytoremediation and bioenergy production. In: Bauddh K, Singh B and Korstad J, eds. *Phytoremediation Potential of Bioenergy Plants.* Springer. Singapore: 269-285.

Larsson M and Lagerås P (2015). New evidence on the introduction, cultivation and processing of hemp (*Cannabis sativa* L.) in southern Sweden. *Environmental Archaeology.* 20(2):111-119.

Laudati AA (2014). Out of the shadows: Negotiations and networks in the cannabis trade in Eastern Democratic Republic of Congo. In: Klantschnig G, Carrier N and Ambler C, eds. *Drugs in Africa.* Palgrave Macmillan. New York: 161–181.

Liu S, Ge L, Gao S, Zhuang L, Zhu Z and Wang H (2017). Activated carbon derived from bio-waste hemp hurd and retted hemp hurd for CO2 adsorption. *Composites Communications*. 5:27-30.

Leggett T (2006). A review of the world cannabis situation. *Bulletin on Narcotics*. 58:1–3.

Lehmann J, Gaunt J and Rondon M (2006). Bio-char sequestration in terrestrial ecosystems:A review. *Mitigation and Adaptation Strategies for Global Change.* 11(2):395–419.

Leinwand MA (1971). The International Law of Treaties and United States legalization of marijuana. *Columbia Journal of Transnational Law.* 10(2):413–441.

Leupin M (1998). Enzymatic degumming trough alkalophilic microorganisms: A new approach for bast fibre processing. Institute of Natural Fibres, Poznan.

Lowitt S (2020). Initial considerations for the creation of an inter-regional industrial hemp value chain between Malawi and South Africa. *UN-WIDER Working Paper* 2020/23.

Mandolino G and Ranalli P (1998). Advances in biotechnological approaches for hemp breeding and industry. In: Ranalli P, ed. *Advances in hemp research*. Food Products Press (of Haworth Press), New York: 185-212.

McAllister WB (2000). *Drug Diplomacy in the Twentieth Century*. Routledge. New York.

Mechoulam R and Shvo Y (1963). The structure of cannabidiol. *Tetrahedron*. 19(12):2073–2078.

Mechoulam R and Den-Shabat S (1999). From gan-zi-gun-nu to anandamide and 2-arachidonoylglycerol: The ongoing story of cannabis. *Natural Products Reports.* 16:131–143.

Mechoulam R and Hanus L (2000). A historical overview of chemical research on cannabinoids. *Chemistry and Physics of Lipids*. 108(1–2) :1–13.

Mediavilla V, Leupin M and Keller A (2001). Influence of the growth stage of industrial hemp on the yield formation in relation to certain fibre quality traits. *Industrial Crops Production.* 13: 49–56.

Mills JH (2003). Cannabis Britannica, Empire, trade, and prohibition. Oxford University Press: Oxford.

Mills E (2012). The carbon footprint of indoor Cannabis production. *Energy Policy*. 46:58–67.

Mills JH (2016). The IHO as actor: The case of cannabis and the Single Convention on Narcotic Drugs 1961. *Hygiea Internationalis*. 13(1):95–115.

Mirizzi F and Wilson C (2018). Hemp: A real green deal. European Industry Hemp Association. Brussels. Available at https://eiha.org/documents/general.

Mirizzi F and Jablonski T (2020). Hemp in China: New big in the new normal? European Industry Hemp Association. Brussels. Available at https://www.linkedin.com/pulse/hemp-china-new-big-normal-francesco-mirizzi.

Moliterni VMC, Cattivelli L, Ranalli P and Mandolino G (2004). The sexual differentiation of *Cannabis sativa* L.: A morphological and molecular study. *Euphytica*. 140:95–106.

MultiHemp (2017). Multipurpose hemp for industrial bioproducts and biomass (Final summary). Available at http://Multihemp.eu.

New Frontier (2018.) The Cannabis Energy Report: The Current and Evolving State of Cannabis Energy Consumption. New Frontier Data. Washington, D.C.

Nutt D, King LA and Saulsbury W (2007). Development of a rational scale to assess the harm of drugs of potential misuse. *The Lancet*. 369(9566):1047-–1053.

McPartland JM (2018). Cannabis systematics at the level of family, genus, and species. *Cannabis and Cannabinoid Research*. 3(1):203–212.

