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Financial Modeling and Scenario Analysis of a Sugarcane Plantation: Assessing Profitability and Sustainability

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Abstract

Sugarcane plays a strategic role in Brazil's economy, positioning the country as a global leader in both sugar and ethanol production. The sector contributes significantly to exports, rural employment, and renewable energy policy, making its financial sustainability a matter of national interest. A defining characteristic of sugarcane cultivation is its semi-perennial nature, which allows for multiple harvests from a single planting through successive ratoon cycles. This factor introduces complex economic and agronomic dynamics that are often underrepresented in existing financial models.

Despite its importance, the financial modeling of sugarcane production has traditionally relied on static assumptions, outdated datasets, and limited capacity for scenario analysis—factors that reduce its usefulness for decision-making under uncertainty. This thesis develops a comprehensive and flexible financial model tailored to the Brazilian sugarcane sector, explicitly incorporating the semi-perennial structure of the crop through detailed modeling of ratoon stages. The model also integrates agronomic, climatic, internal operational, and external economic variables such as rainfall variability, harvest timing, input costs, and market volatility.

A central objective is to evaluate whether a farm operating under an optimized scenario can generate sufficient returns to acquire or finance the operations of a baseline or worst-case scenario farm. This analysis is conducted from two perspectives: one based solely on internal, controllable factors, and another incorporating broader external conditions.

By combining up-to-date financial data with multi-variable scenario simulations, comparative performance analysis, and stress testing, this research delivers a dynamic and practical decision-support tool for producers, investors, and policymakers seeking to enhance the sustainability and strategic planning capacity of the Brazilian sugarcane industry.

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"All models are wrong, but some are useful."
— George E. P. Box

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Chapter 1

Introduction

1.1 Background and Motivation

Sugarcane occupies a central place in Brazil's economy both as a commodity and as the backbone of the country's renewable-energy strategy. In the 2023/24 harvest, Brazil produced some 716 million tonnes of cane-roughly 38 % of global output-and generated R$ 111.2 billion (equivalent to € 20.55 billion at an exchange rate of R$ 1 = € 0.1848 on 31 March 2024) of gross production value from 9.6 million hectare, making it the fourth-largest crop by value in Brazilian agribusiness, behind only soybeans, cattle, poultry, and corn [1, 2]. Beyond sugar, sugarcane by-products underpin a vast bioenergy sector: ethanol from cane juice and molasses displaces imported petroleum, while bagasse cogeneration supplies both process heat and grid-exported electricity, reinforcing Brazil's commitments under the Paris Agreement and exemplifying circular-economy principles [3, 4].

This crop's semi-perennial nature-with multiple ratoon cycles and periodic replanting-introduces complex agronomic and economic dynamics that challenge standard financial projections. Each ratoon cycle delivers declining yields and shifts in input requirements, while replanting incurs significant up-front costs and alters multi-year cash flows.

Despite its strategic importance, existing financial models of sugarcane production remain insufficiently equipped to support high-stakes decision-making under volatility. Early frameworks such as Hoekstra, 1976[5] introduced discounted-cash-flow thresholds for replanting but were largely static and field-specific. More recent viability studies, such as Rezende, 2015 [6], have employed Monte Carlo simulations at the processing level, yet they typically examine single-variable sensitivities (e.g. rainfall or price shocks) rather than the interdependent effects of ratoon longevity, field renovation timing, input-cost inflation, and commodity-price volatility. Moreover, many models rely on outdated or geographically limited datasets-e.g. Roka et al.'s detailed budget analysis of Florida sugarcane production [7]-limiting their relevance to current Brazilian conditions.

These gaps underscore the need for a flexible, data-driven financial model that integrates agronomic cycles, operational costs, and market uncertainties into a unified scenario-analysis framework-providing a robust decision-support tool for producers, investors, and policy-makers in Brazil's sugarcane sector.

1.2 Problem Statement

Brazil relies heavily on sugarcane for both economic growth and renewable energy production. However, the financial models commonly used to evaluate sugarcane farms are too simple to handle the real-world challenges producers face. Most models assume fixed yields and constant prices, testing only one factor at a time. This means they miss how yield declines over successive ratoon cycles interact with rising input costs and volatile market prices [5, 1].

Many existing studies also depend on outdated or geographically narrow data. For example, some models use cost tables from U.S. sugarcane budgets or surveys conducted before 2010, which do not reflect the current practices, cost structures, or climate conditions in Brazil's Center–South region [7]. Without up-to-date, locally relevant data, these models can give misleading profit estimates and investment signals.

Moreover, few tools incorporate weather variability, exchange-rate swings, or policy changes into a single analysis. In practice, a drought one year or a sudden drop in the real's value can cut revenues sharply, but traditional models rarely let users stress-test these combined risks. As a result, farmers and investors lack clear guidance on how to plan for bad seasons or sudden market shocks.

Because of these gaps, decision-makers do not have a flexible, integrated "what-if" tool that brings together agronomic cycles, cost dynamics, and market uncertainty. They need a model that can simulate multiple scenarios at once-showing how different factors work together to affect cash flow, profitability, and investment returns-so they can make better decisions about planting, replanting, and financing.

1.3 Research Objectives

The objectives of this thesis are as follows:

1. **Develop a flexible financial model for a typical mid-sized sugarcane plantation in Brazil (approximately 300 ha)**.

   To achieve this, the model is constructed modularly with separate input, calculation, and output layers. The input layer consolidates agronomic, operational, and market assumptions in a user-friendly control panel. The calculation layer automates volume projections, revenue and cost breakdowns, and composite influence factors, ensuring transparency and auditability. The output layer generates dynamically linked financial statements and valuation metrics (NPV, IRR, payback period, EV/EBITDA), allowing real-time scenario updates.

2. **Explicitly include multiple ratoon cycles and replanting costs in cash-flow projections.**

   We model semi-perennial cultivation by applying an exponential yield-decline function for successive ratoons, calibrated with decay constant $k = 0.145$ for irrigated fields. Ratoon yield projections feed into volume forecasts, while scheduled replanting after a user-defined number of cycles triggers establishment costs, capturing both yield decline and renewal expenses .

3. **Integrate agronomic, operational, and market variables into a unified scenario-analysis framework.**

   The model combines seven composite factors-four internal (ratoon decay, planting-date multipliers, pesticide-use adjustments, water availability) and three external (price elasticity of sugar/ethanol, oil-cost indexing, currency exposure)-multiplying them to simulate multi-driver scenarios. The resulting two-dimensional matrix supports stress-testing across optimistic, base-case, and pessimistic environments, revealing interaction effects on profitability.

4. **Evaluate an optimized farm's capacity to finance or acquire a baseline or adverse-scenario farm.**

   Through acquisition analysis, the model calculates the maximum bid price an optimized ("good management") farm can pay for a peer under baseline or poor-management conditions, using target IRR and debt-service coverage thresholds. This comparison offers practical benchmarks for investors assessing acquisition feasibility under varying external conditions.

1.4 Research Questions

This thesis is structured around two central questions that drive the model design and analysis:

1. **Under what combination of internal (controllable) and external conditions can an optimized farm finance a baseline or worst-case farm?** To answer this, we will:

- Define “internal” factors as those under management control (ratoon-cycle planning, planting-date timing, pesticide and fertilizer use, irrigation scheduling) and “external” factors as those beyond direct control (sugar and ethanol price trajectories, oil-cost inflation, exchange-rate swings, seasonal water availability).
- Use the acquisition-analysis module to calculate, for each external scenario (optimistic, base, pessimistic), the maximum bid price an optimized (“good-management”) farm can pay for a peer operating under baseline or poor-management conditions, subject to target IRR and debt-service coverage thresholds.
- Identify the boundary conditions-i.e. the sets of internal/external parameter values-where acquisition remains viable, thereby informing investors and producers about the resilience of optimized operations against underperforming peers.

2. **How do multi-variable scenarios affect key financial metrics (NPV, IRR, cash-flow)?** To explore this, we will:

   - Construct a two-dimensional scenario matrix by crossing three external environments (optimistic, base-case, pessimistic) with three internal regimes (good, basic, poor management).
   - For each of the nine resulting scenarios, project the full set of financial statements and calculate valuation metrics-net present value (NPV), internal rate of return (IRR), payback period, and annual free cash-flow to the firm (FCFF)-as detailed in the Valuation tab of the model.
   - Analyze how interactions among agronomic decay rates, input-cost inflation, and price volatility drive variability in these metrics, highlighting which factor combinations pose the greatest upside potential or downside risk.

1.5 Scope and Contributions

The scope of this thesis is limited to mid-sized commercial sugarcane plantations (approximately 300 ha) in Brazil’s Center–South region, with particular focus on the states of São Paulo, Goiás, and Minas Gerais. These states together account for the vast majority of national sugarcane output, ensuring that the model reflects the most representative production systems while excluding smallholder and very large-scale outliers.

This work delivers three main contributions:

- **Scenario-analysis framework:** We integrate agronomic optimization (ratoon-cycle planning, planting-date timing, agrochemical and irrigation strategies) with market stress tests (sugar and ethanol price trajectories, oil-indexed input costs, exchange-rate fluctuations, rainfall variability). By crossing internal management regimes (good, basic, poor) with external environments (optimistic, base-case, pessimistic), the model enables comprehensive "what-if" simulations of yield, cost, and return interactions.

- **Modular decision-support tool:** Implemented in a spreadsheet, the tool produces dynamically linked financial statements (income statement, balance sheet, cash-flow statement), valuation metrics (NPV, IRR, payback period, free cash flow), and acquisition-analysis outputs (maximum bid prices under varying conditions). This allows producers, investors, and policymakers to perform real-time sensitivity analyses and risk assessments in a user-friendly interface.

- **Empirical calibration and validation:** All model parameters and assumptions are calibrated using up-to-date, region-specific data from CONAB, IBGE, Embrapa, and industry associations, ensuring that projections reflect current agronomic practices, cost structures, and market conditions in Brazil's Center–South region.

1. **Chapter 1: Introduction** – Presents the motivation, problem statement, research objectives and questions, scope and contributions, and the overall structure of the thesis.

2. **Chapter 2: Literature Review** – Reviews the agronomic characteristics of sugarcane, existing financial modeling approaches, scenario-analysis frameworks, and identifies key gaps in the literature.

3. **Chapter 3: Methodology** – Describes the design and implementation of the financial model, the data sources and calibration procedures, the modeling of ratoon cycles and cost dynamics, and the scenario-generation and valuation methods.

4. **Chapter 4: Financial Model Proposition** – Details the modular, ratoon-aware model architecture (input, calculation, statement and valuation layers) and demonstrates its auditability and transparency

5. **Chapter 5: Application & Results** – Applies the model to a 300 ha Center–South plantation; presents multi-scenario and acquisition analyses; and conducts sensitivity tests across key drivers

6. **Chapter 6: Conclusion and Discussion** – Summarizes the main findings, answer the questions and objectives raised in the Introduction and discusses their implications for producers and investors, outlines the study's limitations, and proposes directions for future research.

Chapter 2

Literature Review

In the context of agribusiness, particularly in Brazil, the effective management of assets plays a crucial role in determining a company's financial success. This is especially true for sugarcane plantations, a key driver of the Brazilian economy. Brazil is the world's largest producer of sugarcane, responsible for a significant share of global sugar and ethanol production. Given this economic importance, optimizing the management of sugarcane plantations can lead to substantial financial benefits for producers, while inadequate management practices may result in diminished returns and reduced competitiveness.

The goal of this literature review is to provide an in-depth analysis of the financial dynamics and management strategies that affect the profitability of sugarcane plantations. A comprehensive understanding of asset management, risk mitigation, and financial modeling in agricultural operations is essential to answering the core questions of this thesis. These questions center around how changes in asset management practices influence the overall value of a company, how various factors impact profitability, and how companies can use these insights to gain competitive advantages, including the potential acquisition of competitors.

By reviewing the existing body of literature, this study will explore several key areas: the significance of sugarcane as an economic asset in Brazil, the critical factors that influence financial returns in sugarcane production, the importance of effective asset management, and risk management strategies for protecting financial returns. Case studies of successful asset management in agriculture will also be examined to provide real-world examples of how companies can leverage strategic management to enhance profitability.

2.1 The Plantation

Sugarcane plantations in Brazil represent not only vast agricultural landscapes but also highly organized operations that integrate technological advancements, labor management, and resource allocation to maximize yields and economic returns. Effective management practices in sugarcane cultivation encompass all stages, from land preparation and planting to harvest and post-harvest handling. Each phase of this process is optimized in large-scale plantations to address both agronomic needs and financial objectives.

