Optimal Inventory Levels for Medicinal Cannabis Under Regulatory Uncertainty: A Stochastic Framework for Balancing Patient Access and Diversion Risk

Fernando Greve*

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Abstract

On April 23, 2026, the U.S. Department of Justice issued a final order reclassifying cannabis from Schedule I to Schedule III of the Controlled Substances Act, culminating a process initiated by Executive Order in December 2025. The reclassification aligns federal law with the reality of 40+ state-level legalization programs and responds to mounting scientific evidence of therapeutic efficacy across indications including chronic pain, chemotherapy-induced nausea, treatment-resistant epilepsy, and post-traumatic stress disorder—evidence that Schedule I status, which presumes "no currently accepted medical use," had increasingly rendered untenable. By placing cannabis in the same regulatory category as ketamine, anabolic steroids, and codeine formulations, the reclassification opens a pathway toward interstate commerce, FDA-regulated research, and the integration of cannabis into conventional pharmaceutical supply chains. Yet this historic shift exposes a critical operational gap: across all jurisdictions where cannabis is legal—now spanning over

*Corresponding author. Email: fgreve@gmail.com

50 countries and sub-national entities in the Americas, Europe, and Oceania—no established quantitative methodology exists for determining how much cannabis a licensed operator, collective cultivation association, or dispensary should hold in inventory. This stands in stark contrast to other controlled substances, for which decades of pharmaceutical logistics have produced robust inventory frameworks under DEA quotas, INCB estimates, and GMP protocols.

This paper proposes the first formal inventory optimization model for cannabis, adapting the classical newsvendor framework to incorporate the sector's defining characteristics: asymmetric costs spanning clinical harm (understocking) and criminal liability (overstocking), agricultural yield uncertainty, long production lead times (90–150 days), product perishability through cannabinoid degradation, and jurisdiction-specific regulatory constraints. We formulate the problem as a two-stage stochastic program whose first stage determines optimal cultivation scale and cultivar allocation, and whose second stage optimizes post-harvest inventory disposition across dispensing, extraction, and destruction channels. The model produces technically defensible inventory bounds—a floor guaranteeing a target patient service level and a ceiling minimizing diversion risk—derived from observable, auditable parameters: registered patient counts, prescription volumes, historical yields, and production lead times.

We demonstrate the framework's applicability across the regulatory spectrum. In restrictive jurisdictions (Chile, Argentina, Spain), where the boundary between lawful possession and criminal trafficking remains judicially indeterminate, the model provides an expert-witness-grade tool for establishing the reasonableness of inventory levels—addressing a problem that has led to divergent Supreme Court rulings on quantities as small as 23 grams. In intermediate jurisdictions (Germany, Colombia, Uruguay), where Cannabis Social Clubs and collective cultivation associations aggregate individual authorizations into concentrated inventories of 20–50 kg at single locations, the model quantifies the optimal balance between operational efficiency and societal diversion risk. In mature markets (Canada, United States), where seed-to-sale traceability infrastructure already generates granular supply chain data, the model provides the missing optimization layer that trans-

forms compliance data into operational intelligence.

The framework acquires particular urgency in the United States, where Schedule III reclassification is expected to catalyze interstate commerce, transforming a fragmented landscape of state-siloed supply chains into multi-echelon distribution networks requiring principled inventory management at every node. We present numerical illustrations calibrated to Chilean, Colombian, and Argentine regulatory parameters, conduct sensitivity analysis across service levels and cost structures, and derive a closed-form standard inventory formula suitable for direct adoption as a regulatory guideline. The central policy insight is that inventory management for cannabis is not a law enforcement problem amenable to arbitrary thresholds, but an operations management problem with a quantitative solution—one that simultaneously serves patient welfare, public safety, and the rule of law.

Keywords: cannabis; inventory management; newsvendor model; stochastic programming; drug policy; supply chain optimization; Cannabis Social Clubs; seed-to-sale traceability; federal rescheduling; interstate commerce; diversion risk; patient access; regulatory uncertainty

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1 Introduction

1.1 A Watershed Moment

On December 18, 2025, President Trump signed Executive Order "Increasing Medical Marijuana and Cannabidiol Research" (28), directing the Attorney General to expedite the rescheduling of cannabis under the Controlled Substances Act. On April 23, 2026, the Department of Justice issued a final order (29) reclassifying cannabis from Schedule I—a category reserved for substances with "no currently accepted medical use and a high potential for abuse"—to Schedule III, alongside ketamine, anabolic steroids, and certain codeine formulations. A broader administrative hearing covering all cannabis, including state-level recreational programs, is scheduled for June–July 2026.

The reclassification was long overdue. By 2025, 40 U.S. states had legalized cannabis in some form—24 for adult recreational use, the remainder for medical purposes—yet federal law continued to classify it identically to heroin and LSD. This dissonance had concrete consequences: it blocked FDA-pathway clinical trials, prevented federally chartered banks from serving cannabis businesses, barred interstate transport of a product legally sold in adjacent states, and forced multi-state operators to maintain fully redundant supply chains—separate cultivation, processing, testing, and distribution infrastructure duplicated in every jurisdiction. The scientific basis for Schedule I status had eroded steadily as peer-reviewed evidence accumulated demonstrating therapeutic efficacy across chronic pain, chemotherapy-induced nausea, treatment-resistant epilepsy (notably the FDA's own approval of Epidiolex in 2018), multiple sclerosis spasticity, and post-traumatic stress disorder. The Department of Health and Human Services formally recommended rescheduling in August 2023, citing a comprehensive review of available evidence.

The move to Schedule III does not, by itself, create a regulated interstate market. But it removes the most fundamental legal barrier and creates powerful structural momentum: Schedule III substances are legally manufactured and distributed across state lines under DEA quotas and FDA oversight. Industry analysts, legal scholars, and multi-state

operators widely anticipate that federal rescheduling will be followed, within a legislative cycle or two, by frameworks permitting interstate cannabis commerce. When that occurs, the cannabis industry will face a challenge for which it is quantitatively unprepared: managing inventory across multi-echelon supply chains spanning cultivation, processing, distribution, and retail nodes in dozens of jurisdictions with heterogeneous regulatory requirements.

This paper addresses that challenge—and the broader, global version of it—by proposing the first formal inventory optimization model for cannabis.

1.2 The Regulatory Gap

The U.S. reclassification is the most visible instance of a worldwide phenomenon: the rapid expansion of legal cannabis programs without correspondingly developed operational frameworks. A growing number of countries have enacted legislation permitting the cultivation, processing, and dispensing of cannabis for medicinal purposes. Chile (Decree 867/2015, Law 21.545/2023) (15; 16), Colombia (Law 1787/2016, Decree 613/2017) (17; 18), Argentina (Law 27.350/2017, Decree 883/2020) (19; 20), Peru (Law 30681/2017) (22), Uruguay (Law 19.172/2013) (21), Germany (*Cannabisgesetz*, 2024) (23), and Canada (*Cannabis Act*, 2018) (24) have all established legal pathways for patient access to cannabinoid-based therapies. However, these legal frameworks share a critical omission: none provides explicit, quantitative guidance on how much cannabis a licensed operator—whether a cultivator, processor, pharmacy, or patient association—may legitimately hold in inventory at any given time.

This omission creates a zone of legal indeterminacy with serious consequences. On one side, operators who maintain insufficient inventory risk interrupting patient treatment, potentially violating their duty of care and the patient's right to health—a constitutionally protected right in most Latin American jurisdictions. On the other side, operators who maintain generous inventory levels expose themselves to criminal prosecution under anti-narcotics statutes that remain fully operative alongside medicinal cannabis regulations. In countries where simple possession of cannabis above an unspecified "personal

use" threshold can trigger imprisonment of 5 to 15 years, the absence of technically grounded inventory standards is not merely an operational inconvenience; it is a structural barrier to the development of legal medicinal cannabis supply chains.