McPartland JM, Geoffrey W G and Hegman W (2018). Cannabis is indigenous to Europe and cultivation began during the Copper or Bronze Age: a probabilistic synthesis of fossil pollen studies. *Vegetation History and Archeobotany*. 27:635–648.

Pacifico D, Miselli F, Carboni A, Moschella A and Mandolino G (2008). Time course of cannabinoid accumulation and chemotype development during the growth of *Cannabis sativa* L. *Euphytica*. 160:231–240.

Pavlovic R, Nenna G, Calvi L, Panseri S, Borgonovo G, Giupponi L, Cannazza G and Giorgi A (2018). Quality traits of "cannabidiol oils": Cannabinoids content, terpene fingerprint and oxidation stability of European commercially available preparations. *Molecules*. 23(5):1230.

Pervaiz M and Sain MM (2003). Carbon storage potential in natural fiber composites. *Resources, Conservation and Recycling*. 39(4):325–340.

Plamondon J (2021). Precision fermented cannabinoids: Disrupting cannabis extracts – Cannabinoids made by precision fermentation pose an existential threat to much of the cannabis farming & processing industry. *Cannabis Law Journal*. September – November 2021. Available at https://journal.cannabislaw.report/jim-plamondon-precision-fermented-cannabinoids-disrupting-cannabis-extracts-cannabinoids-made-by-precision-fermentation-pose-an-existential-threat-to-much-of-the-cannabis-farming-processing-indu/

Polio A (2016). The name of Cannabis: A short guide for nonbotanists. *Cannabis and Cannabinoid Research.* 1(1): 234–238.

Potter DJ (2009). The propagation, characterisation and optimisation of *Cannabis Sativa* L.as a phytopharmaceutical. Thesis, Kings College London. Available at: https://ia801604.us.archive.org/25/items/CANNABISSATIVAASAPHYTOPHARMACEUTICAL/THE%20PROPAGATION%2C%20CHARACTERISATION%20AND%20OPTIMISATION%20OF%20CANNABIS%20SATIVA%20AS%20A%20PHYTOPHARMACEUTICAL.pdf

Prade T, Svensson SE, Andersson A and Mattsson JA (2011). Biomass and energy yield of industrial hemp grown for biogas and solid fuel. *Biomass Bioenergy*. 35:3040–3049.

Radwan MM, Chandra S, Gul S and El Sohly MA (2021). Cannabinoids, Phenolics, terpenes and alkaloids of cannabis. *Molecules*. 26:2774.

Renn O (2008). Concept of risk: An interdisciplinary review. In: *Proceedings of the ISA Conference*. Barcelona. Available at http://www.riskanduncertainty.net/TG04/Ortwin_Renn__concepts.pdf.

Riboulet-Zemouli K (2020). 'Cannabis' ontologies I: Conceptual issues with Cannabis and cannabinoids terminology. *Drug Science, Policy and Law*. 6. Available at https://journals.sagepub.com/doi/10.1177/2050324520945797.

Riboulet-Zemouli K (2021). Sustainable cannabis policy toolkit. *Drug Science, Policy and Law.* 6. Available at https://cannabis2030.org/en.

Riboulet-Zemouli K, Anderfuhren-Biget S, Díaz Velásquez M and Krawitz M (2019). *Cannabis & Sustainable Development: Paving the way for the next decade in Cannabis and hemp policies*. FAAAT think & do tank, Vienna. Available at https://faaat.net/publications/9791097087340.

Riboulet-Zemouli K and Krawitz M (2022). WHO's first scientific review of medicinal *Cannabis*: From global struggle to patient implications. *Drugs, Habits and Social Policy.* 23(1):5–21.

Riddlestone S, Franck R and Wright J (1995). *Hemp for textiles: Growing our own clothes*. BioRegional Development Group, Surrey, United Kingdom.

Romero P, Peris A, Vergara K and Matus JT (2020). Comprehending and improving cannabis specialized metabolism in the systems biology era. *Plant Science*. 298.110571.

Russo EB (2011). Taming THC: Potential cannabis synergy and phytocannabinoid-terpenoid entourage effects. *British Journal of Pharmacology*. 163(7): 1344–1364.

Salentijn EMJ, Zhang Q, Amaducci S, Yang M and Trindade LM (2015). New developments in fiber hemp (*Cannabis sativa* L.) breeding. *Industrial Crops and Products*. 68:32–41.