2.1.1 Land Preparation and Planting Methods

In large-scale sugarcane farming, efficient land preparation is the foundation of a successful plantation. Mechanized tilling and leveling are widely adopted in Brazil to prepare the soil for planting, as they allow for a uniform bed structure that supports robust root establishment and maximizes resource utilization [8]. These practices reduce labor intensity and increase the precision of planting operations. Mechanized planting is favored for its ability to maintain optimal row spacing and depth, which are essential to maximize sunlight exposure and support dense plant growth [9]. Studies further highlight that mechanized planting improves efficiency, reducing overall costs compared to manual planting methods [10].

2.1.2 Growth Cycle of Sugarcane

The growth cycle of sugarcane involves key developmental stages, beginning with germination, where initial shoots and roots emerge to establish a foundation for future growth. Strong root development in this phase is essential, as it supports the plant's ability to uptake water and nutrients, helping to withstand environmental stresses and sustain healthy growth [11]. Research highlights that pre-germinated buds enhance stand establishment, leading to denser and more productive fields [12].

2.1.3 Irrigation and Water Management

Effective water management is critical throughout the sugarcane growth cycle, especially given the crop's high water demand during its vegetative phase. Common irrigation techniques, such as drip and furrow irrigation, are frequently used to maintain consistent soil moisture, supporting robust growth and optimal yield potential [13].

Modern sugarcane plantations in Brazil often employ advanced water management systems, including automated irrigation and precision agriculture technologies, which enable efficient water distribution based on real-time soil and crop data. This approach helps conserve water resources, minimizes costs, and ensures sustainable practices [14].

2.1.4 Maturity and Harvest

Sugarcane typically requires between 12 and 18 months to reach maturity, depending on climate and environmental conditions. The timing of the harvest is carefully managed in large Brazilian plantations to align with these conditions, optimizing both yield and sugar content [15].

The harvest process itself is often mechanized in large-scale operations, with mechanized systems significantly enhancing efficiency and reducing labor costs. Mechanized harvesting also minimizes damage to the cane, preserving its quality. In contrast, smaller plantations may rely on manual harvesting due to cost constraints or the scale of operations [15].

2.1.5 Post-Harvest Handling

Efficient post-harvest handling is vital in sugarcane production, particularly the rapid transportation of harvested cane to processing mills. Delays in transportation can result in sucrose degradation, thereby affecting the quality and economic value of the final product [16].

Once delivered to the mill, sugarcane undergoes immediate processing to extract juice, which is converted into sugar or ethanol. The speed of this process is essential, as rapid post-harvest processing preserves the sugar content, preventing losses in quality and maximizing yield [17].

2.1.6 The plantation semi-perennial characteristic

Sugarcane's semi-perennial habit allows a single planting to yield multiple harvests via ratooning, reducing both replanting frequency and establishment costs. After the first ("plant-cane") crop is cut, dormant buds on the remaining stubble break dormancy and produce successive shoots-ratoons, that mature into full-size stalks without renewing the seed cane. While each ratoon cycle delivers slightly lower yields, it also shortens the interval between harvests and minimizes soil disturbance. This balance of declining per-cycle productivity and lower input outlays underpins the economic logic of ratooning in Brazilian plantations. As illustrated in Figure 2.1, ratoon shoots emerge directly from last season's stubble, exemplifying how semi-perennial growth sustains multi-year production from one planting [18].

Figure 2.1: Ratoon shoots emerging from sugarcane stubble, illustrating the ratoon cropping cycle

2.1.7 By-Products and Their Importance

In the Brazilian sugarcane industry, by-products like bagasse and molasses are fundamental to both economic viability and environmental sustainability. Bagasse, the fibrous residue left after extracting juice from sugarcane, plays a crucial role in the bioenergy sector. In sugarcane mills across Brazil, bagasse is used in cogeneration systems to produce both electricity and steam. This dual-purpose system not only powers the mills themselves but also significantly reduces operational costs by making these facilities largely energy self-sufficient [3].

The environmental benefits of bagasse-based bioenergy are also considerable. Using bagasse instead of fossil fuels for energy generation reduces greenhouse gas emissions and decreases dependency on nonrenewable energy sources. The carbon neutrality of bagasse – since it emits only the CO_2 it absorbed during growth – makes it a valuable tool in Brazil's pursuit of sustainability and its commitments under international climate agreements, such as the Paris Agreement. By relying on bagasse for energy, Brazil's sugarcane industry sets an example of how agriculture can contribute to a low-carbon economy, aligning commercial goals with ecological responsibility.

Molasses, another valuable by-product of sugarcane, is central to Brazil's booming ethanol industry. Rich in fermentable sugars, molasses is a key raw material in ethanol production, making Brazil a global leader in biofuel production and export. Ethanol from sugarcane molasses provides a renewable fuel alternative that emits fewer greenhouse gases than conventional gasoline. This contribution is essential to Brazil's strategy for energy security, reducing dependence on imported petroleum, and creating a steady revenue source within the domestic economy. Ethanol production from molasses and cane juice also aligns with governmental policies like the Proálcool program, which incentivizes ethanol use to diversify the country's energy resources, bolster the rural economy, and decrease transportation sector emissions [4].

In addition to ethanol, molasses has versatile industrial applications, ranging from producing alcoholic beverages and biochemicals to serving as a nutrient-rich component in animal feed. The use of molasses in animal feed, for instance, provides an affordable, energy-dense resource that supports Brazil's livestock sector. Such diversified applications for molasses ensure that it adds value across multiple sectors, contributing to both economic resilience and the profitability of sugarcane processing facilities.

The integrated use of bagasse and molasses exemplifies the Brazilian sugarcane industry's transition toward a circular economy, where all parts of the plant are repurposed for maximum utility. This holistic approach reduces waste, minimizes environmental impact, and enhances the industry's competitiveness by optimizing each step of the production process. The strategic use of these by-products aligns with global trends toward sustainable agriculture and positions Brazil as a model for efficient resource utilization in agro-industrial systems. By fully utilizing bagasse and molasses, the sugarcane industry not only amplifies its economic returns but also contributes positively to Brazil's environmental sustainability and energy independence goals [3, 4].

2.2 The Significance of Sugarcane for Brazil

Sugarcane is not only a key agricultural commodity but also a driving force behind Brazil's energy strategy, making it one of the most important crops in the country. As the world's second-largest producer of sugarcane, Brazil leverages this versatile plant for a range of uses, from the production of sugar and ethanol to bioelectricity generation. Sugarcane has shaped Brazil's economy for centuries, and its significance continues to grow with the expansion of the biofuel industry and the country's move toward renewable energy. The Proálcool Program and modern biofuel policies have cemented sugarcane as the foundation of Brazil's energy security, while its byproducts contribute to the country's renewable energy supply. Beyond energy, sugarcane remains a vital export commodity, contributing significantly to Brazil's agricultural GDP and trade balance. This section delves into the dual significance of sugarcane, exploring its role both as a vital commodity for Brazil's economy and as a cornerstone of its energy transition toward sustainability. We can see an example of a real sugarcane field in Brazil in Figure 2.2

Figure 2.2: Picture of a sugarcane field

2.2.1 Energetic Significance

Biofuel Production: Ethanol

To better understand the historical context and data surrounding ethanol as a biofuel and its connection to sugarcane plantations, it is essential to understand the production process. Sugarcane ethanol is created through fermentation, where yeast converts the sugar extracted from the cane into ethanol. The process can be better understood by looking at Figure 2.4. Figure 2.3 shows a real example of an ethanol mill in Brazil. This process is more energy-efficient than other biofuel feedstocks, such as corn, making it economically viable for Brazil to use sugarcane as its primary biofuel. The tropical climate in Brazil is particularly conducive to sugarcane growth, providing ideal conditions for high yields and efficient production, which further enhances the country's capacity to produce ethanol on a large scale [19].

Sugarcane has been a cornerstone of Brazil's biofuel industry for a long time. The country's ethanol production, derived primarily from sugarcane, is one of the most successful biofuel programs globally. The Proálcool Program, launched in the 1970s, was a pioneering initiative aimed at using ethanol as a replacement for gasoline in Brazil's transportation sector. Initially, the program aimed to substitute

Figure 2.3: Example of an ethanol production mill

gasoline with ethanol produced from sugarcane. During the early years, Proálcool's production was relatively small, but as the program expanded, so did sugarcane acreage and ethanol production. This program was a direct response to the oil crises of the 1970s, which highlighted the vulnerability of nations reliant on imported oil. Prior to this, sugarcane was primarily cultivated for its role in producing sugar and alcohol for beverages, not for energy. Proálcool led to the large-scale planting of sugarcane specifically for ethanol production. Brazil invested heavily in developing technologies and infrastructure for ethanol production and distribution, including the creation of an ethanol-only fuel, the E85, which was introduced in the mid-1980s.

By the 1980s, Brazil had constructed a vast network of ethanol plants and distilleries, making sugarcane the primary feedstock for ethanol. In the past decade, an average of over 50% of Brazil's sugarcane production mix has been directed towards ethanol production, resulting in a significant increase in ethanol yields, with Brazil's ethanol yield now reaching more than 7,000 liters per hectare-an improvement from 2,500 liters per hectare in the 1970s [20].

This transformation was driven by technological advances, including mechanized harvesting and improved crop varieties that enhanced sugarcane productivity and ethanol efficiency [21]. Ethanol production expanded from 10.6 billion liters in the 2000/01 crop year to 31.2 billion liters in the 2022/23 crop year, demonstrating the exponential growth of Brazil's ethanol industry over the past two decades. During this period, hydrous ethanol accounted for a larger share of the country's ethanol production, growing from 46% to 57% of total biofuel production. Additionally, the amount of anhydrous ethanol blended into gasoline increased from 20% to 27%,

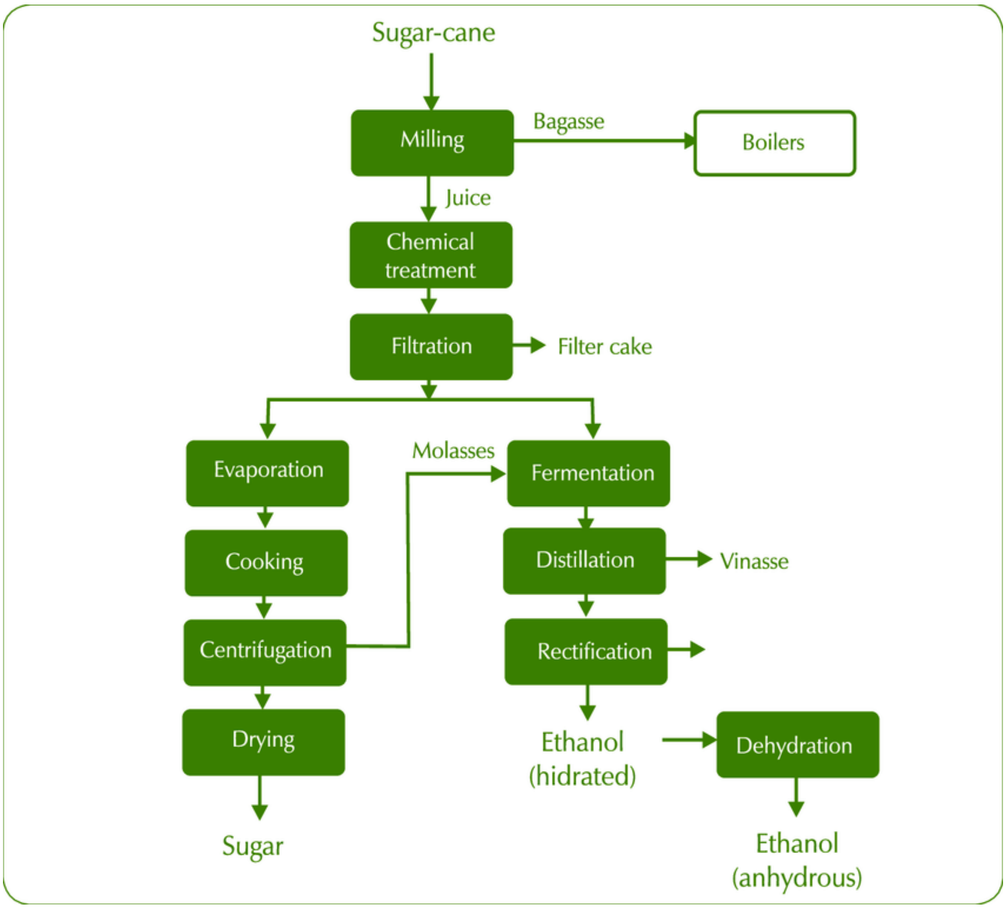

Figure 2.4: Sugar and sugarcane-based bioethanol production flowchart

reinforcing the government's will to increase ethanol consumption [22].