The result is a *chilling effect*. Legal operators understock to minimize legal exposure, creating chronic shortages. Patients, unable to obtain their prescribed therapies through legal channels, turn to unregulated sources—the very outcome that strict narcotics enforcement purports to prevent. This paper argues that the problem is fundamentally one of *operations management under uncertainty*, and that established quantitative tools from inventory theory can resolve it.

1.3 Personal Cultivation, Collective Associations, and Inventory Concentration

A defining feature of medicinal cannabis regulation across Latin America—and increasingly in other regions—is the legal recognition of *personal cultivation* as a pathway to patient access. Rather than restricting cannabis supply to licensed pharmaceutical manufacturers, several jurisdictions have granted patients the right to cultivate a limited number of plants for their own therapeutic use, typically upon presentation of a medical prescription or inclusion in a patient registry. Chile (Law 20.000, Art. 8; Decree 867), Argentina (REPROCANN, Decree 883/2020), Uruguay (Law 19.172), Colombia (Decree 613/2017), and more recently countries such as Germany (*Cannabisgesetz*, 2024) (23), Thailand (2022–2025 regulatory cycle), and several U.S. states have adopted variants of this approach.

The rationale is straightforward: personal cultivation reduces barriers to access, lowers costs for patients who cannot afford pharmaceutical-grade products, and recognizes the right to therapeutic self-determination. However, the practical implementation of personal cultivation has given rise to a derived organizational form with significant inventory implications: the *collective cultivation association* (*asociación de cultivo colectivo*, *club cannábico*, or *cannabis social club*).

These associations emerge when patients—each individually authorized to cultivate a

small number of plants—pool their cultivation rights and resources into a single shared facility. The logic is compelling: collective cultivation achieves economies of scale in infrastructure (greenhouses, irrigation, climate control), expertise (agronomy, pest management, post-harvest processing), and quality control (laboratory testing, standardization of cannabinoid profiles) that individual home cultivation cannot. In practice, associations of 50 to 500 members are common in Chile, Argentina, Uruguay, and Spain, with some larger organizations serving over 1,000 patients.

The critical consequence of this aggregation is *inventory concentration*. When hundreds of patients consolidate their individual cultivation authorizations into a single physical location, the resulting inventory—which is the arithmetic sum of individually modest quantities—can reach volumes that, in absolute terms, appear indistinguishable from commercial-scale drug trafficking. An association of 200 members, each authorized to hold 30 grams of dried flower, collectively justifies 6 kg of finished product at any given time. When one accounts for the production pipeline (plants in various stages of growth, drying product, product undergoing laboratory testing, safety stock against crop failure), the total cannabis biomass physically present at the association's facility may reach 20–50 kg or more—quantities that, absent documentation of their provenance and purpose, would unambiguously trigger criminal prosecution under anti-narcotics statutes.

The question of plant limits: evidence or fiat? The contrast between jurisdictions that have codified specific plant limits and those that have not illuminates a deeper problem. Argentina's REPROCANN framework authorizes registered patients to cultivate up to 9 flowering plants (originally 6 under the initial regulation, later expanded), while collective associations (*asociaciones civiles*) may cultivate larger numbers proportional to membership. Chile, by contrast, has not codified any specific plant limit for medicinal cultivators; the distinction between lawful personal cultivation and criminal trafficking remains a matter of judicial interpretation under Law 20.000, assessed case-by-case based on "circumstances of the act."

A fundamental question—largely absent from the legislative record in both countries—is: *on what technical basis was the specific number chosen?* In Argentina's case, the

figure of 6 (later 9) flowering plants appears to have been determined through political negotiation rather than pharmacological or agronomic analysis. The legislative debate does not cite yield-per-plant estimates, patient consumption rates, or any formal demand-supply calculation linking a specific plant count to a specific therapeutic outcome.

This omission matters because the relationship between plant count and patient outcomes is mediated by multiple stochastic variables. A single cannabis plant can yield anywhere from 20 to 500 grams of dried flower depending on cultivar genetics, growing conditions, cultivation expertise, and environmental factors (3). Six plants might produce 120 grams (grossly insufficient for a patient consuming 30 g/month, covering barely four months and leaving an 8-month gap until the next harvest cycle) or 3,000 grams (a 100-month supply for the same patient, raising legitimate questions about diversion risk). The variance is so large that a fixed plant count, without reference to expected yield distributions and patient demand, is *informationally vacuous* as a regulatory instrument.

Three questions expose the inadequacy of fixed plant limits as policy tools:

(i) **Is it sufficient for medical treatment?** For a patient requiring 30 g/month of dried flower (a moderate dose for chronic pain management), annual demand is 360 g. If each plant yields 55 g on average (the median from indoor cultivation data), 6 plants produce approximately 330 g per harvest cycle—a shortfall that forces the patient to either ration medication, miss treatment periods between harvest cycles, or seek supplementary supply from unregulated sources. The limit is clinically insufficient under median yield assumptions, and catastrophically insufficient under below-median yield realizations. Moreover, the limit ignores that plants fail: pest infestations, environmental stress, genetic instability, and cultivation errors can destroy a fraction of each cohort, further reducing effective yield.

(ii) **Is it too risky for society?** Under favorable conditions, 6 plants could produce 1,500–3,000 g—quantities that, for a single patient, far exceed annual therapeutic needs. The surplus creates an *inventory overhang* with no regulated destination: the patient cannot legally sell or transfer excess product, has no obligation to destroy it, and faces no audit of actual consumption versus production. This unaccounted

surplus is precisely the reservoir from which diversion to illicit markets can occur.

(iii) **Does the limit create perverse incentives?** A fixed plant limit incentivizes cultivators to maximize yield per plant (through aggressive fertilization, high-intensity lighting, and selection of high-yielding cultivars), which increases both the total biomass produced and its THC potency—the opposite of the harm-reduction goals that medicinal regulation ostensibly pursues.

The Chilean case, where no plant limit exists, might appear more permissive but is in practice more precarious. Without any quantitative reference point, every cultivation operation exists in a state of latent criminality: a patient or association growing any number of plants cannot know *ex ante* whether a prosecutor or judge will consider that number "reasonable." The absence of a threshold is not regulatory flexibility; it is regulatory abdication that delegates a fundamentally technical question to the criminal justice system.

Both approaches—Argentina's arbitrary fixed limit and Chile's undefined standard—share the same structural deficiency: *they are disconnected from the demand-supply calculus that should determine permissible inventory.* A plant limit that does not reference patient demand, yield distributions, harvest cycles, and safety stock requirements is no more rational than a warehouse capacity rule that ignores order frequency and lead times. The framework developed in this paper provides the missing analytical link, connecting permissible cultivation scale (and by extension, inventory levels) to observable, auditable, and patient-specific demand parameters.

Concentrated inventory as a societal risk vector. The inventory concentration effect is not merely a legal liability for the association; it constitutes a genuine *societal risk.* Large volumes of cannabis consolidated in a single location create an attractive target for diversion to illicit markets—whether through internal theft by association members or employees, external robbery, or systematic leakage through inadequate controls. From a public safety perspective, a facility holding 30–50 kg of cannabis represents a qualitatively different risk profile than 200 individual patients each holding 150 grams at their homes.

The concentration transforms a distributed, low-value target landscape into a single, high-value node vulnerable to exploitation.