Schäfer G (1944). Flachs und Hanf. Ciba-Rundschau. 62: 2262–2273.

Schafroth MA, Mazzoccanti G, Reynoso-Moreno I, Erni R, Pollastro F, Caprioglio D, Botta B, Allegrone G, Grassi G, Chicca A, Gasparrini F, Gertsch J, Carreira EM and Appendino G (2021). Δ9-cis-Tetrahydrocannabinol: Natural occurrence, chirality, and pharmacology. *Journal of Natural Products*. 84(9):2502–2510.

Scheerer S (1997). North-American Bias and non-American roots of cannabis prohibition. In: Böllinger L, ed. Cannabis Science: From Prohibition to Human Right. Peter Lang, Bern, Switzerland. https://archive.org/details/north-american-bias-and-non-american-roots-of-cannabis-prohibition

Schluttenhofer C and Yuan L (2017). Challenges towards revitalizing hemp: A multifaceted crop. *Trends in Plant Science*. 22(11): 917–929.

Small E (2015). Evolution and classification of *Cannabis sativa* (marijuana. hemp) in relation to human utilization. *The Botanical Review*. 81: 189–294.

Small E (2017). *Cannabis: A Complete Guide.* CRC Press. Taylor & Francis Group, London.

Small E (1979). The species problem in Cannabis: science and semantics. *Semantics*. 2.

Small E and Cronquist A (1976). A practical and natural taxonomy for Cannabis. *Taxon*. 25:405–435.

Tang K, Struik PC, Yin X, Thouminot C, Bjelková M, Stramkale V and Amaducci S (2016). Comparing hemp (*Cannabis sativa* L.) cultivars for dual-purpose production under contrasting environments. *Industrial Crops and Products.* 87:33–44.

United Nations (1973). Commentary on the Single Convention on Narcotic Drugs, 1961. (United Nations publication. Sales No. E.73.XI.1. New York). Available at https://www.unodc.org/documents/commissions/CND/Int_Drug_Control_Conventions/Commentaries-OfficialRecords/1961Convention/1961_COMMENTARY_en.pdf.

UN News (2020). UN commission reclassifies cannabis, yet still considered harmful. New York. Available at https://news.un.org/en/story/2020/12/1079132.

UNCTAD (2019a). *Synthetic Biology and its Potential Implications for BioTrade and Access and Benefit-Sharing*. UNCTAD/DITC/TED/INF/2019/12. (United Nations publication. Sales No. Sales No.: E.21.II.D.14. New York and Geneva)

UNCTAD (2019b*). International Classification of Non-tariff Measures.* 2019 version. UNCTAD/DITC/TAB/2019/5. (United Nations publication. Sales No. E.21.II.D.14. New York and Geneva). Available at https://unctad.org/webflyer/international-classification-non-tariff-measures-2019-version.

UNCTAD (2021). *Commodities and Development Report: Escaping from the Commodity Dependence Trap through Technology and Innovation*. UNCTAD/DITC/COM/2021/1. (United Nations publication. Sales No. E.21.II.D.14. New York and Geneva). Available at https://unctad.org/system/files/official-document/ditccom2021d1_en.pdf

UNODC (2022). *Recommended methods for the identification and analysis of cannabis and cannabis products.* Vienna https://www.unodc.org/documents/scientific/Recommended_methods_for_the_identification_and_analysis_of_cannabis_and_cannabis_products.pdf

UNODC (2021). *World Drug Report 2021*. (United Nations publication, Sales No. E.21.XI.8. Vienna).

UNODC (2013). *The International Drug Control Conventions*. (United Nations publication, Sales No. E.21.XI.8. Vienna). Available at https://www.unodc.org/documents/commissions/CND/Int_Drug_Control_Conventions/Ebook/The_International_Drug_Control_Conventions_E.pdf

USDA (2000). Industrial hemp in the United States: Status and market potential. (AGES-001E). Washington, DC. Available at https://www.ers.usda.gov/publications/pub-details/?pubid=41757.

USDA and Global Agricultural Information Network (GAIN)(2020). *China: 2019 Hemp Annual Report*. (Report CH2020-0018). Washington, DC. Available at https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=2019%20Hemp%20Annual%20Report_Beijing_China%20-%20Peoples%20Republic%20of_02-21-2020.

Van der Werf HMG, Van Geel WCA and Wijlhuizen M (1995). Agronomic research on hemp (*Cannabis sativa* L.) in the Netherlands, 1987–1993. *Journal of the International Hemp Association*. 2: 14–17.