Brazil's ethanol industry has remained integral to the country's energy matrix, especially with the introduction of flex-fuel vehicles (FFVs) in the early 2000s. These vehicles, capable of running on either ethanol or gasoline, now account for over 70% of the national vehicle fleet. Today, ethanol accounts for approximately 21.5% of Brazil's total fuel consumption, making the country a global leader in ethanol production [23]. The RenovaBio program, introduced in 2016, builds on the success of Proálcool by further promoting ethanol and biodiesel as key components of Brazil's energy mix [24, 21].

Today, Brazil has become the world's second-largest producer and exporter of ethanol, following the United States. In 2.5 is a graph showing Brazil's global importance regarding ethanol production:

Ethanol consumption has had a profound impact on Brazil's energy sector. Brazil's ethanol blending policy plays a critical role in shaping the country's energy

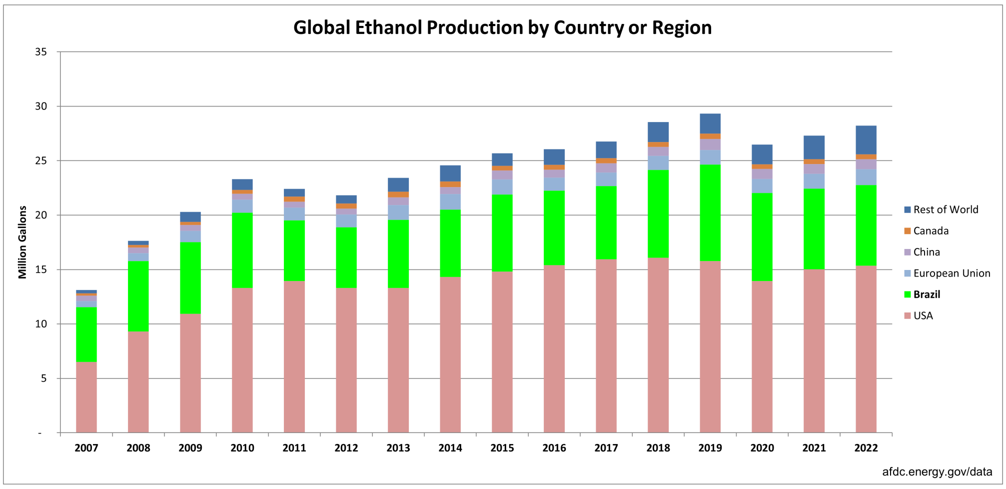

Figure 2.5: Global ethanol production by country/region from 2007 to 2022 [Energy, Effieciency & Renewable Energy (EERE). U.S. department of energy. Altern fuels data cent; 2024.]

matrix and reducing its reliance on imported oil. At the heart of this policy is the requirement that ethanol be blended into gasoline, with the typical ethanol content at 27% (E27). This mandated blending rate is subject to adjustment based on factors such as ethanol availability, crop yields, and market conditions. The flexibility of the ethanol blending rate allows Brazil to manage fluctuations in ethanol production, ensuring that fuel availability and prices remain stable, even in times of market or environmental instability [23].

The ethanol blending program has been a key component of Brazil's broader biofuel strategy, first implemented during the Proálcool program (1975), and it continues to evolve with modern biofuel policies like RenovaBio. By blending ethanol into gasoline, Brazil has drastically reduced its consumption of imported fossil fuels, particularly crude oil, which had previously constituted a significant portion of the country's fuel supply. This shift not only reduces the cost of fuel imports but also insulates Brazil from global oil price volatility, providing a greater degree of energy independence [23].

Furthermore, the increase in ethanol blending has contributed to Brazil's economic stability. By using domestically produced ethanol from sugarcane, the country avoids the financial burden of purchasing foreign petroleum, which can be subject to sudden price hikes due to geopolitical factors or changes in the global supply chain. For example, during times of oil price spikes, Brazil's reliance on ethanol acts as a buffer, protecting the country's economy from the worst effects of fuel price increases [23].

Additionally, the implementation of ethanol blending helps support energy security by diversifying Brazil's energy sources. With ethanol being derived from a renewable domestic resource-sugarcane-the country's energy system becomes less vulnerable to the shocks often caused by dependency on imported fossil fuels. This resilience is particularly important as Brazil seeks to further integrate renewable energy solutions into its national grid and transportation systems. Ethanol blending, therefore, not only addresses immediate energy needs but also aligns with long-term sustainability goals, including carbon neutrality targets for 2050 [23].

In summary, Brazil's ethanol blending policy is a cornerstone of the nation's energy security, allowing it to reduce reliance on imported oil, mitigate fuel price volatility, and promote domestic renewable energy production. This policy, combined with advances in ethanol production technology and sustained agricultural efforts, positions Brazil as a global leader in biofuels and continues to contribute to the country's energy independence and environmental sustainability goals [23].

Lastly, ethanol derived from sugarcane is considered one of the most efficient biofuels in terms of reducing carbon emissions. The OECD published a study in 2008 comparing greenhouse gas emissions during the lifecycle of various biofuel sources. According to the findings, ethanol derived from sugarcane achieves an impressive reduction in greenhouse gas emissions, averaging 85% lower emissions than gasoline. In scenarios where sugarcane mills utilize crop residues to generate electricity for production, the emissions reduction reaches 100%. In contrast, ethanol produced from wheat reduces emissions by 30% to 50%, while ethanol from corn offers a modest average reduction of only 20% [25].

This contributes significantly to Brazil's national efforts to meet international climate change goals under agreements such as the Paris Climate Accord [26].

Electricity Generation: Bagasse as Bioenergy

In addition to ethanol production, sugarcane plays a pivotal role in Brazil's renewable energy sector. After the juice is extracted from sugarcane during the production of sugar and ethanol, the leftover fibrous material-bagasse-is used to generate electricity. This is done through co-generation systems, where bagasse is burned to produce steam, which drives turbines that generate electricity. Sugar mills and distilleries across Brazil operate these systems, using the energy produced not only to power the sugar mills themselves but also to contribute to the national electricity grid [27].

Bagasse is also used in the production of Second-Generation (G2) ethanol, a more sustainable biofuel compared to First-Generation (G1) ethanol, which is derived from food crops like sugarcane. While G1 ethanol has been the cornerstone of Brazil's biofuel strategy, G2 ethanol presents new opportunities for more sustainable production. In Brazil, G2 ethanol is produced from residual sugarcane biomass (bagasse), although competition exists for its use in energy generation [27].

In co-generation systems, G1 bagasse is burned to produce steam, which powers turbines for electricity generation in sugar mills, with some surplus energy exported to the grid. As of recent estimates, sugarcane bagasse now accounts for approximately 17% of Brazil's total renewable energy consumption, making it a key player in the national energy mix [27]. With the advent of G2 technology, Brazil is exploring the use of remaining bagasse for advanced biofuel production, further improving sustainability in both energy and agriculture. Proving this point, it is estimated that around 20% of Brazilian plants, most of them in São Paulo, are producing and selling surplus electricity [27].

A major advantage of G2 ethanol over G1 is that it uses agricultural waste, reducing competition for arable land and addressing food security concerns. By utilizing non-food biomass, G2 ethanol can reduce greenhouse gas emissions by up to 90% compared to gasoline, making it a highly sustainable alternative. Additionally, G2 ethanol promotes rural development by creating markets for agricultural residues and supporting the cultivation of energy crops on marginal lands, providing new income streams for farmers [27].

In some regions of Brazil, especially in the São Paulo state, sugar mills with advanced co-generation facilities are producing more electricity than they consume. These mills can sell surplus electricity back to the national grid, further contributing to Brazil's energy mix and creating a source of additional revenue for the sugarcane sector.

2.2.2 Commodity Significance

Economic Impact and Global Significance

Brazil has been known as the world's largest producer of sugarcane, contributing 716 million tons of sugarcane stalks in the 2023/2024 harvest, which represented approximately 38% of global production [22]. In 2023, the sugarcane industry generated R$ 111.2 billion from 9.6 million hectares of cultivated land, underscoring its importance to the national economy. Ranking fourth in gross agricultural production value, sugarcane is only behind soybeans, cattle, chicken, and corn, further emphasizing its significance as a key commodity in Brazil's agribusiness landscape [2].

The introduction of sugarcane mills brings a series of positive socioeconomic impacts to municipalities. Investments linked to mill construction often represent 130% of the average municipal GDP, driving transformative changes. Within three years of a mill's establishment, the local GDP typically grows by 30%, accompanied by a 10% population increase, a 40% surge in employment, a 49% rise in wages, and a 31% boost in tax revenues [28].

In the 2023–2024 period, the volume of sugar exports reached an impressive 35.2 million tons, representing a significant increase compared to previous periods, such as 2021–2022, when exports totaled 26 million tons, according to data from the Observatory of Economic Complexity (OEC, 2023). This remarkable performance underscores the industry's robust contribution to Brazil's trade balance. In terms of value, sugar exports generated USD 18.3 billion from January to November 2024. This value accounts for 5.85% of Brazil's total export revenue (USD 312.13 billion) and 12% of total agribusiness exports during the same period, as reported by Brazil's Ministry of Agriculture (2024).

The sugar industry's impact extends beyond national trade figures to its critical role in regional development. São Paulo, which accounts for 50.04% of the total harvested sugarcane area in the 2022/2023 harvest season [1], is the leader in sugar production in Brazil. The state's dominance has been facilitated by investments in rural infrastructure, including transportation networks, storage facilities, and advanced processing plants, which ensure high productivity and efficient logistics. Even though its centrality has been decreasing over the years-declining from 55.74% of the total harvested sugarcane area in 2010 to 50.04% in 2023, as previously mentioned-São Paulo's role as the leader in sugarcane production remains indisputable. The state with the second-largest share of production in Brazil during the 2022/2023 season, Goiás, accounted for only 11.54% of the total harvested area [22].

Social Impact and Regional Development

The sugarcane sector directly generates more than 730,000 formal jobs in Brazil, while indirect employment within the sugarcane value chain raises this figure to approximately 2.2 million individuals [29]. These opportunities are dispersed across the country, with over 1,200 municipalities (20% of all Brazilian municipalities) engaged in sugarcane cultivation across nearly 10 million hectares [30, 22].

The sugarcane sector involves approximately 70,000 independent suppliers, emphasizing its role in sustaining rural livelihoods [22]. In areas like Mato Grosso do Sul, the entry of sugarcane mills has reshaped local agriculture, transitioning land use from extensive cattle pastures to sugarcane fields. This shift not only enhances land productivity but also stimulates economic diversification and increases agricultural efficiency [28].

The social impacts of sugarcane production in Brazil vary significantly across regions, reflecting the industry's adaptability and influence on local economies. In the highly developed South-Central region, where mechanization rates exceed 90%, the sugarcane sector has driven formal employment rates to 87% among its workers, compared to 34% in the general agricultural sector [28]. Workers in this region enjoy better wages, with average monthly incomes of USD 495.40 compared to USD 298.68 in the North-Northeast region [29]. In contrast, the North-Northeast region, characterized by lower mechanization due to challenging terrain, remains reliant on manual labor, leading to significant but less stable job creation [28].

Education and generational mobility are also notable effects of the sugarcane sector. Sugarcane workers and their offspring exhibit slightly higher levels of schooling compared to general agricultural workers, with offspring achieving on average 8.4 years of schooling compared to 8.1 years in general agriculture [28]. The inter-generational transmission of socioeconomic benefits, including improved access to education and formal employment, underscores the role of sugarcane production in fostering rural development. Additionally, the sector's integration into municipal economies often leads to broader benefits, such as increased financial services, infrastructure development, and agricultural productivity [31].

Industrial and Byproduct Utilization

Sugarcane byproducts in Brazil, such as molasses, vinasse, and bioplastics, showcase the industry's commitment to sustainability and economic diversification. Molasses, a byproduct of sugar extraction, is widely used in livestock feed due to its high nutritional value and as a substrate in biotechnological processes like yeast and alcohol production, contributing significantly to regional agribusiness [32]. Vinasse, a liquid residue from ethanol production, is produced in large quantities-up to 10–15 liters per liter of ethanol-and is repurposed as an eco-friendly fertilizer rich in potassium, reducing the need for chemical fertilizers and enhancing soil health [33].