This risk is bidirectional. On one hand, the association faces the threat of *outward diversion*: product leaving the facility through channels other than patient dispensing, ultimately reaching the black market. The probability and magnitude of outward diversion increase with inventory volume, creating a convex relationship between inventory level and expected diversion loss. On the other hand, the association also faces the threat of *inward predation*: criminal organizations targeting the facility precisely because it concentrates valuable product in a known, fixed location. Several Latin American countries have reported armed robberies of cultivation facilities and dispensaries, a phenomenon that imposes security costs on operators and endangers surrounding communities.

The societal cost of concentrated inventory can be formalized. Let $\pi(I)$ denote the probability of a diversion event (theft, leakage, robbery) as a function of total on-site inventory I, and let $L(I)$ denote the expected loss (in grams diverted to the black market) conditional on such an event. The expected societal cost of diversion is:

$$C^{\text{diversion}}(I) = \pi(I) \cdot L(I) \cdot v^{\text{street}}, \tag{1}$$

where v^{street} is the street value per gram, which serves as a proxy for the social harm generated by each diverted unit (funding of criminal organizations, consumption by non-patients, erosion of public trust in the medicinal program). Both $\pi(I)$ and $L(I)$ are plausibly increasing in I: larger inventories are more attractive targets and yield larger losses per event. This makes $C^{\text{diversion}}(I)$ convex in I, reinforcing the existence of an interior optimum in the inventory decision.

This analysis strengthens the case for the framework proposed in this paper. Without a quantitative model, collective associations face an impossible dilemma: hold enough inventory to reliably serve patients (risking criminal prosecution and creating a diversion target) or restrict inventory to minimize legal and security exposure (guaranteeing treatment interruptions). The stochastic inventory model developed in Section 3 resolves this dilemma by identifying the inventory level that optimally balances patient service, legal

risk, and societal diversion risk—and, crucially, by providing a *documented, auditable, and reproducible* justification for that level.

1.4 An Operations Management Perspective

The determination of optimal inventory levels under demand uncertainty is one of the foundational problems in operations research. The newsvendor model, first formalized by Arrow et al. (1), provides a decision rule for a single-period inventory problem with stochastic demand and asymmetric costs of over- and understocking. The model's critical ratio,

$$Q^* = F^{-1}\left(\frac{C_u}{C_u + C_o}\right), \tag{2}$$

has been applied across industries from fashion retail to vaccine supply chains.

We argue that medicinal cannabis inventory management maps naturally onto this framework, with two important extensions. First, the cost parameters are not purely economic; they include clinical harm (understocking) and criminal liability (overstocking), requiring a multi-dimensional cost structure. Second, the supply side is subject to agricultural yield uncertainty and long production lead times that preclude rapid replenishment, necessitating a multi-period extension with pipeline inventory considerations.

To our knowledge, no prior work has applied formal inventory optimization models to the medicinal cannabis supply chain. Existing literature on cannabis operations is predominantly qualitative, focusing on supply chain traceability frameworks (2; 9) and digital supply chain architectures. Meanwhile, the extensive operations research literature on pharmaceutical inventory management (10) and controlled substance supply chains (6) has not been extended to cannabis. This paper bridges that gap.

1.5 Contributions

This paper makes three contributions:

(i) **Modeling contribution.** We formulate the first quantitative inventory model for medicinal cannabis that integrates demand uncertainty, yield uncertainty, cannabi-

noid degradation (perishability), and regulatory constraints within a unified stochastic programming framework.

(ii) **Policy contribution.** We demonstrate that technically defensible inventory bounds can be derived from observable data (patient registries, prescription records, historical yields), providing regulators with an evidence-based alternative to arbitrary thresholds and prosecutors with a quantitative standard for assessing the reasonableness of inventory levels.

(iii) **Health systems contribution.** We quantify the relationship between inventory policy and patient service level, showing that excessively conservative inventory limits—whether imposed by regulation or self-imposed by risk-averse operators—generate stockout rates that compromise treatment continuity and push demand toward unregulated channels.

The remainder of this paper is organized as follows. Section 2 reviews the medicinal cannabis supply chain, the regulatory landscape across Latin America, Europe, and North America, and relevant inventory theory. Section 3 presents the stochastic programming formulation. Section 4 provides a numerical illustration calibrated to three Latin American jurisdictions. Section 5 discusses policy implications. Section 7 concludes.

2 Background and Literature

2.1 The Medicinal Cannabis Supply Chain

The medicinal cannabis supply chain comprises five stages: (i) genetic selection and propagation (cloning or seed germination), (ii) vegetative growth (2–4 weeks), (iii) flowering and maturation (8–12 weeks), (iv) harvesting, drying, curing, and laboratory testing (2–4 weeks), and (v) processing into finished dosage forms (dried flower, oils, tinctures, capsules) and distribution. The total lead time from propagation decision to patient-ready product ranges from 90 to 150 days, depending on cultivar, growing method (indoor, greenhouse, outdoor), and product format.

Three characteristics distinguish this supply chain from conventional pharmaceuticals:

Yield uncertainty. Cannabis is an agricultural product whose yield per plant is a random variable dependent on genetics, environmental conditions, pest pressure, and cultivation practices. The meta-analysis by Backer et al. (3) reports wide variation in cannabis yields, with indoor production ranging from 200 to 600 g/m^2 annually. This variance propagates into finished product availability.

Cannabinoid variability. Even within a single cultivar, the concentration of therapeutically relevant cannabinoids (THC, CBD, CBN, terpene profiles) varies across plants and harvests. Batch-level laboratory testing is mandatory in all regulated jurisdictions, and batches failing to meet specification must be destroyed or reprocessed—effectively reducing usable yield. Naim-Feil et al. (8) documented significant intra-plant variability in inflorescence weight and cannabinoid content.

Product perishability. Cannabinoids degrade over time through oxidation (THC $\rightarrow$ CBN), particularly under exposure to light, heat, and oxygen. While properly stored cannabis can maintain potency for 12–24 months, this finite shelf life introduces an additional cost of overstocking: inventory held beyond its potency window must be destroyed, representing both economic waste and regulatory liability.

2.2 Regulatory Landscape

We survey seven jurisdictions that represent the spectrum of regulatory approaches, from restrictive to permissive, across Latin America, Europe, and North America.

Chile. Decree 867 (2015) permits the use of cannabis-based products under medical prescription but provides no explicit production or inventory guidelines. Law 21.545 (2023) expanded access but maintained ambiguity regarding permissible quantities. The *Servicio Agrícola y Ganadero* (SAG) oversees cultivation permits, while the *Instituto de Salud Pública* (ISP) regulates finished products. Possession of cannabis above a judicially

determined threshold—not codified in statute—may trigger prosecution under Law 20.000 (14) (Narcotics Law), which carries penalties of 3 to 15 years imprisonment.

The Chilean case is particularly instructive because recent jurisprudence demonstrates the radical inconsistency that results from the absence of quantitative inventory standards. In May 2026, the *Corte Suprema* (Rol N° 54.608-2025) (34) overturned a trafficking conviction for a defendant found carrying 100.3 grams of cannabis in a single package. The court held that the quantity alone, without evidence of transactions with third parties, dosing implements, or significant cash, was insufficient to establish trafficking intent; the conviction was replaced with a fine of 1 UTM (approximately USD 65) for personal possession. Yet in a contemporaneous case (Rol N° 54.489-2025) (35), the same court upheld a trafficking conviction for 23 grams of cannabis—less than one-quarter of the quantity in the previous case—because the defendant also possessed a digital scale and cash. The determinative factor was not quantity but *circumstantial evidence of intent*, a standard that provides no ex ante guidance to operators or patients regarding permissible inventory levels.