Van Klingeren B and Ten Ham M (1976). Antibacterial activity of D 9-tetrahydrocannabinol and cannabidiol. *Antonie Van Leeuwenhoek.* 42: 9–12.

Vignon MR, Dupeyre D and Garcia-Jaldon C (1996). Morphological characterization of steam-exploded hemp fibers and their utilization in polypropylene-based composites. *Bioresource Technology.* 58(2):203–215.

Voegelin W and Vetterli WA (1962). Der hanf. *Ciba Rundsch*. 5: 2–30.

Vosper J (2011). The role of industrial hemp in carbon farming. Submission to the Australian Parliament # 035. Available at www.aphref.aph.gov.au_house_committee_ccea_24march2011_subs_sub035%20.pdf.

Watts G (2006). Cannabis confusions. *The British Medical Journal*. 332:175–176.

Westerhuis W, Amaducci S, Struik PC, Zatta A, Van Dam JEG and Stomph TJ (2009). Sowing density and harvest time affect fibre content in hemp (*Cannabis sativa* L.) through their effects on stem weight. *Annals of Applied Biology*. 155:225–244.

Williams DW (2019). Industrial Hemp as a Modern Commodity Crop. John Wiley & Sons Ltd. Hoboken.

Williams DW and Mundell R (2018). *An Introduction to Industrial Hemp and Hemp Agronomy*. University of Kentucky College of Agriculture, Food and Environment. Cooperative Extension Service. Lexington, KY.

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

Wood TB (1899). Cannabinol, Part I. *Journal of the Chemical Society*. 75:20–36.

WTO, UNCTAD and ITC (2021). *World Tariff Profiles*. Geneva. Available at https://www.wto.org/english/res_e/publications_e/world_tariff_profiles21_e.html.

Wu Y, Trejo HX and Chen G (2021). Phytoremediation of contaminants of emerging concern from soil with industrial hemp (*Cannabis sativa* L.): A review. *Environment, Development and Sustainability*. 23:14405–14435.

Wyse J and Luria G (2021). Trends in intellectual property rights protection for medical cannabis and related products. *Journal of Cannabis Research*. 3, Article no.1. Available at https://jcannabisresearch.biomedcentral.com/articles/10.1186/s42238-020-00057-7.

Xiaobing L, Yansheng L, Bingjin H, Qiuying Z, Keqin Z, Xingyi Z, Masoud H (2012). Yield response of continuous soybean to one-season crop disturbance in a previous continuous soybean field in Northeast China. *Field Crops Research*, 138: 52-56.

Zimmer H and Kloss D (1995). Ultraschallaufschluss von Hanf. Ziele-Technologie-Anwendung-Resultate-QualitaÈtsmanagement. Nova-Institut, *Proceedings of the Bioresource Hemp '95 Symposium.* Frankfurt.

Zimmerman L (2020). Curing the nice classification: Expanding trademark classes to include hemp & cannabis goods and services. (Unpublished manuscript). Available at http://dx.doi.org/10.2139/ssrn.3782739.

Annex

Table A.1 Hemp in the national tariff lines, selected countries

	HS 4 digits	HS 6 digits	Tariff line	Description
Japan	12.07			Other oil seeds and oleaginous fruits, whether or not broken:
			1207.99.010	Other: Hemp seeds
	12.11			Plants and parts of plants (including seeds and fruits), of a kind used primarily in perfumery, in pharmacy or for insecticidal, fungicidal or similar purposes, fresh, chilled, frozen or dried, whether or not cut, crushed or powdered
			1211.90.600	Other: Cannabis plant
	13.02			Vegetable saps and extracts; pectic substances, pectinates and pectates; agar-agar and other mucilages and thickeners, whether or not modified, derived from vegetable products
			1302.19.220	Vegetable saps and extracts: Other: Extracts or tincture of cannabis and crude cocaine
	30.04			Medicaments (excluding goods of heading 30.02, 30.05 or 30.06) consisting of mixed or unmixed products for therapeutic or prophylactic uses, put up in measured doses (including those in the form of transdermal administration systems) or in forms or packings for retail sale
			3004.90.010	Other, containing alkaloids or derivatives thereof: Of narcotics, of cannabis or of awakening-amines
	53.11	5311.00		Woven fabrics of other vegetable textile fibres; woven fabrics of paper yarn.
			5311.00.020	Woven fabrics of true hemp or paper yarn