Furthermore, the emergence of sugarcane-based bioplastics highlights Brazil's innovation in renewable materials, with molasses and vinasse increasingly utilized in producing polyhydroxybutyrate (PHB), a biodegradable alternative to petroleum-based plastics [34]. This growing bioplastics sector offers promising economic returns and positions Brazil as a leader in sustainable agricultural practices, demonstrating the economic and environmental value of sugarcane byproducts [35].

Regulatory Framework and Policies

The Brazilian government has implemented a range of subsidies to support the sugarcane industry, emphasizing financial aid and infrastructure development to enhance competitiveness and sustainability. Programs like the National Program for Strengthening Family Agriculture (PRONAF) provide smallholder farmers with subsidized credit lines of up to R$ 20,000 per year at interest rates as low as 2–5% per year, significantly below commercial rates of 10–12% [36]. During market downturns, the government has also employed price stabilization mechanisms; for instance, in 2018, approximately R$ 1.8 billion was allocated to support sugarcane and ethanol producers affected by falling global sugar prices [2]. Additionally, infrastructure investments through initiatives like the Growth Acceleration Program (PAC) have injected R$ 5 billion into transportation and storage facilities between 2015 and 2020, reducing logistical costs and improving supply chain efficiency [37]. These targeted subsidies underscore the government's commitment to maintaining the sugarcane sector as a cornerstone of Brazil's economy.

2.3 Main Sources of Revenue & Costs

2.3.1 Revenue in Sugarcane Farming

The use of sugarcane as a feedstock for bioproducts is highly extensive and diversified, offering a robust foundation for revenue generation. Traditional products like sugar and ethanol remain the backbone of the industry, while byproducts such as bagasse, used for bioelectricity, and innovative derivatives like xylitol and biodegradable plastics illustrate the sector's adaptability to emerging market demands. Additionally, sustainability initiatives have introduced new revenue streams, such as carbon credits, which capitalize on the environmental benefits of ethanol and bioelectricity production. These diverse opportunities, supported by technological advancements and policy incentives, underscore the economic importance of sugarcane as a renewable resource [38].

For our model, we will focus and take a deeper look into one of the main sources of revenue derived from sugarcane: the raw sugarcane itself, even though other sources may contribute to revenues from bigger mills, like sugar, ethanol, bagasse, surplus bio-electricity, and carbon credits. These core streams represent the most significant contributors to the financial outcomes of the sugarcane industry, and their brief analysis in this sector will provide insights into the drivers of profitability and sustainability within this sector, and for the deeper analysis which will be conducted regarding raw sugarcane.

Revenues from Raw Sugarcane

Raw sugarcane is often sold to processing mills by independent farmers or cooperatives. This revenue stream is particularly vital for smaller producers who do not operate their own mills, typically smallholder farmers or agricultural cooperatives with limited access to capital for industrial operations. These smaller producers rely on local mills to process their crops into sugar and ethanol, creating a symbiotic relationship within the supply chain.

The price of raw sugarcane is influenced by global sugar prices and ethanol demand, creating a direct linkage between upstream agricultural productivity and downstream market dynamics. In Brazil, the Consecana system standardizes the pricing of raw sugarcane, ensuring equitable revenue distribution between farmers and mills. This system calculates payment based on the total recoverable sugars (ATR) in the sugarcane, with prices linked to both international sugar prices and domestic ethanol market trends, fostering fairness and transparency in the supply chain [39].

Revenues from Sugar

Sugar remains the cornerstone of revenue generation for a typical sugarcane farm, with refined and raw sugar being the primary products. A typical farm generates income through the sale of sugarcane to mills, which process it into sugar. The revenue depends heavily on farm yield, quality of the cane, and the farm's proximity to processing facilities, which influences transportation costs. Additionally, sugar prices depend on market dynamics, such as global supply, demand, and competition from alternative sweeteners. The type and quality of sugar produced, whether raw or refined, further affect its market value and profitability.

Revenues from Ethanol

Ethanol derived from sugarcane provides a renewable fuel alternative and is a cornerstone of Brazil's energy policy. Ethanol revenue is supported by Brazil's ethanol blending mandates, which stabilize domestic demand, while international exports add another revenue layer, particularly to markets like the United States and Japan. Another key factor influencing ethanol revenue is the price of crude oil; higher oil prices improve ethanol's competitiveness as a fuel alternative, driving demand both domestically and internationally [21].

Revenues from Surplus Bioelectricity

Revenue from electricity sales is also influenced by seasonal factors, as the production of surplus electricity from bagasse is closely tied to the sugarcane harvest period. During the off-harvest months, when mills are not actively processing sugarcane, electricity generation declines significantly due to reduced bagasse availability. Additionally, market conditions, such as fluctuations in spot prices for electricity in Brazil's free energy market, impact revenue. During periods of high demand or energy shortages, such as those caused by low rainfall reducing hydroelectric reservoir levels, bagasse cogeneration becomes particularly valuable, contributing significantly to Brazil's energy supply by offsetting hydroelectric shortfalls [40]. This alignment with critical energy needs can boost revenue opportunities for mills during such periods.

Revenues from Carbon Credits

Carbon credits have become a crucial revenue source for sugarcane mills, particularly through Brazil's RenovaBio program. This initiative formalized the CBio

(Decarbonization Credit Generated by Biofuels), which monetizes the environmental benefits of biofuels like ethanol and bioelectricity. Each CBio corresponds to one metric ton of avoided or mitigated CO2 emissions, providing mills with a financial incentive to adopt sustainable practices [38].

The importance of this revenue stream lies in its dual role of encouraging sustainability while enhancing profitability. The value of CBios is directly tied to a mill's energy-environmental efficiency grade, which evaluates its ability to reduce GHG emissions. Mills equipped with advanced technologies, such as the Dedini Sustainable Mill (DSM), benefit from greater CBio generation due to their superior GHG reduction performance. For example, the DSM has been shown to achieve emissions mitigation of up to 132% when using 50% of sugarcane straw for bioelectricity production, significantly surpassing the 89% reduction achieved by traditional mills [38].

This innovative revenue stream is influenced by both internal factors, such as technological adoption, and external market conditions, including the growing demand for carbon offsets. In the next section, we will see an example of how carbon credits contribute to the revenue of sugarcane mills, using the examples of Usina Santa Adélia and Grupo Balbo.

Revenue Distribution: Insights from Usina Santa Adélia and Grupo Balbo

The financial performance of Usina Santa Adélia and Grupo Balbo for the 2023/24 season offers valuable insights into the distribution of revenue streams across typical sugarcane farm operations. These cases highlight how sugarcane farming operations generate income from multiple sources, including sugar, ethanol, energy, and byproducts. Their main revenue streams were:

- **Sugar:** Sugar remains a significant revenue source. At Grupo Balbo, sugar sales amounted to R$ 635.1 million in 2023/24, reflecting both refined sugar and organic sugar sales. Organic sugar contributed an additional R$ 325.1 million, showing a growing market for premium products. Similarly, Usina Santa Adélia produced 200,000 tons of sugar, contributing to 32.5% of its total revenue. The shift towards sugar production was driven by favorable market conditions and rising global prices.

- **Ethanol:** Ethanol production is another major revenue driver. Grupo Balbo reported ethanol sales of R$ 840.5 million, with R$ 91.4 million coming from organic ethanol. This represents the largest revenue share for the group. Usina Santa Adélia mirrored this trend, with ethanol contributing 62% of its net revenue, showcasing its importance in stabilizing income amidst volatile sugar markets.

- **Energy Cogeneration:** Bagasse, the fibrous byproduct of sugarcane processing, is used to produce electricity. Grupo Balbo generated R$ 15.9 million from energy sales, while Usina Santa Adélia reported that energy cogeneration accounted for 5.5% of its total revenue. While a smaller component, energy sales provide additional diversification and stability to operations.
- **Other Products and Services:** Grupo Balbo's revenue diversification includes R$ 41.8 million from other organic products, R$ 16.3 million from yeast derivatives, and R$ 5.6 million from bagasse sales. These smaller streams exemplify the farm's ability to extract value from all production stages. Similarly, both entities benefited from the sale of CBIOs (carbon credits), with Grupo Balbo earning R$ 27.8 million from these certificates in 2023/24.

Both Usina Santa Adélia and Grupo Balbo showcase strategic production shifts based on market trends. For example, Grupo Balbo's revenue from organic products demonstrates a focus on niche markets, while Usina Santa Adélia increased sugar production by 43.6% in response to high prices. Revenue diversification, particularly through byproducts and renewable energy, enhances financial resilience and ensures sustainable growth despite market volatility.

2.3.2 Costs in Sugarcane Farming

The production of sugarcane involves a wide range of costs, reflecting the complexity of growing and maintaining this important crop. From planting to the final harvest, farmers face significant expenses across various stages of the production cycle. These include the costs of land preparation, fertilizers, pesticides, labor, irrigation, and machinery. Additionally, as a perennial crop, sugarcane offers the advantage of multiple harvests from a single planting, but declining yields with each successive ratoon necessitate replanting every few years, incurring periodic reestablishment costs.

When replanting becomes necessary, the associated costs increase significantly compared to maintaining ratoon crops. Replanting involves intensive land preparation, such as heavy and light disking, soil testing, and leveling. According to a study conducted by Alvarez et al., in a plantation on muck soils in Florida, these costs sum up to approximately $293 per acre. Planting itself, including high-quality seed cane, fertilizers, and other necessary inputs, adds another $329 per acre. These expenses make replanting one of the costliest phases of sugarcane production in this region [7].

In contrast, managing ratoon crops is considerably less expensive, with costs estimated at $134.50 per acre in Florida, as these require fewer inputs and no seed cane. However, the higher costs during replanting are offset by the long-term benefits of improved yields and quality in subsequent ratoon cycles, which are critical for the financial sustainability of sugarcane operations [7].

One of the largest ongoing expenses in sugarcane farming is related to agricultural inputs like fertilizers and pesticides, which are essential for maintaining soil health and protecting the crop against pests and diseases. Labor costs, while reduced in some regions due to mechanization, remain substantial in areas that rely on manual harvesting. Transportation costs, particularly the delivery of harvested cane to processing mills, are another critical expense, heavily influenced by the farm's proximity to industrial facilities. For example, in Florida, field burning (if necessary), cutting, and hauling rates averaged $6.50 per ton for distances up to 25 miles [7].

In this model, we will consider and examine the main categories of costs involved in sugarcane farming: raw materials (sugarcane seeds), fertilizers and pesticides, labor costs, land preparation, ratoon maintenance, and transportation. Understanding these cost components will help identify the key factors influencing the financial viability of sugarcane farming and explore opportunities for greater efficiency and sustainability within the industry.

Raw Materials (Matérias-primas)

This category covers the acquisition of sugarcane seeds or seed cane, which is vital for establishing new plantations or renewing fields after ratoon cycles. The quality of seed cane directly impacts productivity and crop resilience. External factors such as climate conditions and the availability of high-quality seed cane can influence costs. For instance, droughts or diseases affecting seed cane availability can raise prices, leading to higher planting costs.

Agricultural Inputs and Consumables Costs

This category includes fertilizers, pesticides, and other materials essential for crop health and productivity. Fertilizers are critical for replenishing soil nutrients after each harvest, particularly nitrogen, potassium, and phosphorus. Pesticides help protect the crop against pests and diseases that thrive in tropical climates. The cost of these inputs is heavily influenced by global commodity prices, particularly crude oil, as many fertilizers are petroleum-based [7]. Currency exchange rates also play a role, especially in countries like Brazil, where a weaker currency increases the cost of imported inputs. The variability of input prices adds a layer of financial unpredictability for sugarcane growers.

Depreciation and Amortization Expenses

This cost represents the wear and tear or reduction in value of long-term assets such as biological assets (crops), bearer plants, equipment, and machinery. Depreciation of machinery occurs as equipment like tractors and harvesters are used intensively during planting, maintenance, and harvesting. Amortization of biological assets is significant in sugarcane, as ratoon crops lose productivity with each successive cycle, necessitating replanting. In our case, we will amortize the replanting costs throughout the years of the cycle. External factors impacting this cost include technological advancements that make older equipment obsolete and climatic events that accelerate wear on assets.