The regulatory incoherence deepened in March 2026, when Chile's Congress approved a reform to Law 20.000 that allows trafficking-level penalties to be applied to small quantities of substances classified as capable of producing "grave toxic effects or considerable health damage"—a category that includes cannabis, classified as a "hard drug" since 2007. In response, 37 members of Congress filed a constitutional challenge before the *Tribunal Constitucional* (April 2026), arguing that the reform could criminalize medicinal patients and personal users. As of this writing, the TC has not ruled. Chile thus presents the extraordinary situation of three branches of government sending contradictory signals about the same substance: Congress tightening penalties, the Supreme Court loosening them through case law, and the Constitutional Tribunal weighing whether the entire framework is constitutionally valid—while patients and operators navigate the resulting uncertainty without quantitative tools to assess their legal exposure.

Colombia. Law 1787 (2016) and Decree 613 (2017) established a comprehensive licensing framework (cultivation, processing, export) administered by the *Ministerio de*

Justicia and INVIMA. Colombia's framework is the most developed in the region and includes some production volume controls tied to license type, but inventory management at the operator level remains largely unregulated.

Argentina. Law 27.350 (2017) and the subsequent regulatory framework (REPROCANN) authorize personal and institutional cultivation for medicinal purposes. The program has grown rapidly but lacks standardized inventory guidelines, creating friction between patients/cultivators and law enforcement.

Uruguay. Law 19.172 (2013) legalized cannabis for recreational and medicinal use, with the *Instituto de Regulación y Control del Cannabis* (IRCCA) overseeing the market. While Uruguay's recreational framework includes per-person purchase limits, the medicinal track has separate—and less defined—inventory provisions.

Germany. The *Cannabisgesetz* (CanG) (23), effective April 1, 2024, made Germany the largest European economy to legalize adult-use cannabis. The law permits adults to possess up to 25 g in public and 50 g at home, cultivate up to three plants, and—since July 2024—join non-profit Cannabis Social Clubs (*Anbauvereinigungen*) of up to 500 members that collectively cultivate and distribute cannabis to their members. Members may receive up to 25 g per day and 50 g per month (30 g/month with a 10% THC cap for ages 18–21). As of early 2026, only a fraction of the hundreds of clubs that applied had received licenses, and the conservative CDU/CSU coalition that took power after the 2025 federal election has signaled possible tightening of the framework. Germany's clubs face precisely the inventory concentration problem described in Section 1.3: a 500-member club dispensing 50 g/month per member must manage up to 25 kg of monthly throughput, plus pipeline inventory from cultivation cycles of 3–5 months—volumes that, without a quantitative justification framework, invite regulatory scrutiny and law enforcement intervention. Separately, Germany's medical cannabis market—which generated over €450 million in 2024 and serves an estimated 200,000+ patients—saw a surge in prescriptions after legalization, prompting a 2025 amendment requiring in-person physi-

cian consultations and banning mail-order medical cannabis, further disrupting supply chains and inventory planning.

Spain. Spain presents the canonical example of legal indeterminacy in cannabis operations. An estimated 400 Cannabis Social Clubs (*asociaciones cannábicas*) operate across the country—concentrated in Catalonia and the Basque Country—under the Constitutional right of association, but without specific enabling legislation. The Spanish Supreme Court has ruled that "organized, institutionalized and persistent cultivation and distribution of cannabis among an association open to new members" constitutes drug trafficking under the Penal Code (Art. 368) (31), while simultaneously recognizing a narrow "shared consumption doctrine" that tolerates closed-group, non-commercial cultivation. The result is a legal gray zone where clubs that comply scrupulously with operational requirements (closed membership, non-profit structure, consumption logs, cultivation records) may still face prosecution if a court determines that their scale exceeds "shared consumption needs"—a determination made without reference to any quantitative standard. In 2024, Barcelona's city council ordered the closure of 30 clubs and intensified raids throughout tourist districts; in 2025, national police operations across Murcia, Tenerife, and Granada resulted in seizures of thousands of plants and prosecution of operators. The inability to distinguish legitimate collective cultivation from trafficking operations—precisely because no quantitative inventory standard exists—is the central enforcement failure that our framework addresses.

Canada. Canada's *Cannabis Act* (2018) (24) established the most comprehensive regulatory framework globally, with over 900 licensed producers, processors, and retailers subject to Health Canada oversight. Yet even this mature system faces inventory management challenges. As of early 2026, nearly 10,000 active personal and designated production registrations exist nationwide, with Health Canada having refused or revoked over 4,100 registrations—approximately 3,400 for public health and safety reasons—as of March 2025. The regulator has explicitly acknowledged concerns about "the potential for misuse and diversion of cannabis from these types of licences, especially those associated

with high daily limits." The Cannabis Tracking System (CTS), which requires monthly reporting of production, inventory, distribution, and sales data, generates the infrastructure for oversight but not the analytical framework for determining *optimal* inventory levels. Health Canada's 2025 amendments (25) streamlined reporting requirements and expanded micro-cultivation limits fourfold (to 800 m^2), reflecting an ongoing tension between reducing regulatory burden and maintaining diversion prevention—a tension that a principled inventory optimization framework could help resolve.

2.3 Inventory Models for Controlled Substances

The pharmaceutical industry has developed robust frameworks for managing inventories of controlled substances (Schedule II–V under the UN Single Convention on Narcotic Drugs, 1961) (33). The U.S. Drug Enforcement Administration (DEA) requires registrants to maintain Aggregate Production Quotas and Individual Manufacturing Quotas calibrated to estimated medical, scientific, and industrial demand plus allowances for exports and reserve stocks. These quotas are determined annually through a demand forecasting process codified in 21 CFR §1303 (30).

Similar systems exist internationally: the International Narcotics Control Board (INCB) requires parties to the Single Convention to furnish annual estimates of drug requirements, which serve as *de facto* inventory ceilings at the national level.

Cannabis, however, has historically been excluded from these estimation systems in most Latin American countries due to its Schedule I/IV status under international treaties. As jurisdictions create medicinal exceptions, they must develop inventory management frameworks *without* the institutional infrastructure that exists for other controlled substances.

2.4 Beyond Latin America: Global Applicability

While this paper's numerical illustrations focus on Latin American jurisdictions, the regulatory gap it addresses is global in scope. Mature cannabis markets in North America and emerging frameworks in Europe face structurally identical challenges—differing in

degree but not in kind.

In the United States, the majority of states with legal cannabis programs mandate seed-to-sale tracking through government-contracted platforms. Metrc (41) (Marijuana Enforcement Tracking Reporting Compliance), used in over 16 states including California, Colorado, Massachusetts, and Michigan, assigns unique RFID tags to every plant and package, recording each transition—from seedling to harvest, to processing, to laboratory testing, to retail sale—in a centralized state database. BioTrack provides similar functionality in other jurisdictions. These systems generate granular, time-stamped data on every gram of cannabis moving through the licensed supply chain, enabling regulators to verify that product entering a dispensary originated from a licensed cultivator and that no inventory is unaccounted for.

Canada, under the *Cannabis Act* (2018) (24), requires licensed producers to maintain detailed records of all cannabis produced, processed, stored, and sold, with monthly reporting to Health Canada. While Canada does not mandate a unified digital tracking platform comparable to Metrc, licensed producers operating under Health Canada's Good Production Practices (GPP) must maintain batch-level traceability conforming to ALCOA++ data integrity principles (Attributable, Legible, Contemporaneous, Original, Accurate, plus Complete, Consistent, Enduring, and Available).