	HS 4 digits	HS 6 digits	Tariff line	Description
United States	12.07			Other oil seeds and oleaginous fruits, whether or not broken
			1207.99.0320 (from 2012 to 2020)	Hemp seeds, whether or not broken
			1207.99.0340 (since 2021)	Other: Hemp: for sowing
			1207.99.0360 (since 2021)	Other: Hemp: other
	15.15			Other fixed vegetable fats and oils (including jojoba oil) and their fractions, whether or not refined, but not chemically modified
			1515.90.8010	Other: Hemp oil
	23.06			Oilcake and other solid residues, whether or not ground or in the form of pellets, resulting from the extraction of vegetable fats or oils, other than those of heading 2304 or 2305
			2306.90.0130	Other: Of hemp seeds
	5311	5311.00		Woven fabrics of other vegetable textile fibres; woven fabrics of paper yarn
			5311.00.4010	Of true hemp fibres
European Union	12.07			Other oil seeds and oleaginous fruits, whether or not broken
			1207.99.91	Other: Hemp seeds
	53.08			Yarn of other vegetable textile fibres; paper yarn
			5308.20.10	True hemp yarn: Not put up for retail sale
			5308.20.90	True hemp yarn: Put up for retail sale

	HS 4 digits	HS 6 digits	Tariff line	Description
Canada	06.02			Other live plants (including their roots), cuttings and slips; mushroom Spawn
			0602.90.90.90	Other: Live Plants
	12.07			Other oil seeds and oleaginous fruits, whether or not broken
			1207.99.00.11	Other: Hemp seeds for sowing
			1207.99.00.19	Other: Hemp seeds, other
	12.09			Seeds, fruit and spores, of a kind used for sowing
			1209.99.10.29	Cannabis seeds for sowing
	12.11			Plants and parts of plants (including seeds and fruits), of a kind used primarily in perfumery, in pharmacy or for insecticidal, fungicidal or similar purposes, fresh, chilled, frozen or dried, whether or not cut, crushed or powdered
			1211.90.90.50	Other: Cannabis plants, herbs & seeds used in pharmacy
	13.01			Lac; natural gums, resins, gum-resins and oleoresins (for example, balsams)
			1301.90.00.10	Other: Cannabis
	13.02			Vegetable saps and extracts; pectic substances, pectinates and pectates; agar-agar and other mucilages and thickeners, whether or not modified, derived from vegetable products.
			1302.19.00.10	Vegetable saps and extracts: Cannabis oil, extracts, and tinctures
	15.15			Other fixed vegetable fats and oils (including jojoba oil) and their fractions, whether or not refined, but not chemically modified
			1515.90.00.10	Other: Hemp oil
	30.04			Medicaments (excluding goods of heading 30.02, 30.05 or 30.06) consisting of mixed or unmixed products for therapeutic or prophylactic uses, put up in measured doses (including those in the form of transdermal administration systems) or in forms or packings for retail sale.
			3004.90.00.21	Other: Medicaments for retail sale, containing cannabis or cannabinoids
	57.02			Carpets and other textile floor coverings, woven, not tufted or flocked, whether or not made up, including “Kelem”, “Schumacks”, “Karamanie” and similar hand-woven rugs
			5702.99.10.00	Of other textile materials: Of straw, hemp, flax tow or jute

Source: Authors, based on selected national tariff schedules.
Note: All national tariff schedules include the HS 6-digit categories defined internationally.
The tariff line is the product code used at the national level, beyond the 6 digits of the Harmonized System, and varies by country.

Table A.2 Top five exporters of true hemp products (HS classification), selected years
(Millions of United States dollars)

Rank	Exporter	Year	Value	Rank_W
1	France	2020	10.3	1
2	China	2020	8.5	5
3	United States	2020	5.0	9
4	Romania	2020	4.0	4
5	Netherlands	2020	3.9	2
1	France	2019	9.5	1
2	China	2019	6.5	4
3	Netherlands	2019	2.8	2
4	Hungary	2019	2.5	15
5	Lithuania	2019	2.1	6
1	France	2018	9.0	1
2	China	2018	4.1	4
3	Netherlands	2018	3.1	2
4	Hungary	2018	1.6	9
5	Romania	2018	1.2	5
1	France	2017	6.6	1
2	Netherlands	2017	4.3	2
3	China	2017	3.0	5
4	Romania	2017	2.5	4
5	Germany	2017	1.3	3
1	France	2010	4.8	1
2	China	2010	2.5	6
3	Germany	2010	1.5	2
4	Italy	2010	1.4	8
5	Netherlands	2010	0.8	3
1	France	2002	2.6	1
2	Netherlands	2002	1.8	2
3	China	2002	1.6	6
4	Germany	2002	1.1	3
5	Japan	2002	0.8	14