Labor and Third-Party Services Costs

Labor costs encompass wages for workers involved in planting, maintenance, and harvesting. In regions where mechanization is limited, manual labor represents a substantial portion of costs. Even in mechanized systems, tasks that require precision or care, such as ratoon management, still rely heavily on manual labor, underscoring its continued importance in sugarcane farming [41]. Third-party services include specialized tasks like soil testing, pest control, and custom harvesting or hauling services. Labor costs are influenced by minimum wage policies, local labor availability, and seasonal demand, while third-party service rates may fluctuate based on competition and regional demand for outsourced operations.

Transportation and Maintenance Costs

Transportation costs are primarily related to hauling harvested cane to processing mills. The distance between farms and mills plays a critical role, with longer hauls requiring more fuel and labor, increasing overall costs. Factors such as fuel prices, road conditions, and the availability of reliable vehicles also heavily influence transportation expenses. Maintenance costs refer to the upkeep of machinery and equipment, such as tractors and harvesters, which are vital for efficient operations. Poor maintenance or delays in repairs can lead to equipment failures during critical periods, further escalating costs [7].

Cost Distribution: Insights from Usina Santa Adélia and Grupo Balbo

The cases of Usina Santa Adélia and Grupo Balbo provide valuable real-world examples of cost structures in the sugarcane industry, complementing the theoretical analysis previously discussed. These two entities demonstrate the predominant cost drivers and illustrate how production strategies and market conditions shape financial outcomes in the sector. In their cost structure, we can highlight:

- **Raw Material Acquisition:** A key driver of costs for both operations is raw material acquisition, particularly sugarcane itself, which constitutes the largest single expense category. In 2023/24, this component represented a significant portion of total costs in both companies, reflecting the critical role of sugarcane procurement and its associated logistics, including cutting, transportation, and handling. For Santa Adélia, these costs alone amounted to R$ 248.1 million, while Grupo Balbo reported a similar pattern, with raw material-related expenses accounting for approximately 98% of total production costs. This underscores the importance of sugarcane supply efficiency, especially in managing high-volume operations.

- **Depreciation and Amortization Expenses:** Depreciation and amortization reflect investments in machinery, equipment, and infrastructure essential for maintaining competitive operations. In Santa Adélia, this category accounted for over R$ 115.5 million in 2023/24, a reflection of its large-scale operations. Grupo Balbo, although focused on organic and premium production, similarly relies on capital-intensive equipment, indicating that mechanization and long-term asset utilization are universal characteristics of efficient sugarcane production.

- **Labor Costs:** Labor costs are another prominent factor in the cost structure of both companies. Personnel expenses, including wages, benefits, and training programs, are critical for maintaining operational performance. For instance, Santa Adélia allocated R$ 151.4 million to labor costs, while Grupo Balbo's labor expenses were proportionally significant within its total operating costs. These costs are not only tied to the workforce needed for field and industrial operations but also reflect inflationary pressures and investments in staff development.

- **Other Significant Costs:** Both companies also incur considerable expenses in energy, maintenance, and transportation. The reliance on bagasse for energy cogeneration partially offsets energy costs but does not eliminate them. Maintenance of machinery and equipment, as well as fuel expenditures, collectively reached tens of millions of reais in both cases. Freight and storage costs further highlight the logistical complexity of large-scale sugarcane operations, particularly when raw material and finished product transport is involved.

Despite these shared cost drivers, differences in strategic focus influence how costs are distributed. Grupo Balbo, for example, integrates sustainability and organic production into its operations, introducing additional costs related to certification, specialized marketing, and organic input usage. These investments, while higher upfront, position the company to capture premium market segments. Santa Adélia, on the other hand, leverages economies of scale, with higher production volumes helping to dilute fixed costs across operations.

In both cases, the interplay of raw material acquisition, labor, depreciation, and logistical costs illustrates the fundamental cost structure of sugarcane production. While their strategies may differ, these examples highlight the shared challenges of managing rising input costs, optimizing operational efficiencies, and responding to market demands. By applying theoretical principles to these practical cases, it becomes evident how cost management decisions influence financial resilience and long-term sustainability in the sugarcane sector.

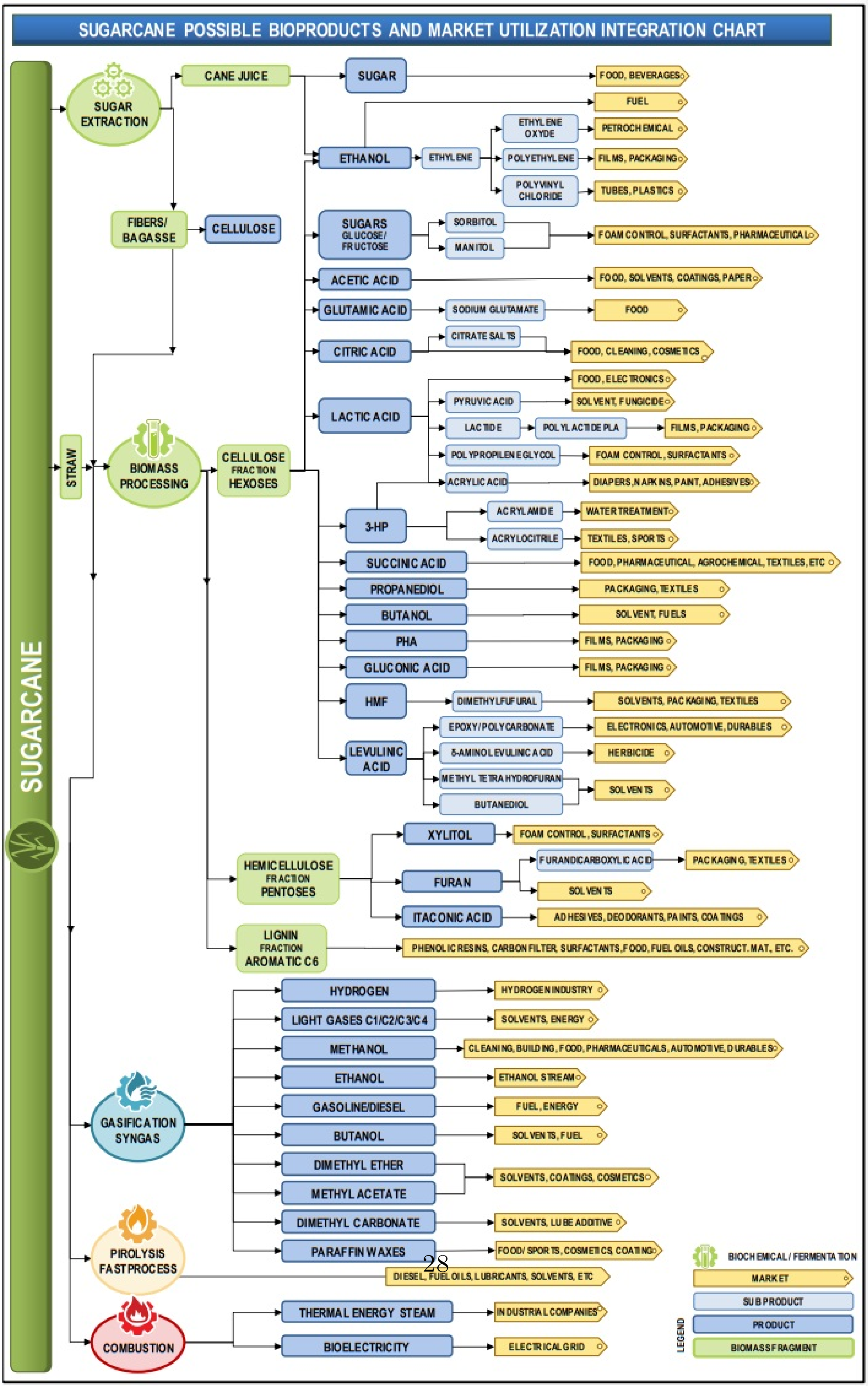

Figure 2.6: Integration of sugarcane as feedstock for possible bioproducts and marketing utilization [38].

2.4 Financial Statements in Agriculture

Financial management in agriculture is essential for sustainability and profitability. It involves analyzing key financial statements to monitor liquidity, solvency, and overall financial performance. The unique characteristics of agricultural enterprises require a tailored approach to financial reporting. This section explores three main financial statements: the market value balance sheet, the accrual income statement, and the statement of owner's equity, focusing on their application in agriculture.

2.4.1 Market Value Balance Sheet

The market value balance sheet provides a systematic organization of a farm's assets and liabilities, offering a snapshot of its financial position at a specific point in time. By estimating asset values based on current market prices, this balance sheet type accommodates the inherent volatility of agricultural operations. In farming, asset values such as crops, livestock, and equipment can fluctuate significantly due to seasonality, market trends, and environmental factors. For instance, a case study of an Indiana farm demonstrated how the timing of crop inventory valuation at the beginning and end of the year influenced the farm's working capital calculations, with inventories constituting a large portion of current assets [42].

This approach is particularly useful for assessing solvency and liquidation potential. By estimating the liquidation values of assets, the market value balance sheet provides critical information for evaluating a farm's ability to meet long-term financial obligations. For example, changes in land values-a common feature in agriculture-can significantly influence total asset calculations and, in turn, solvency ratios. In the Indiana case, the farm's solvency was bolstered by an increase in land values, which contributed to a 1.5% rise in total assets over the year, showcasing the interplay between market conditions and financial metrics [42].

However, while the market value balance sheet is advantageous in providing a dynamic view of a farm's financial status, it presents limitations in separating retained earnings from capital gains. This complexity arises because changes in owner equity are influenced by both factors, making it difficult to isolate the farm's operational profitability from external market-driven gains. As observed in the Indiana case farm, the equity increase in 2019 was attributable to both retained earnings and capital gains from land value appreciation. This dual impact complicates efforts to assess the true financial growth of the farm over time [42].

Moreover, when comparing farms of different sizes, the use of percentages rather than absolute dollar values in the balance sheet can provide better insights into the relative importance of assets and liabilities. For instance, in the Indiana study, land represented 54.7% of the total assets, underscoring its central role in agricultural asset management [42]. This percentage-based approach enhances comparability across farms, enabling better benchmarking and decision-making.

In summary, the market value balance sheet is a critical financial tool for agricultural enterprises. It accommodates the dynamic nature of farm assets, supports solvency assessments, and aids in benchmarking across different operations. However, its limitations in disentangling retained earnings from capital gains highlight the need for supplementary analysis to comprehensively evaluate financial performance and growth.

2.4.2 Accrual Income Statement

The accrual income statement is a vital tool for measuring a farm's profitability over a defined period. Unlike cash accounting, it records revenues and expenses when they are earned or incurred, regardless of when cash transactions occur. This approach is particularly valuable in agriculture, where factors such as inventory fluctuations, seasonal operations, and depreciation play significant roles in financial performance [42].

One critical advantage of this method is its ability to account for inventory changes over time. For example, on the Indiana case farm, approximately 50% of crops were sold before the end of the calendar year, with the remaining inventory carried over to the next year. This operational model significantly impacted net farm income, as revenue recognition depended on the timing of crop sales and inventory adjustments [42]. By considering these inventory shifts, the accrual income statement offers a more accurate reflection of the farm's actual economic performance than cash-based accounting.

Additionally, depreciation is another significant element captured in accrual accounting. The Indiana case farm utilized economic depreciation to estimate machinery and equipment values, which provided a more realistic measure of asset usage compared to tax-based depreciation. This adjustment allowed for better tracking of asset performance and maintenance costs, further enhancing the utility of the income statement in evaluating operational efficiency [42].

The accrual income statement also provides essential data for calculating profitability metrics. Metrics such as the operating profit margin ratio and rate of return on farm assets rely heavily on accrual net farm income, as this measure reflects the true financial outcome of farming activities. For instance, the Indiana case farm achieved a net farm income of $180,558 in 2019, which could be analyzed further on a per-acre basis, revealing a profit of approximately $60 per acre [42]. These insights are critical for farmers to understand the efficiency of their operations and make informed decisions regarding investments, resource allocation, and cost management.

In summary, the accrual income statement offers a comprehensive perspective on a farm's financial health by incorporating all relevant financial activities, regardless of cash flow timing. Its ability to track inventory changes, account for depreciation, and support profitability analysis makes it an indispensable tool for agricultural enterprises aiming to optimize performance and ensure long-term viability.