These mature markets have thus solved the *traceability* problem: they can track where every gram is and where it came from. What they have *not* solved is the *optimization* problem: how much inventory *should* each node in the supply chain hold? The traceability infrastructure generates precisely the data—production volumes, yield per plant, batch testing pass rates, demand by product type and time period—needed to calibrate the stochastic model proposed in this paper. A Metrc-integrated implementation of our framework could provide licensed operators with real-time, data-driven inventory recommendations that simultaneously satisfy regulatory compliance requirements, minimize diversion risk, and guarantee target patient service levels.

As discussed in Section 1.1, the federal reclassification of cannabis to Schedule III creates powerful structural momentum toward interstate commerce. The prospect of

interstate supply chains transforms the inventory management problem from a single-facility optimization to a multi-echelon network design challenge. Interstate commerce introduces additional lead time variability (cross-state transportation, customs-equivalent regulatory inspections), demand uncertainty (serving heterogeneous state markets with different product preferences and consumption patterns), and regulatory heterogeneity (differing state-level testing requirements, potency limits, and packaging standards). Each node in an interstate supply chain—cultivator, processor, distributor, dispensary—must determine its own optimal inventory level while accounting for upstream supply variability and downstream demand uncertainty. This is precisely the class of problem that our two-stage stochastic framework naturally accommodates, and for which the seed-to-sale data infrastructure (Metrc, BioTrack) already provides the calibration data.

The framework proposed here is therefore not only a tool for developing markets navigating legal uncertainty, but also a foundation for operational optimization in the industrialized, interstate cannabis supply chains that federal reclassification is poised to create. The convergence of regulatory reform (Schedule III reclassification), data infrastructure (seed-to-sale traceability), and analytical methodology (stochastic inventory optimization) positions this work at the intersection of an emerging and urgent operational need.

2.5 The Newsvendor Model and Extensions

The classical newsvendor model considers a decision-maker who must determine order quantity Q before observing demand D, which follows a known probability distribution $F(\cdot)$. Excess inventory incurs overage cost C_o per unit, while unmet demand incurs underage cost C_u per unit. The optimal order quantity is given by eq. (2).

Extensions relevant to our setting include: the newsvendor with random yield (11), where the quantity received is a random fraction of the quantity ordered or planted; the perishable inventory newsvendor (7), incorporating product lifetime; and the multi-period newsvendor (5), extending the single-period framework to sequential decisions.

The two-stage stochastic programming formulation of the farmer's problem (4) gen-

eralizes the newsvendor to multiple products with joint resource constraints—directly applicable to a multi-cultivar cannabis operation deciding how to allocate limited greenhouse capacity.

3 Model Formulation

3.1 Setting and Notation

Consider a licensed medicinal cannabis operator serving a patient population over a planning horizon of T periods (months). The operator cultivates K cannabis cultivars (indexed $k = 1, \ldots, K$), each with distinct cannabinoid profiles suited to different therapeutic applications. Table 1 summarizes the notation.

Table 1: Model notation.

Symbol	Definition
x_k	Number of clones planted of cultivar k (first-stage decision)
D_k	Random demand for finished product from cultivar k (g/period)
Y_k	Random yield per clone of cultivar k (g/clone)
C_k^u	Unit cost of unmet demand (underage) for cultivar k
C_k^o	Unit cost of excess inventory (overage) for cultivar k
S	Total greenhouse capacity (clone slots)
τ	Production lead time (periods from planting to finished product)
λ_k	Cannabinoid degradation rate for cultivar k (fraction/period)
$I_k^{\max}$	Maximum permissible inventory of cultivar k (regulatory ceiling)
α	Target patient service level (e.g., 0.95)

3.2 Cost Structure

The critical innovation of our model is a multi-dimensional cost structure that captures the unique characteristics of the medicinal cannabis context.

Underage cost (stockout). The cost of failing to meet patient demand comprises:

$$C_k^u = c_k^{\text{clinical}} + c_k^{\text{substitution}} + c_k^{\text{reputational}}, \tag{3}$$

where c_k^{clinical} represents the clinical harm from treatment interruption (quantifiable through quality-adjusted life years lost or equivalent metrics), $c_k^{\text{substitution}}$ is the cost of patients resorting to unregulated sources (a negative externality that undermines the regulatory regime itself), and $c_k^{\text{reputational}}$ captures the operator's loss of patient trust and regulatory standing.

Overage cost (excess inventory). The cost of maintaining inventory above patient needs comprises:

$$C_k^o = c_k^{\text{holding}} + c_k^{\text{degradation}} + c_k^{\text{diversion}} + c_k^{\text{legal}}, \tag{4}$$

where c_k^{holding} is the conventional warehousing and security cost, $c_k^{\text{degradation}}$ is the cost of cannabinoid potency loss over time, $c_k^{\text{diversion}}$ represents the expected cost of inventory diversion to illicit channels (a function of security controls and their efficacy), and c_k^{legal} is the expected legal-criminal cost—the probability of prosecution multiplied by the severity of sanctions, conditional on inventory level.

The term c_k^{legal} is particularly important and distinguishes this model from standard pharmaceutical inventory problems. In jurisdictions with vague possession thresholds, c_k^{legal} is not a step function (legal below threshold, criminal above) but a *continuous, increasing function of inventory level*—reflecting the reality that prosecutorial discretion and judicial assessment of "reasonable" quantities are probabilistic.

3.3 Two-Stage Stochastic Program

First stage (pre-planting decisions).

$$\min_{\{x_k\}} \sum_{k=1}^{K} c_k^{\text{plant}} \cdot x_k \; + \; \mathbb{E}_{\boldsymbol{\xi}}[\, Q(\mathbf{x}, \boldsymbol{\xi}) \,] \tag{5}$$

subject to:

$$\sum_{k=1}^{K} x_k \leq S \qquad \text{(greenhouse capacity)} \tag{6}$$

$$x_k \geq 0,\ x_k \in \mathbb{Z} \quad \forall\, k \tag{7}$$

where $\boldsymbol{\xi} = (D_1, \ldots, D_K,\, Y_1, \ldots, Y_K)$ is the vector of random variables and $Q(\mathbf{x}, \boldsymbol{\xi})$ is the second-stage recourse cost.

Second stage (post-harvest allocation). Given realized yield $Y_k \cdot x_k$ for each cultivar k and realized demand d_k:

$$Q(\mathbf{x}, \boldsymbol{\xi}) = \min_{\{s_k, e_k, w_k, r_k\}} \sum_{k=1}^{K} \left[\, C_k^u \cdot w_k \;+\; C_k^o \cdot e_k \;+\; c_k^{\text{extract}} \cdot r_k \,\right] \tag{8}$$

subject to:

$$s_k + e_k + r_k = Y_k \cdot x_k + I_k^{\text{initial}} \qquad \forall\, k \quad \text{(inventory balance)} \tag{9}$$

$$s_k + w_k = d_k \qquad \forall\, k \quad \text{(demand satisfaction)} \tag{10}$$

$$s_k + e_k \leq I_k^{\max} \qquad \forall\, k \quad \text{(regulatory ceiling)} \tag{11}$$

$$s_k,\ e_k,\ w_k,\ r_k \geq 0 \qquad \forall\, k \tag{12}$$

where s_k is quantity sold/dispensed, e_k is excess inventory carried, w_k is unmet demand (stockout), and r_k is quantity diverted to secondary processing (extraction into oils or concentrates).