Source: Authors' calculations based on UN Comtrade information in WITS.
Note: Rank_w refers to rank obtained for corresponding weight (in tons) values.

Table A.3 Top five importers of true hemp products (HS classification), selected years
(Millions of United States dollars)

Rank	Importer	Year	Value	Rank_W
1	Spain	2020	6.7	1
2	Switzerland	2020	4.9	6
3	United States	2020	3.0	5
4	Germany	2020	2.9	3
5	Netherlands	2020	2.8	4
1	Germany	2019	3.8	3
2	Spain	2019	3.3	1
3	Czechia	2019	3.2	2
4	Austria	2019	2.7	20
5	United States	2019	2.3	4
1	Germany	2018	5.0	1
2	Czechia	2018	3.4	2
3	Spain	2018	2.7	3
4	United States	2018	1.9	4
5	Austria	2018	1.8	10
1	Germany	2017	4.2	2
2	United States	2017	3.8	4
3	Czechia	2017	3.5	1
4	Spain	2017	2.0	3
5	Italy	2017	0.8	12
1	Spain	2010	2.5	1
2	United Kingdom	2010	1.7	3
3	Czechia	2010	1.4	2
4	Germany	2010	1.3	4
5	Republic of Korea	2010	0.9	12
1	Spain	2002	1.9	1
2	Italy	2002	1.6	7
3	Germany	2002	1.6	4
4	Türkiye	2002	1.4	2
5	China	2002	1.1	6

Source: Authors' calculations based on UN Comtrade information in WITS.
Note: Rank_w refers to rank obtained for corresponding weight (in tons) values.

Table A.4 Trade flows in national tariff schedules, 2016–2020
(Millions of United States dollars)

	Product	Flow	2016	2017	2018	2019	2020
European Union	1207.99.91 Hemp oil seeds not for sowing	Imports	39,957	56,132	43,577	42,449	54,282
		Exports	45,121	33,426	50,167	60,676	75,803
	5308.20.10 Hemp yarn put up for retail sale	Imports	555	750	996	1926	2557
		Exports	920	1020	590	639	846
	5308.20.90 Hemp yarn (excl. that put up for retail sale)	Imports	663	681	662	768	758
		Exports	438	475	765	798	749
Canada	1207.99.00.11 Hemp seeds, for sowing	Imports	7	5	274	843	187
	1207.99.00.19 Hemp seeds, w/n broken, except for sowing	Imports	365	1,118	707	466	560
	1209.99.10.29 *Cannabis* seeds for sowing	Imports	946	667	1,092	821	1,341
	1211.90.90.50 *Cannabis* plants, herbs and seeds used in pharmacy	Imports	0	0	35	1,333	20
	1301.90.00.10 *Cannabis* lac, natural gums, resins, gum-resins and oleoresins	Imports	0	0	1	3	15
	1302.19.00.10 *Cannabis* oil, extracts, and tinctures	Imports	0	0	729	11	136
	1515.90.00.10 Hemp oil	Imports	0	803	249	551	473
	3004.90.00.21 Medicaments for retail sale, containing cannabis or cannabinoids	Imports	0	0	24	108	19
	5702.99.10.00 Carpets of straw, hemp, flax tow or jute, woven, made up	Imports	2,236	2,067	3,001	3,323	3,409