2.4.3 Statement of Owner's Equity

The statement of owner's equity records changes in a farm's equity over time, distinguishing between retained earnings and valuation equity. This distinction is particularly significant in agriculture, where land and equipment values often appreciate due to market dynamics. Continuing with the Indiana case farm, retained earnings derived from net farm income accounted for the majority of its equity growth in 2019, while the remaining portion was attributed to increases in land values [42].

Tracking these changes is essential for assessing long-term sustainability and profitability. It enables farmers to evaluate whether equity growth aligns with their financial goals and operational strategies. By identifying the key drivers of equity growth, such as profitability and asset appreciation, this statement supports informed decision-making and financial planning, ensuring the farm's viability over time [42].

2.4.4 Integrated Analysis of Financial Statements

By integrating these financial statements, farmers can comprehensively monitor their financial performance, enhance decision-making, and support sustainable growth. The market value balance sheet, as discussed, provides critical insights into liquidity and solvency. Ratios like the current ratio and working capital-to-gross revenue derived from this statement offer a clear picture of a farm's capacity to meet short-term obligations without disrupting operations. For example, a strong liquidity position, indicated by a working capital-to-gross revenue ratio above benchmarks, reflects the farm's ability to weather financial fluctuations effectively [42].

Similarly, the accrual income statement plays a pivotal role in profitability analysis. Measures such as the operating profit margin ratio, calculated using net farm income and value of farm production, provide valuable insights into cost management and operational efficiency. These metrics allow farmers to benchmark their performance against industry standards and identify areas for improvement. For instance, in the Indiana case farm, profitability per acre was a key measure used to evaluate operational decisions and resource allocation [42].

Finally, the statement of owner's equity complements these analyses by offering a long-term view of financial health. By tracking changes in retained earnings and valuation equity, it provides a roadmap for strategic planning and equity growth.

As seen in the Indiana case farm, monitoring equity sources helped align operational outcomes with financial goals, ensuring the farm's sustainability and resilience over time [42].

When used together, these financial statements not only provide a detailed snapshot of a farm's current position but also guide future planning and risk management. This integrated approach is vital for navigating the uncertainties inherent in agricultural operations while fostering long-term growth and profitability.

2.5 Gaps in the Literature

The existing literature on the financial modeling of sugarcane production provides foundational frameworks and insights, yet several critical gaps remain that limit the applicability and robustness of these models for contemporary decision-making. Notably, earlier works such as Hoekstra (1976) developed a method to determine optimal replanting thresholds based on discounted cash flows, introducing concepts such as yield correction, ratoon stage decline, and plough-out thresholds [5]. While methodologically sound, Hoekstra's approach was static and field-specific, lacking the integration of broader environmental and operational variables. Nevertheless, its core logic remains relevant and will be incorporated as one of the analytical components in this thesis's financial modeling framework.

Similarly, while some financial viability studies, such as the one conducted by Rezende and Richardson (2015), employed advanced techniques like Monte Carlo simulations and evaluated key financial indicators such as NPV and ROE, they were primarily centered on processing-level analysis [6]. These models often lacked the integration of agronomic variables and the multi-variable scenario flexibility necessary to address the full complexity and volatility of sugarcane production systems.

One prominent gap is the absence of comprehensive multi-factor scenario analysis. Most existing models focus on single-variable sensitivity (e.g., rainfall or price changes), without integrating the combined effects of key operational and environmental variables such as number of harvests before replanting (ratoon cycles), timing of harvests, climatic conditions, and market volatility. This thesis seeks to address this deficiency by constructing a robust model capable of simulating complex inter-dependencies between these factors.

Another limitation observed in the literature is the use of outdated or geographically limited data, which restricts the relevance of such models to current economic conditions and regional specifics. For example, while Roka et al.'s (2010) detailed budget analysis of Florida's sugarcane production offers valuable insights, it is based on data from the 2008–2009 season and reflects conditions specific to the U.S. context, limiting its relevance for contemporary modeling of Brazilian production systems [7].

Furthermore, there is a lack of emphasis on quantifying the performance gain of optimized scenarios relative to a base case. While feasibility studies often highlight the viability of a given configuration, they do not thoroughly explore or benchmark the degree of improvement achieved through optimized decision-making. This thesis introduces this comparative analysis as a central feature, offering clearer guidance for producers and investors.

Finally, although existing literature discusses financial modeling and risk exposure [42], there is an opportunity to extend this by integrating financial stress testing into the operational modeling of sugarcane farms, particularly under varying climatic and policy scenarios.

In sum, this research intends to fill these gaps by delivering a modern, data-driven, and flexible financial model for sugarcane farming that incorporates multiple scenarios, current data, and comparative performance assessments, thus providing a practical decision-support tool for the sector.

Chapter 3

Scope and Data Collection

3.1 Defining the Size of a Representative Sugarcane Plantation

In order to develop a financial model that realistically reflects the operations of a commercial sugarcane-producing enterprise in Brazil, it is essential to define a representative plantation size. This size serves as the foundational unit for extrapolating and analyzing financial data. The objective is not to capture the extremes of the sector-neither the very small family-run properties nor the largest agro-industrial complexes-but rather to identify a typical commercial-scale farm that is both agriculturally significant and financially oriented. To arrive at a realistic estimate, we developed a methodology that integrates statistical analysis, sectoral data, and academic studies, all focused on Brazil's primary sugarcane-producing regions.

Scope and Delimitations

This analysis deliberately excludes smallholder and family farms. These units often operate at subsistence or semi-commercial levels, typically cultivating between 3.9 and 17.4 hectares of sugarcane [36], and are characterized by production models that do not align with the financial logic of this study. Their focus tends to be on diversified agricultural practices, with sugarcane playing a secondary role, often for animal feed or artisanal alcohol production. Including these would distort the average and undermine the financial relevance of the modeling exercise.

Geographically, the scope of this study is limited to Brazil's Center-South region, with a particular emphasis on the states of São Paulo, Goiás, and Minas Gerais. These states collectively account for the vast majority of Brazil's sugarcane output, with São Paulo alone contributing over 50%, and Goiás and Minas Gerais contributing 11% and 12% respectively [1]. This regional focus ensures that the estimated plantation size reflects the heart of Brazil's sugar-energy sector.

Data Sources and Methodological Approach

To determine the representative farm size, data were gathered from several authoritative sources, including:

- IBGE Agricultural Census (2017) [30]
- CONAB/MAPA sector reports [2]
- Embrapa typology and cluster studies [36]
- Academic literature and field research in key producing regions [43]
- Industry association data, particularly from ORPLANA [44]

These sources provided data on total sugarcane-planted areas, number of establishments, and classifications of farm size and production systems. We filtered the data to exclude smallholders (defined as those operating under 50 hectares of cane or falling within family-farming categories), focusing instead on commercially oriented farms dedicated primarily to sugarcane.

Estimation Strategy

Three estimation strategies were combined to arrive at a reliable average:

1. *Weighted Census Analysis:* We used IBGE's census data to derive average farm sizes by analyzing the distribution of sugarcane areas within commercial size classes. For example, in São Paulo's 4.5 million hectares under cane, the vast majority is concentrated among farms over 100 hectares [30].

2. *Academic Studies:* We relied on academic surveys that provided farm-level data. A survey in Goiás and Mato Grosso do Sul reported an average property size of 883 hectares among commercial sugarcane producers, with Mato Grosso do Sul featuring larger plantations due to recent agricultural expansion [43]. Embrapa's typology studies also highlighted clusters of specialized sugarcane farms, with average total areas ranging from 249 to 536 hectares, and sugarcane-specific areas between 98 and 362 hectares [36].

3. *Sector Reports and Associations:* According to ORPLANA, which represents around 12,000 independent producers, the average area of sugarcane cultivation is approximately 74 hectares [44]. However, this figure excludes mill-owned

land and does not reflect the scale of larger commercial operations. Embrapa identified other clusters of large-scale producers averaging over 3,000 hectares, though these are statistical outliers that do not represent the typical commercial producer [36].

Triangulation and Synthesis

After cross-analyzing the various data points, a consistent pattern emerged: the vast majority of sugarcane in Brazil is cultivated on farms with several hundred hectares. Although some producers operate on scales exceeding 1,000 hectares, most commercial farms fall in the 200–500 hectare range. The most representative clusters identified by Embrapa featured 98 to 362 hectares of cane, which aligns with the range found in census-derived estimations and regional academic surveys [36, 30, 43].

Given this convergence, we determined that the most representative sugarcane farm size for financial modeling purposes is **approximately 300 hectares**. This figure balances the inclusion of mid-sized commercial operations while excluding smallholders and extreme outliers. It is consistent with farms that supply sugar mills either independently or under long-term partnerships and accurately reflects the production and investment scale relevant to financial analyses in the sector.

This estimated average of 300 hectares will therefore serve as the base unit for modeling in this study.

3.2 Overview of the Modeling Framework

The concept of a financial model is traditionally associated with a structured and quantitative representation of the economic reality of a given system or business, designed to project financial performance, simulate scenarios, or assess viability under various assumptions. These models are widely used in corporate finance, project evaluation, and investment analysis, and they often involve interconnected spreadsheets, parameterized calculations, and dynamic links between input assumptions and output indicators. As highlighted by Lukić [45], financial models serve as comprehensive and customized quantifications of a company's operations, combining descriptive, explanatory, and predictive elements. They are essential decision-support tools, enabling stakeholders to understand the financial implications of strategic decisions through a structured and logically connected framework that mirrors the underlying operational and financial dynamics of the business.

In the context of this study, the financial model developed goes beyond a simple projection tool. It was specifically designed to simulate the dynamics of sugarcane production systems under different management strategies, integrating agronomic elements (such as ratoon-cycle productivity and field renovation) with financial and economic dimensions (such as net present value, internal rate of return, and cash-flow evolution). Rather than serving as a mere analytical appendix, the model developed here is the foundation upon which the entire study is built. It supports the scenario analysis, profitability assessments, and sustainability evaluations presented throughout this work. As Damodaran emphasizes [46], the primary role of a financial model is to translate assumptions into outcomes, offering a transparent framework for testing the financial consequences of strategic decisions-a process essential for sound valuation and investment planning. Similarly, Lukić reinforces that a well-built financial model is not merely a spreadsheet of numbers, but a structured representation of the operational and financial logic of a business, capable of generating consistent and insightful projections when driven by sector-informed assumptions and robust inter-variable links.

The primary objective of a financial model is to serve as a decision-support instrument by quantifying how operational strategies and external conditions affect business performance over time. Rather than offering absolute predictions, a well-structured model provides a controlled environment to explore the financial implications of different assumptions, allowing stakeholders to weigh risks, identify trade-offs, and prioritize strategic paths. This forward-looking functionality is particularly valuable in contexts where decision-making involves long-term commitments and high exposure to external volatility [46, 45].

In this study, the financial model was developed with the specific purpose of evaluating the long-term economic implications of different sugarcane field management strategies-particularly the balance between ratoon longevity and field renewal. Through its integration of agronomic yield data and financial metrics, the model enables a granular analysis of profitability trajectories under distinct scenarios. This is especially relevant in the sugarcane sector, where biological cycles, cost structures, and commodity prices introduce layers of complexity not captured by conventional corporate planning models. Therefore, the model not only fulfills the classic role of supporting investment appraisal and operational planning, but also serves as a platform to test sustainability-oriented interventions and quantify trade-offs inherent to agricultural production systems.

To facilitate a first understanding of how the model integrates agronomic cycles with financial outcomes, Figure 3.1 provides a consolidated overview of the key relationships and outputs. While it is revisited in greater detail in the results chapter, its early presentation here helps anticipate the main dynamics that will shape the subsequent analysis.