3.4 The Optimal Inventory Bound

For the single-cultivar, single-period case, the model reduces to a modified newsvendor with random yield. If yield per clone follows $Y \sim \text{LogNormal}(\mu_Y, \sigma_Y^2)$ and demand follows

$D \sim \mathcal{N}(\mu_D, \sigma_D^2)$, the optimal planting decision satisfies:

$$x^* = \frac{F_D^{-1}\left(\dfrac{C^u}{C^u + C^o}\right)}{\mathbb{E}[Y]} \tag{13}$$

and the corresponding optimal inventory level (in expectation) is:

$$I^* = x^* \cdot \mathbb{E}[Y] = F_D^{-1}\left(\frac{C^u}{C^u + C^o}\right). \tag{14}$$

The **technically defensible inventory range** is then defined by:

$$I^{\text{floor}} = F_D^{-1}(\alpha) \tag{15}$$

$$I^{\text{ceiling}} = I^{\text{floor}} + \underbrace{\mu_D \cdot \tau}_{\text{pipeline stock}} + \underbrace{z_\beta \cdot \sigma_D \cdot \sqrt{\tau + \frac{\mu_D^2\, \sigma_Y^2}{\mathbb{E}[Y]^2}}}_{\text{safety stock (demand + yield)}} \tag{16}$$

where I^{floor} is the minimum inventory to guarantee service level α, and z_β is the safety factor corresponding to a desired protection level β against joint demand and yield variability.

3.5 Incorporating Cannabinoid Degradation

To account for perishability, we model usable inventory as a fraction of physical inventory:

$$I_k^{\text{usable}}(t) = I_k^{\text{physical}}(t) \cdot e^{-\lambda_k \cdot a(t)}, \tag{17}$$

where $a(t)$ is the average age of inventory at time t. This creates an endogenous upper bound on useful inventory: even absent regulatory ceilings, there exists a natural maximum beyond which additional inventory degrades faster than it can be dispensed. This result provides a *pharmacological* justification for inventory ceilings that complements the regulatory one.

4 Numerical Illustration

4.1 Parameter Calibration

We calibrate the model to a hypothetical licensed operator in Santiago, Chile, serving a registered patient population. Parameters are drawn from publicly available data and the academic literature.

Demand parameters. Chile's medicinal cannabis program does not publish granular demand data. We estimate demand from proxy sources: Fundación Daya (37) (Chile's largest patient advocacy organization) reports serving approximately 4,000 patients as of 2023. Clinical literature suggests average monthly consumption of 20–60 g of dried flower equivalent, depending on condition and administration route. We model demand as $D \sim \mathcal{N}(\mu_D = 120{,}000 \text{ g/month}, \sigma_D = 24{,}000 \text{ g/month})$ for a mid-scale operator serving 4,000 patients at 30 g/month average.

Yield parameters. Based on Backer et al. (3) and industry reports, indoor cannabis yield per clone is modeled as $Y \sim \text{LogNormal}(\mu = 4.0, \sigma = 0.5)$, corresponding to a median of approximately 55 g/plant with right-skewed distribution.

Cost parameters. We use the illustrative values in Table 2. Sensitivity analysis follows in Section 4.3.

Table 2: Baseline parameter values.

Parameter	**Value**	**Rationale**
C^u (underage)	USD 15/g	Clinical substitution cost + patient externality
C^o (overage)	USD 5/g	Holding + degradation + expected legal cost
τ (lead time)	4 months	Typical indoor cultivation cycle
λ (degradation)	0.02/month	THC degradation under proper storage
α (service level)	0.95	Target: 95% prescription fill rate

4.2 Results

With the baseline parameters, the critical ratio is:

$$\frac{C^u}{C^u + C^o} = \frac{15}{15+5} = 0.75. \tag{18}$$

The optimal base inventory is:

$$I^* = F_D^{-1}(0.75) = \mu_D + z_{0.75} \cdot \sigma_D = 120{,}000 + 0.674 \times 24{,}000 = 136{,}176 \text{ g}. \tag{19}$$

The pipeline stock for a 4-month lead time:

$$SS_{\text{pipeline}} = \mu_D \times \tau = 120{,}000 \times 4 = 480{,}000 \text{ g}. \tag{20}$$

The safety stock (at 95% protection):

$$SS_{\text{yield}} = z_{0.95} \cdot \sigma_D \cdot \sqrt{\tau + \frac{\mu_D^2 \, \sigma_Y^2}{\mathbb{E}[Y]^2}} \approx 86{,}400 \text{ g}. \tag{21}$$

Total defensible inventory: approximately 702 kg (702,576 g).

This figure—roughly 5.9 months of average demand—is the technically justifiable

maximum inventory for this operator. Any prosecution arguing that this quantity exceeds "reasonable" medicinal needs would need to demonstrate that the model's assumptions are flawed, not that the quantity is "too large" in absolute terms.

4.3 Sensitivity Analysis

We examine how the optimal inventory changes with key parameters.

Service level sensitivity. Increasing the target service level from 90% to 99% increases optimal inventory by approximately 35%, reflecting the well-known tradeoff between service level and inventory investment (Table 3).

Table 3: Sensitivity to target service level.

Service Level (α)	**Optimal Inventory (kg)**	**Months of Coverage**	**Stockout Prob.**
0.90	618	5.2	10.0%
0.95	703	5.9	5.0%
0.97	762	6.4	3.0%
0.99	948	7.9	1.0%

Cost ratio sensitivity. The ratio C^u/C^o is the primary determinant of optimal inventory. When the clinical and social costs of stockouts are perceived as high relative to the legal costs of excess inventory, the model prescribes higher inventories. Conversely, in jurisdictions where narcotics enforcement is aggressive, the model prescribes lower inventories—quantifying the chilling effect that punitive drug policy exerts on patient access (Table 4).

Table 4: Sensitivity to cost ratio.

Scenario	C^u **(USD/g)**	C^o **(USD/g)**	**Critical Ratio**	**Opt. Inv. (kg)**
High clinical priority	25	3	0.89	849
Baseline	15	5	0.75	703
High legal risk	10	15	0.40	474
Hostile enforcement	5	25	0.17	351

The "hostile enforcement" scenario—where the expected legal cost of excess inventory vastly exceeds the perceived cost of patient stockouts—results in an inventory level that covers only 2.9 months of demand. Given a 4-month production lead time, this *guarantees* supply disruptions. This result formalizes the intuition that excessively punitive drug policy, absent clear inventory guidelines, is incompatible with reliable patient access.

Lead time sensitivity. Production lead time has a multiplicative effect on required inventory through the pipeline stock component. Operators with faster production cycles (e.g., autoflowering cultivars at 75 days, or pre-established mother plant banks reducing propagation time) can justify lower inventories. This has regulatory implications: policies that support operational efficiency in licensed cultivation directly reduce the inventory levels required to maintain service, thereby reducing diversion risk.

4.4 Cross-Country Comparison

We apply the framework to three regulatory contexts to illustrate how the same model produces jurisdiction-specific inventory recommendations.

Chile (restrictive). Under Law 20.000, criminal penalties for drug trafficking are severe (5–15 years) and the boundary between "personal use" and "trafficking" is judicially determined case-by-case. We model this as a high-c^{legal} environment. Result: the model recommends conservative inventory ($\approx$500 kg for our reference operator) with mandatory documentation linking every gram to a registered patient prescription.

Colombia (permissive framework, moderate enforcement). Colombia's licensing system provides regulatory cover for licensed operators, reducing c^{legal}. We model this as moderate-c^{legal}. Result: the model recommends higher inventory ($\approx$750 kg), justified by the additional export channel that creates demand volatility requiring larger buffers.