	Product	Flow	2016	2017	2018	2019	2020
Japan	1207.99.010 Hemp seeds oil	Imports	2,267	1,723	1,154	1,638	2,084
	1302.19.220 Extracts or tincture of cannabis and crude cocaine	Imports	69	50	114	443	240
	3004.90.010 Medicaments containing alkaloids or derivatives thereof: of narcotics, of cannabis or of awakening-amines	Imports	41,133	39,726	37,874	37,703	40,472
	5311.00.020 Woven fabrics of true hemp or paper yarn	Imports	695	616	602	413	260
United States	1207.99.03.20 Hemp seeds, whether or not broken	Imports	51,183	43,233	46,791	62,696	79,900
		Exports	0	0	0	0	799
	1515.90.80.10 Hemp oil	Imports	6,240	7,979	14,205	12,979	8,635
	2306.90.01.30 Hemp seeds oilcake and other solid residues resulting from hemp seeds oil	Imports	8,764	11,661	10,626	10,025	8,123
	5311.00.40.10 Woven fabrics of true hemp fibers	Imports	768	1,871	7,085	2,223	3,065

Source: ITC-TRADE MAP and National statistics
Note: For the European Union, ITC calculations based on Eurostat statistics since January 2017 and on UN Comtrade before that date.

Table A.5 Import tariff rates in tariff line, MFN and preferential (latest year available)
(Percentage and cents/kg)

Area	Product	MFN	Pref.	Special*
European Union	1207.99.91 Hemp seeds not for sowing	0	0	
	5302.10.00 Hemp raw or retted but not spun	0	0	
	5302.90.00 Hemp processed other than retted, tow and waste	0	0	
	5308.20.10 Hemp yarn put up for retail sale	3	0	
	5308.20.90 Hemp yarn (excl. that put up for retail sale)	4.9	0	
Canada	0602.90.90.90 Live plants	6	5 and 0	
	1207.99.00.11 Hemp seeds, for sowing	0	0	
	1207.99.00.19 Hemp seeds, w/n broken, except for sowing	0	0	
	1209.99.10.29 *Cannabis* seeds for sowing	0	0	
	1211.90.90.50 *Cannabis* plants, herbs and seeds used in pharmacy	0	0	
	1301.90.00.10 *Cannabis* lac, natural gums, resins, gum-resins and oleoresins	0	0	
	1302.19.00.10 *Cannabis* oil, extracts, and tinctures	0	0	
	1515.90.00.10 Hemp oil	0	0	
	3004.90.00.21 Medicaments for retail sale, containing cannabis or cannabinoids	0	0	
	5302.10.00.00 Hemp raw or retted, but not spun	0	0	
	5302.90.00.00 Hemp processed (other than retted)	0	0	
	5308.20.00.00 True hemp yarn	0	0	
	5702.99.10.00 Carpets of straw, hemp, flax tow or jute, woven, made up	6	2 and 0	

Area	Product	MFN	Pref.	Special*
Japan	1207.99.010 Hemp seeds oil	0	0	
	1211.90.600 Plants or part of plants: cannabis	3	0	
	1302.19.220 Extracts or tincture of cannabis and crude cocaine	0	0	
	3004.90.010 Medicaments containing alkaloids or derivatives thereof: of narcotics, of cannabis or of awakening-amines	0	0	
	5302.10.000 Hemp raw or retted, but not spun	0	0	
	5302.90.000 Hemp processed (other than retted)	0	0	
	5308.20.000 True hemp yarn	2	0	
	5311.00.020 Woven fabrics of true hemp or paper yarn	3.5	0	
United States	1207.99.03.20 Hemp seeds, whether or not broken	0	0	0
	1207.99.0340 Hemp seeds for sowing	0	0	0
	1207.99.0360 Hemp seeds, other uses than sowing	0	0	0
	1515.90.80.10 Hemp oil	3.2	0	20
	2306.90.01.30 Hemp seeds oilcake and other solid residues resulting from hemp seeds oil	0.32₵/kg	0	4.4₵/kg
	5302.10.00.00 Hemp raw or retted, but not spun	0	0	4.4₵/kg
	5302.90.00.00 Hemp processed (other than retted)	0	0	4.4₵/kg
	5308.20.00.00 True hemp yarn	0	0	35
	5311.00.40.10 Woven fabrics of true hemp fibers	0	0	40

Source: Canada: Canada Border Services Agency, at https://cbsa-asfc.gc.ca/trade-commerce/tariff-tarif/menu-eng.html; Japan: Japan Customs, athttps://www.customs.go.jp/english/tariff/2021_9/index.htm; Europe: TARIC database, at https://ec.europa.eu/taxation_customs/dds2/taric/taric_consultation.jsp?Lang=en;
United States: United States International Trade Commission, at https://hts.usitc.gov/.
Note: * Tariffs imposed by the United States on imports from Cuba and the Democratic People's Republic of Korea

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