3.2.1 Building the Model

A standard financial model, particularly in corporate or project finance, is typically organized into a sequence of interconnected modules that transform raw

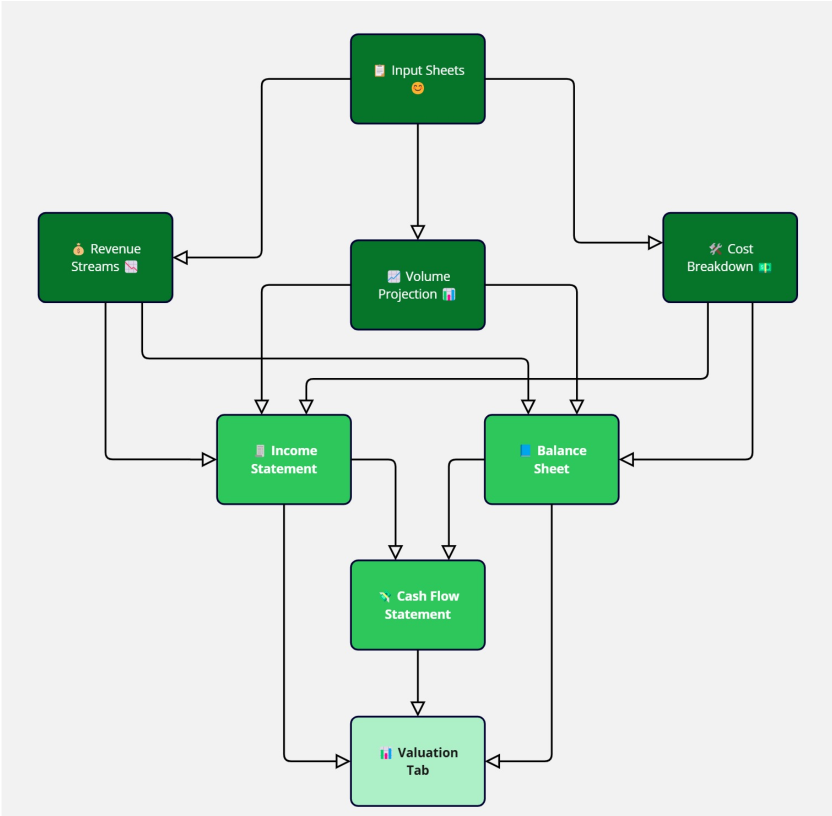

Figure 3.1: Flowchart of the financial model architecture

assumptions into structured outputs-most commonly, financial statements and investment metrics. As noted by Lukić [45], well-constructed models rely on three core layers: inputs, processing logic, and outputs. The input layer consists of both historical and forecasted operational and market data, which feed into a central calculation engine responsible for projecting revenues, costs, taxes, financing flows, and ultimately the three key financial statements-income statement, balance sheet, and cash-flow statement. These outputs are then used to derive valuation and performance metrics such as net present value (NPV), internal rate of return (IRR), and payback period. Importantly, the entire model should remain dynamically linked, so that changes in assumptions propagate logically through to the final outputs, enabling real-time scenario testing and strategic simulations.

The model developed for this study follows that classical structure but introduces several adaptations tailored to the agronomic and economic realities of sugarcane production. It is implemented as a spreadsheet-based model and organized across multiple tabs, each serving a specific function within the broader modeling logic.

Spreadsheet Tabs Overview

In our sheet, there are three main sections of the model - inputs, calculations, financials - and a separate raw data sheet. This organization follows the three-layer structure of professional financial models (inputs, processing logic, outputs), promoting transparency and enabling real-time scenario analysis.

0. Valuation The Valuation tab brings together outputs from the core financial statements (Balance Sheet, Income Statement and Cash-flow Statement) to produce a comprehensive suite of investment metrics:

- **Net Present Value (NPV):** discounts forecast free cash flows to the firm (FCFF) at the user-specified cost of capital (WACC), then subtracts the initial outlay.
- **Internal Rate of Return (IRR) & Modified IRR (MIRR):** IRR is the discount rate that zeroes out NPV; MIRR assumes interim cash flows are reinvested at the project's WACC.
- **Payback Period:** the (undiscounted) length of time required for cumulative cash inflows to recoup the original investment.
- **Cost of Capital (WACC):** a weighted average of cost of equity (via CAPM) and after-tax cost of debt, based on the model's target leverage.
- **EV/EBITDA Multiple:** enterprise value (sum of discounted FCFF plus net debt) divided by terminal-year EBITDA.

Results are reported for the Base, Optimistic and Pessimistic scenarios in parallel tables and charts. An "Acquisition Analysis" section uses these same cash-flow forecasts and hurdle-rate parameters to calculate the maximum bid price consistent with the target IRR and debt-service coverage criteria. Both the scenario comparisons and the acquisition framework will be explained in greater detail later in the Methodology.

0. Control Panel The Control Panel centralizes all user-modifiable inputs into two panels:

1. **Agronomic Drivers:**
    - Ratoon-cycle decay rate and maximum number of cycles before replanting
    - Planting-date multipliers (early, normal, late)
    - Water-availability factor (field-capacity vs. wilting point)

Valuation

In R$ '000 (except if said otherwise)	2024	2025E	2026E	2027E	2028E	2029E	2030E	2031E	2032E	Perpet.
Cash Flow										
EBITDA		**1.683**	**1.271**	**937**	**652**	**479**	**2.672**	**2.440**	**1.998**	**2.067**
(-) D&A		(683)	(719)	(754)	(785)	(812)	(866)	(889)	(938)	(501)
EBIT		**1.000**	**553**	**183**	**(132)**	**(334)**	**1.806**	**1.551**	**1.060**	**1.566**
(-) Taxes		(340)	(188)	(62)	–	–	(614)	(527)	(360)	(533)
% effective rate		34%	34%	34%	0%	0%	34%	34%	34%	34%
(=) NOPLAT		**660**	**365**	**121**	**(132)**	**(334)**	**1.192**	**1.023**	**700**	**1.034**
(+) D&A		683	719	754	785	812	866	889	938	501
(+/-) Working Capital Variation		(76)	69	26	25	7	(537)	384	(7)	(63)
Capital de giro		*1.756*	*1.686*	*1.660*	*1.635*	*1.628*	*2.165*	*1.780*	*1.788*	*1.850*
(=) Operational Cash Flow		**1.268**	**1.152**	**901**	**678**	**486**	**1.521**	**2.297**	**1.630**	**1.472**
(-) CAPEX		–	(353)	(353)	(310)	(276)	(3.190)	(231)	(484)	(501)
(=) Investments Cash Flow		–	**(353)**	**(353)**	**(310)**	**(276)**	**(3.190)**	**(231)**	**(484)**	**(501)**
(=) Free Cash Flow to Firm (FCFF)		**1.268**	**800**	**548**	**368**	**210**	**(1.669)**	**2.066**	**1.146**	**971**
% Cash Conversion (over EBITDA)		*45,3%*	*65,5%*	*80,2%*	*57,9%*	*57,6%*	*57,9%*	*58,2%*	*58,3%*	*74,4%*
Discounted Cash Flow										
Discounted Cash Flow		**1.171**	**631**	**369**	**212**	**103**	**(701)**	**741**	**351**	**298**
Discount factor		*92%*	*79%*	*67%*	*58%*	*49%*	*42%*	*36%*	*31%*	*31%*
Mid/Endpoint		*0,5*	*1,5*	*2,5*	*3,5*	*4,5*	*5,5*	*6,5*	*7,5*	*7,5*

Cost of capital (WACC)	**17,1%**
Cost of Equity (Ke)	21%
% Target E/(E+D)	60,0%
Cost of Debt (Kd)	17%
% Target D/(E+D)	40%
% Rate IR	34%
Perpetuity Growth	4%

Figure 3.2: Print Screen showing the start of the Valuation Tab, with symbolic values

2. **Market & Cost Assumptions:**
   - Sugar and ethanol price trajectories under each macro scenario
   - Exchange-rate forecasts and stress cases
   - Input-cost indices for fertilizer, pesticide and fuel

Each input is color-coded (blue) and data-validated; modifying any lever here automatically cascades through the Calculations and Financials sheets, instantly updating the Valuation tab. This streamlined interface supports rapid "what-if" testing and sensitivity sweeps on key agronomic and market parameters.

Control Panel

Control Panel

Cycle Duration (years)	6	Herbicides Use (0 - Base Case, 1- Low Use, 2- High Use)	-	Sugar price	1
Increase in costs due to scale	0%	Insecticides Use (0 - Base Case, 1- Low Use, 2- High Use)	-	Ethanol price	1
Price Increase (inflation vs cagr)	-	Fungicites Use (0 - Base Case, 1- Low Use, 2- High Use)	-	Oil price	1
Dollar variation (0-Base,1-Low,2-High)		Planting Windown (days)	-	Water Availability (0 - Base, 1-Dry, 2-Wet)	-

Figure 3.3: Print Screen showing the Control Panel Tab, with symbolic values

Inputs The Inputs section gathers all of the assumptions that drive the model:

4. **Macroeconomic** Key macro driver-IPCA (Índice Nacional de Preços ao Consumidor Amplo, Brazil's Broad Consumer Price Index measuring household inflation), IGP-M (Índice Geral de Preços–Mercado, the General Market Price Index covering wholesale, construction and consumer prices), the SELIC rate (Sistema Especial de Liquidação e de Custódia, Brazil's central bank overnight

policy rate), real-term interest assumptions (inflation-adjusted cost of capital) and exchange-rate forecasts (R$/US$ projections affecting input costs and export competitiveness)-are tabulated by year. Monthly and annualized projections allow both price and cost lines elsewhere in the model to inflate correctly. Source annotations (e.g. Itaú BBA Dez/24) document the origin and vintage of each curve.

4. **Cane Market:** Public-domain metrics, average ATR (Açúcares Totais Recuperáveis, or apparent total recoverable sugar, measured via polarization to quantify sucrose content and estimate per-ton sugar yield), total planted area, aggregate production, spot price per ton (the prevailing market price for immediate delivery of raw cane), and regional cost benchmarks (localized production cost indices), are imported here. These inputs calibrate the model's base-case price and yield assumptions and remain editable for stress-testing against alternative market research. [2].

4. **COGS Estimate:** A staged breakdown of cost of goods sold by agronomic phase (soil preparation, planting, cultural treatments, harvest) and administrative overhead. Each line shows per-hectare unit costs, total cost for the modeled area and percentage participation. Users can swap in bespoke contractor-rate quotes or adjust machine-hour costs to refine the COGS (Costs of goods sold) profile. [36, 7].

4. **Internal Factors** This sheet defines all in-field drivers: ratoon cycles before replanting, yield-decay curves per cycle, planting-date multipliers (early/normal/late) and irrigation efficacy. These factors feed directly into the Volume sheet to simulate realistic agronomic performance under varying management regimes.

4. **External Factors:** Here we model external multipliers-commodity-price adjustment factors, fuel-cost indices, fertilizer-price linkages and FX (Foreign exchange rate) pass-through coefficients. Each series is expressed as a yearly multiplier and drives the Revenue and COGS sheets so that the model reacts dynamically to shifts in global markets and input-cost inflation.

Calculations This section transforms inputs into operational metrics and preliminary financial flows:

2. **Revenue:** Here, sugarcane volume (from the Volume sheet) is multiplied by product prices and alternative offtake streams (e.g. raw cane vs. ethanol) to derive Gross Revenue per year. A YoY growth row calculates the percentage change and flags any flat or negative projections for review. This level of

granularity lets the user trace top-line figures back to unit-price and volume assumptions.

2. **Costs & Expenses:** Costs are broken into field-level (harvest, treatments, transport) and plant-level (processing, utilities, maintenance) categories. Each cost line is expressed in R$ '000 and linked to specific volume drivers (e.g. hectares harvested, tons processed). A separate opex section captures fixed overhead and administrative expenses. Margins and cost-per-unit metrics are computed to support variance analysis.

3. **Volume:** This sheet aggregates planted area, yield per hectare and ratoon-cycle decay rates to project annual production volume (in '000 tons). Historical baseline data from CONAB is blended with agronomic-cycle parameters (from Internal Factors) to generate a smooth forecast curve, with built-in switches to test "early" vs. "late" planting scenarios.

Financials Here the three core statements and investment metrics are generated:

1. **BS:** This sheet presents the projected statement of financial position, denominated in R$ Mil. Line items are grouped into Current Assets, Non-Current Assets, Current Liabilities and Non-Current Liabilities, with a reconciling Equity section at the bottom. Forecasts run from the model's first year through the terminal year, linked directly to the Cash-flow and Income Statement sheets via working-capital balances (receivables, inventory, payables) and retained-earnings roll-forwards. All subtotals update automatically when upstream drivers change, ensuring consistency across the three core financial statements.

1. **IS:** The Profit & Loss template calculates gross revenue by product line, subtracts cost of goods sold to arrive at gross profit, then layers on operating expenses (SG&A), depreciation & amortization, and non-operating items (interest expense, other income). Taxes are applied to pre-tax profit to yield Net Income. Year-over-year growth rates and margin ratios are shown in adjacent columns for quick performance appraisal. All linkages to the "Revenue" and "Costs & Expenses" build-up sheets preserve auditability of each line item.