Argentina (fragmented). REPROCANN authorizes personal and community cultivation, creating a decentralized system where many small operators each hold modest quantities. The per-operator inventory is lower, but the same principles apply at each node. Result: the model recommends per-association inventories proportional to registered membership, with a recommended 4-month rolling supply.

5 Policy Implications

5.1 From Arbitrary Thresholds to Evidence-Based Inventory Standards

The model's primary policy contribution is replacing arbitrary or undefined inventory limits with a quantitative methodology grounded in observable parameters. We propose that regulatory agencies adopt the following framework.

Demand-linked inventory authorization. Each licensed operator's permissible inventory ceiling should be a function of: (i) the number of patients served, as documented through prescription registries; (ii) average consumption per patient, based on clinical protocols; (iii) the coefficient of variation of demand, reflecting the predictability of patient needs; and (iv) the production lead time specific to the operator's cultivation method.

This approach has the advantage of being self-adjusting: as the operator's patient base grows or shrinks, the justifiable inventory changes proportionally—without requiring regulatory amendments or ad hoc negotiations.

Standard inventory formula. We propose that jurisdictions adopt a standard formula for the maximum justifiable inventory:

$$I^{\max} = N \cdot \bar{d} \cdot \left(\tau + z_\alpha \cdot CV_D \cdot \sqrt{\tau}\right), \tag{22}$$

where N is the number of registered patients, $\bar{d}$ is the average monthly dose per patient (grams), τ is the production lead time in months, z_α is the safety factor for target service level α, and CV_D is the coefficient of variation of aggregate demand.

This formula can be: (a) published as a regulatory guideline; (b) applied by operators for self-assessment; (c) verified by inspectors through routine audits; and (d) cited by courts as the standard of reasonableness in prosecutorial proceedings.

5.2 Implications for Criminal Justice

In jurisdictions where possession of cannabis above an undefined threshold triggers criminal investigation, the model provides an *expert-witness-grade* tool for assessing whether an operator's inventory is consistent with legitimate medicinal supply. The defense argument is straightforward: the inventory level is the output of a peer-reviewed, published optimization model calibrated to the operator's documented patient base, verified prescription records, and auditable production data.

This shifts the burden of proof. Rather than the operator needing to justify why they hold a certain quantity (a subjective inquiry with no clear standard), the prosecution would need to demonstrate either that the model's parameters are incorrect (an empirical claim that can be tested) or that the operator's actual inventory exceeds the model's recommended ceiling by a margin indicative of diversion intent.

5.3 The Paradox of Excessive Restriction

Our sensitivity analysis reveals a counterintuitive but important policy insight: *overly restrictive inventory limits can increase rather than decrease diversion risk.* When legal operators are forced to maintain sub-optimal inventories, patients experience stockouts

and turn to unregulated sources. These unregulated sources—by definition—have no traceability, no quality control, and no inventory accountability. The aggregate effect is a net increase in the volume of cannabis circulating outside regulatory oversight.

We formalize this as a "diversion paradox": let $V^{\text{unreg}}(\bar{I})$ denote the volume of cannabis obtained through unregulated channels as a function of the regulatory inventory ceiling $\bar{I}$. Under reasonable assumptions about patient behavior (patients seek unregulated supply when legal supply is unavailable), we have:

$$\frac{\partial V^{\text{unreg}}}{\partial \bar{I}} < 0 \quad \text{for} \quad \bar{I} < I^*, \tag{23}$$

i.e., *increasing* the legal inventory ceiling *decreases* unregulated market volume, up to the optimal inventory level. Beyond I^*, additional legal inventory no longer displaces unregulated supply and merely increases holding costs and diversion opportunity.

This result has direct policy implications: there exists an interior optimum $\bar{I}^*$ that minimizes total unregulated cannabis volume. Setting the regulatory ceiling below this optimum is counterproductive from a public health and drug control perspective.

5.4 Implementation Roadmap

We propose a phased implementation strategy for regulatory adoption:

Phase 1: Data infrastructure. Establish standardized patient registries and prescription tracking systems that generate the demand data required to calibrate the model. Several Latin American countries already have partial systems (Chile's ISP registry, Colombia's INVIMA database, Argentina's REPROCANN) that can be extended.

Phase 2: Pilot calibration. Apply the model to a small number of licensed operators to generate initial inventory recommendations and validate them against actual dispensing data. Iteratively refine the demand distribution parameters.

Phase 3: Regulatory publication. Publish the standard inventory formula (eq. (22)) as a regulatory guideline, with jurisdiction-specific parameter values for z_α and CV_D based on pilot data.

Phase 4: Judicial integration. Develop expert-witness protocols and training materials that enable the model to be presented as evidence in criminal proceedings. Engage with judicial academies and prosecutorial training programs.

6 Limitations and Future Research

This paper has several limitations that suggest directions for future research.

First, our cost parameters—particularly c^{clinical} and c^{legal}—are illustrative rather than empirically estimated. A natural extension is to conduct stated-preference or revealed-preference studies to estimate the clinical cost of treatment interruption and the expected legal cost of excess inventory across jurisdictions. Discrete choice experiments with patients and legal professionals could provide robust estimates.

Second, we model demand as stationary, whereas in practice the medicinal cannabis patient population is growing rapidly across Latin America. A non-stationary demand model with trend and seasonality components would improve the framework's applicability to growing markets.

Third, we treat each cultivar independently in the single-period analysis. In practice, demand substitution across cultivars (e.g., a patient switching from a high-THC to a balanced cultivar when the former is unavailable) creates cross-cultivar dependencies that the multi-cultivar stochastic program captures but the closed-form solutions do not.

Fourth, the model assumes a single operator. Network-level extensions—coordinating inventory across multiple operators, or between operators and a centralized government stockpile—could further reduce system-wide inventory requirements while maintaining patient service levels.

Finally, the political economy of inventory regulation deserves attention. The model assumes a rational regulator seeking to balance patient access and diversion risk, but ac-

tual regulatory behavior is shaped by electoral incentives, international treaty obligations, and public opinion regarding drug policy. Integrating these factors into the framework requires a political economy extension beyond the scope of this paper.

7 Conclusion

This paper proposes a quantitative framework for determining optimal inventory levels for medicinal cannabis in Latin American jurisdictions where the absence of explicit guidelines creates legal uncertainty, operational risk, and patient harm. By adapting the classical newsvendor model to incorporate clinical, legal-criminal, and pharmacological cost dimensions alongside agricultural yield uncertainty, we produce technically defensible inventory bounds that can serve regulators, operators, and courts.

The central policy insight is that inventory management for medicinal cannabis is not a law enforcement problem to be solved through arbitrary restrictions, but an operations management problem to be solved through evidence-based optimization. The tools exist; the data infrastructure is developing; and the regulatory need is acute. We hope this paper contributes to the transition from discretionary judgment to quantitative standards in a domain where the consequences of poor inventory decisions fall ultimately on patients.

References

[1] Arrow, K. J., Harris, T., & Marschak, J. (1951). Optimal inventory policy. *Econometrica*, 19(3), 250–272.

[2] Abu Zwaida, T., Pham, C., & Beauregard, Y. (2026). Harmonizing health logistics: A digital framework for balancing medical cannabis demand and supply. *Sustainable Futures*, 7, 100483.

[3] Backer, R., Schwinghamer, T., Rosenber, P., et al. (2019). Closing the yield gap for cannabis: A meta-analysis of factors determining cannabis yield. *Frontiers in Plant Science*, 10, 495.

[4] Birge, J. R. & Louveaux, F. (2011). *Introduction to Stochastic Programming.* Springer, 2nd edition.

[5] Khokhlov, V. (2026). Multi-period newsvendor model. *arXiv preprint arXiv:2602.11821.*

[6] Nagurney, A., Daniele, P., & Shukla, S. (2015). A supply chain network game theory model of cybersecurity investments with nonlinear budget constraints. *Annals of Operations Research*, 248(1–2), 405–427.

[7] Nahmias, S. (1982). Perishable inventory theory: A review. *Operations Research*, 30(4), 680–708.

[8] Naim-Feil, E., Breen, E. J., Pembleton, L. W., et al. (2022). Empirical evaluation of inflorescences' morphological attributes for yield optimization of medicinal cannabis cultivars. *Frontiers in Plant Science*, 13, 858519.

[9] Pongsakornrungsilp, S., et al. (2023). An innovation framework of medical organic cannabis traceability in digital supply chain. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(4), 196.

[10] Uthayakumar, R. & Priyan, S. (2013). Pharmaceutical supply chain and inventory management strategies: Optimization for a pharmaceutical company and a hospital. *Operations Research for Health Care*, 2(3), 52–64.

[11] Yano, C. A. & Lee, H. L. (1995). Lot sizing with random yields: A review. *Operations Research*, 43(2), 311–334.

[12] Petruzzi, N. C. & Dada, M. (1999). Pricing and the newsvendor problem: A review with extensions. *Operations Research*, 47(2), 183–194.

[13] López-Mata, E., et al. (2022). Crop planting and harvesting planning: Conceptual framework and sustainable multi-objective optimization for plants with variable molecule concentrations. *Applied Mathematical Modelling*, 112, 495–515.

[14] República de Chile (2005). Ley 20.000: Sustituye la Ley N°19.366, que sanciona el tráfico ilícito de estupefacientes y sustancias sicotrópicas. *Diario Oficial de la República de Chile*, 16 de febrero de 2005. Available at: https://www.bcn.cl/leychile/navegar?idNorma=235507

[15] República de Chile (2015). Decreto 867: Aprueba reglamento que regula productos de uso médico elaborados a base de cannabis y sus derivados. *Ministerio de Salud*, 2015. Available at: https://www.bcn.cl/leychile/navegar?idNorma=1090894

[16] República de Chile (2023). Ley 21.545: Modifica el Código Sanitario y otros cuerpos legales, en materia de uso medicinal de productos de cannabis y sus derivados. *Diario Oficial de la República de Chile*, 2023.

[17] República de Colombia (2016). Ley 1787 de 2016: Por medio de la cual se reglamenta el Acto Legislativo 02 de 2009 [marco regulatorio del cannabis medicinal y científico]. *Diario Oficial*, 6 de julio de 2016.

[18] República de Colombia (2017). Decreto 613 de 2017: Por el cual se reglamenta la Ley 1787 de 2016 y se subroga el Título 11 de la Parte 8 del Libro 2 del Decreto 780 de 2016, en relación con el acceso seguro e informado al uso médico y científico del cannabis. *Ministerio de Salud y Protección Social*, 10 de abril de 2017.

[19] República Argentina (2017). Ley 27.350: Investigación médica y científica del uso medicinal de la planta de Cannabis y sus derivados. *Boletín Oficial de la República Argentina*, 19 de abril de 2017.

[20] República Argentina (2020). Decreto 883/2020: Reglamentación de la Ley N° 27.350. Creación del Programa Nacional para el Estudio y la Investigación del Uso Medicinal de la Planta de Cannabis (REPROCANN). *Boletín Oficial*, 12 de noviembre de 2020.

[21] República Oriental del Uruguay (2013). Ley 19.172: Marihuana y sus derivados— Control y regulación del Estado de la importación, producción, adquisición, almacenamiento, comercialización y distribución. *Diario Oficial*, 7 de enero de 2014.

[22] República del Perú (2017). Ley 30681: Ley que regula el uso medicinal y terapéutico del cannabis y sus derivados. *Diario Oficial El Peruano*, 17 de noviembre de 2017.

[23] Bundesrepublik Deutschland (2024). Cannabisgesetz (CanG): Gesetz zum kontrollierten Umgang mit Cannabis und zur Änderung weiterer Vorschriften. *Bundesgesetzblatt*, Teil I, Nr. 109, 27. März 2024. Effective 1 April 2024.

[24] Government of Canada (2018). *Cannabis Act* (S.C. 2018, c. 16). Available at: https://laws-lois.justice.gc.ca/eng/acts/c-24.5/

[25] Health Canada (2025). Regulations Amending Certain Regulations Concerning Cannabis (Streamlining of Requirements), SOR/2025-37. *Canada Gazette, Part II*, Vol. 159, No. 6, 12 March 2025.

[26] Health Canada (2025). Compliance and enforcement report: Cannabis inspection data summary 2024–2025. Available at: https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/research-data/compliance-enforcement-report-cannabis-inspection-data-summary/2024-2025.html

[27] Health Canada (2025). Notice of Intent: Potential amendments to the Cannabis Tracking System Order (CTSO). *Canada Gazette, Part I*, Vol. 159, No. 35, 30 August 2025.

[28] The White House (2025). Executive Order: Increasing Medical Marijuana and Cannabidiol Research. 18 December 2025.

[29] U.S. Department of Justice (2026). Final order: Schedules of controlled substances—Rescheduling of certain categories of marijuana to Schedule III. *Federal Register*, 23 April 2026.

[30] U.S. Drug Enforcement Administration (2024). Title 21, Code of Federal Regulations, Part 1303: Quotas. 21 CFR §1303.

[31] Reino de España (1995). Ley Orgánica 10/1995, de 23 de noviembre, del Código Penal, Artículos 368–378 [Delitos contra la salud pública]. *Boletín Oficial del Estado*, Núm. 281, 24 de noviembre de 1995.

[STC 144/2017] Tribunal Constitucional de España (2017). Sentencia 144/2017, de 14 de diciembre de 2017: Inconstitucionalidad de la Ley Foral 24/2014 de Navarra reguladora de los Clubes Sociales de Cannabis. *BOE*, Núm. 15, 17 de enero de 2018.

[33] United Nations (1961). Single Convention on Narcotic Drugs, 1961, as amended by the 1972 Protocol. *United Nations Treaty Series*, vol. 520, p. 151.

[34] Corte Suprema de Chile (2025). Rol N° 54.608-2025, Segunda Sala Penal. Fallo de mayo de 2026: Anulación de condena por tráfico de drogas por posesión de 100,3 gramos de cannabis; recalificación a falta del artículo 50 de la Ley 20.000; multa de 1 UTM.

[35] Corte Suprema de Chile (2025). Rol N° 54.489-2025, Segunda Sala Penal. Confirmación de condena por microtráfico por posesión de 23 gramos de cannabis con indicios de comercialización.

[36] International Narcotics Control Board (2024). *Report of the International Narcotics Control Board for 2024*. United Nations, Vienna.

[37] Fundación Daya (2023). Memoria anual 2023. Santiago, Chile. Available at: https://www.fundaciondaya.org/

[38] Instituto de Regulación y Control del Cannabis (2023). Informe de gestión y mercado regulado de cannabis, Uruguay. Available at: https://www.ircca.gub.uy/

[39] StratCann (2026). Health Canada, Public Safety Canada provide updates on personal/designated medical cannabis licences. 26 April 2026. Available at: https://stratcann.com/news/health-canada-public-safety-personal-designated-medical-cannabis/

[40] Prohibition Partners (2025). Germany adult-use cannabis market 2025. *European Cannabis Report 2025*. Available at: https://prohibitionpartners.com/

[41] Metrc LLC (2024). Metrc: Cannabis regulatory tracking system. Available at: https://www.metrc.com/