1. **CF:** This sheet computes Free Cash Flow to the Firm (FCFF) by starting with EBIT, subtracting cash taxes to get NOPLAT, adding back non-cash charges (depreciation and amortization), adjusting for changes in working capital, and deducting projected CAPEX. Separate subtotals display Operating Cash Flow, Investing Cash Flow and Financing Cash Flow, facilitating checks on liquidity and debt repayments. The FCFF series feeds directly into the Valuation tab for NPV/IRR computation.

Raw Data

z. Historical Prices: A repository of raw time series for key commodities (raw cane, crystal sugar, Brent oil), sourced from Ipeadata and CONAB. This sheet underpins the calibration of price-forecast curves and allows back-testing of model outputs against actual historical performance.

The dynamic links among these tabs ensure that any change in Inputs propagates through Calculations to the Financials, allowing instant recalculation of NPV, IRR, payback period, and other key metrics.

What distinguishes this model from conventional corporate templates is its integration of biological productivity cycles-particularly the modeling of ratoon yield decay and replanting thresholds-which are central to both the operational strategy and the financial performance of sugarcane cultivation. Each component of the model will be described in detail throughout the chapter.

3.2.2 Financial Basis of the Model: Income Statement and Balance Sheet

The construction of the model is anchored in the two fundamental financial statements traditionally used in corporate finance and investment analysis: the Balance Sheet and the Income Statement. Although these elements have already been theoretically addressed in the literature review, this section briefly outlines their practical application within the model developed for this study, as well as the specific account structures adopted to reflect the economic and operational characteristics of a sugarcane-producing enterprise.

Balance Sheet

The design of the balance sheet in this model follows the conventional logic of financial modeling, with Assets, Liabilities, and Equity presented in a structured and interlinked format. However, given the specific focus on sugarcane plantation management, the selected accounts have been adjusted to reflect the operational and biological realities of the sector. The selection process was based on a standard corporate chart of accounts, cross-validated against publicly available financial statements of several sugarcane producers and agro-industrial companies operating in Brazil and internationally. This comparative approach ensured the inclusion of sector-relevant items-such as biological assets and specialized equipment-while maintaining a coherent and generalizable financial framework.

More specifically, accounts such as *Cane Inventory*, *Rootstock Value*, and *Field Development (Replanting)* were included to capture the biological asset dynamics inherent in perennial cropping systems. The differentiation between *Land*, *Infrastructure*, and *Field Improvements* allows the model to track capital investments with agricultural-specific depreciation and valuation behavior. On the liabilities side, items such as *Short-Term Rural Credit*, *Long-Term Loans*, and *Environmental Reserves* reflect common financing and regulatory structures observed in sugar-energy projects. Owner's Equity accounts maintain a straightforward composition suitable for owner-managed agricultural businesses, including *Reinvested Earnings* and, where applicable, *Capital Revaluation*.

Estimating Balance Sheet Opening Values for 2024

To estimate each account of the balance sheet for a 300-hectare sugarcane property, we combined recent sectoral data with agricultural accounting principles. Average parameters from the Brazilian sugar-energy sector (2023/24 harvest) were used, based on data from IBGE, CONAB, MAPA, Embrapa, ORPLANA and academic research, then scaled to 300 hectares. The general steps were:

- **Production Profile:** Yields per hectare were taken from CONAB [2] and adjusted to 300 ha, forming the basis for revenue, receivables, and inventory values.
- **2024 Price and Cost Assumptions:** Cane prices (ATR-linked) and input costs (fertilizers, agrochemicals) were drawn from Consecana and Pecege surveys [47].
- **Land Structure and Typology:** Embrapa and ORPLANA typologies [44] defined land ownership, mechanization levels, and per-hectare capital. Based on IBGE (2017) and IPEA studies, we assumed 100% owned land.

Current Assets

- *Cash and Cash Equivalents:* Set at $\sim$ 3.5% of annual revenue, reflecting low cash retention among mid-sized producers.
- *Accounts Receivable:* R$450 000, 1.1 months of sales, to account for ATR adjustments [47].
- *Provision for Doubtful Accounts (PDD):* 5% of receivables, per conservative accounting norms [48].
- *Cane Inventory:* Fair value of standing cane less harvest & transport costs, per CPC 29.

- *Supplies Inventory:* R$90 000 (10% of annual inputs); inputs cost R$915 000/year [49].
- *Prepaid Expenses:* R$150 000 for insurance, software, and advances.

Non-Current Assets

- *Land (Owned):* R$66 000/ha $\times$ 300 ha = R$19.8 m [50, 51].
- *Buildings & Infrastructure:* R$300 000 (∼R$1 000/ha), depreciated 10 years [47].
- *Field Improvements:* R$100 000, depreciated 10 years; <5% irrigated in Southeast Brazil [30].
- *Machinery & Equipment:* R$1 000 000, depreciated 10 years [47].
- *Vehicles:* R$250 000, depreciated 10 years.
- *Rootstock Value:* R$1.4 m (R$9 231/ha $\times$ 300 ha $\times$ 50% unamortized) [2].

Current Liabilities

- *Accounts Payable:* R$250 000 (30% of input purchases financed) [47].
- *Wages & Benefits Payable:* Accrual for 6 field + 1 admin staff, 1–2 months.
- *Short-Term Loans:* R$200 000 (5–10% of operational costs) [52, 53].
- *Current Portion of Long-Term Debt:* 13–15% annual amortization of R$1.5 m [52].
- *Taxes Payable:* IRPJ/CSLL and Funrural accruals [48].
- *Lease Payments Due:* R$360 000 for tractor leases + other rentals.

Non-Current Liabilities

- *Long-Term Debt:* 40–60% of R$2.5–3 m fixed assets financed [52].
- *Lease Obligations:* R$900 000 for 3 years of equipment leases [51].

Owner's Equity

- *Share Capital:* 90% of land value financed by equity.
- *Retained Earnings:* Cumulative R$2 m from prior years.
- *Net Income (2024):* From the income statement below.
- *Revaluation Surplus:* Land appreciation per market data [50].

Income Statement

The income statement was built by estimating each line item for the 300-hectare farm in 2024:

Revenue & Deductions

- *Gross Revenue:* Yield/ha × 300 ha × price/ton [2].
- *Sales Cancellations:* 1% of gross revenue.
- *Taxes & Deductions:* PIS/COFINS at blended 1.8% + Funrural 1.2% of sales [48].

Operating Costs & Expenses *COGS* was split into:

- *Cana-Planta:* R$6 469/ha (maintenance and harvest) [49].
- *Soil Preparation & Planting:* R$9 231/ha [49].
- *Cana-Soca:* R$5 575/ha (ratoon maintenance and harvest) [49].

Operating Expenses: R$270/ha covering admin, insurance, utilities [54].
Provision for Doubtful Accounts (PDD): 5% of receivables as an operating expense [54].
Other Operating Income: Minor revenue (straw sales, rentals) estimated conservatively.

Depreciation, Financing & Taxes

- *Depreciation & Amortization:* Machinery (10 year SL) + 1/5 of replant cost (5 year SL) [47].
- *Financial Result:* 8% interest on total debt [52].
- *Income Tax & CSLL:* 34% of pre-tax income under Lucro Real [48].

3.3 Composite Influence Factors

To capture, in a single term, all sources of variability driving our three key outputs-harvest volume V_n, realized price P_n, and total cost C_n-we express each as a baseline value multiplied by a composite factor:

$$V_n = V_1 \times F_{V,n}, \quad P_n = P_1 \times F_{P,n}, \quad C_n = C_1 \times F_{C,n}.$$

Each composite multiplier $F_{\cdot,n}$ is built from the following seven sub-factors (see Sections 3.3.1–3.3.7):

1. **Ratoon Yield Decline** (R_n): Captures the exponential decay of yield across successive ratoon cycles (Section 3.3.1).
2. **Planting-Date Productivity Multiplier** (H_n): Reflects the ±30-day shift effects on sugar accumulation from "dry-off" trials (Section 3.3.2).
3. **Pesticide-Use Volume Factor** ($Z_{V,n}$): Translates non-linear dose–response yield gains into a multiplicative volume adjustment (Section 3.3.3).
4. **Water Availability Factor** (W_n): Embeds soil-moisture stress via the FAO yield-response function, indexed to field-capacity and wilting-point thresholds (Section 3.3.6).
5. **Sugarcane Market-Price Adjustment** (M_n): Converts crystal-sugar and ethanol price scenarios into a sugarcane price factor through estimated elasticities (Section 3.3.4).
6. **Oil-Price Cost Adjustment** (O_n): Projects Brent-price forecasts via Holt's smoothing and scales the oil-sensitive share of per-hectare costs (Section 3.3.5).
7. **Currency Exposure Factor** (X_n): Captures USD/BRL swings' impact on both export-linked revenue and imported-input costs (Section 3.3.7).

Grouping these, the composite multipliers are defined as

$$F_{V,n} = R_n \times H_n \times Z_{V,n} \times W_n, \tag{3.1}$$
$$F_{P,n} = M_n \times X_n, \tag{3.2}$$
$$F_{C,n} = Z_{C,n} \times O_n \times X_n, \tag{3.3}$$

where $Z_{C,n}$ is the pesticide-cost factor from Section 3.3.3. Factors 1–3 are *internal* (under management control), while 4–7 are *external* (reflecting climate and market uncertainties), enabling both agronomic optimization and stress-testing under varied scenarios.

In selecting the composite influence factors for this model, priority was given to variables whose effects on price, production volume or unit costs can be directly quantified. To this end, a systematic review of the entire sugarcane production chain was conducted to identify all potential drivers, and from this universe of possibilities we retained only those factors that (a) admit straightforward measurement or estimation and (b) meaningfully reflect either controllable, internal management decisions (e.g. ratoon age, fertilization level) or observable, external conditions (e.g. market price indices, climatic indicators). This dual-criteria approach ensures the model remains both practically actionable, by focusing on levers under the grower's influence, and empirically grounded, by relying on data sources that are readily available and consistently reported.

Internal vs. External Drivers

Each sub-factor belongs to one of two broad categories:

1. **Internal factors (under our control)** These represent management-driven choices-planting density, fertilizer and pesticide schedules, irrigation applications, harvest timing, and ratoon-cycle planning. We will optimize these internal levers to demonstrate how proactive decisions can improve volume, price realization, and cost efficiency.

2. **External factors (beyond our control)** These capture the uncertainty of the operating environment-commodity price swings, exchange rates, season-to-season weather variability, and input-price inflation. By treating these as scenario parameters, we can show how our optimized internal settings perform under differing external conditions.

By structuring our model around three annual composite factors, each built from internally-optimizable and externally-scenario-driven sub-factors, we achieve two goals:

- *Optimization:* quantify how better agronomic and operational choices (internal) boost returns.

- *Scenario analysis:* assess resiliency and downside risk when external conditions (prices, climate, costs) shift.

The following subsections will define each sub-factor in detail, explain how internal ones are calibrated or optimized, and describe the external scenarios against which we'll test our management strategies.

3.3.1 Ratoon Yield Decline Model

To capture the decline in sugarcane yield across successive ratoon harvests, we adopt a negative exponential decay model of the form

$$R_n \;=\; \exp\Big(-k\,(n-1)\Big),$$

where R_n is the ratio of the nth ratoon yield to the plant-cane yield ($n = 1$ -> $R_1 = 1$), and k is the decay constant. This formulation implies a constant fractional yield loss per cycle, so that

$$Y_n \;=\; Y_1\,R_n \;=\; Y_1 \exp\Big(-k\,(n-1)\Big)\,,$$

with Y_1 the plant-cane yield.

Rationale for Exponential Form.

- *Theoretical plausibility.* Factors such as soil nutrient depletion, pest buildup, and compaction exert cumulative, compounding effects on ratoon fields. A fixed percentage loss per cycle (e.g. "≈10% per ratoon") better matches agronomic observations than a fixed absolute drop, and naturally prevents negative yields by asymptotically approaching zero.
- *Parsimony and interpretability.* With only one decay parameter k, the model is straightforward to fit and explain: k directly measures the mean fractional loss per ratoon. This contrasts with higher-order polynomials (multiple coefficients) or complex process models (many parameters).

Empirical Calibration. We fit the model to irrigated sugarcane yield data from Keerthipala & Dharmawardene (2000)[55], using the first four cycles in three irrigated contexts (Sevanagala irrigated settler, Hingurana irrigated settler, Hingurana irrigated out-grower). Taking logarithms,

$$\ln(Y_n) \;=\; \ln(Y_1) \;-\; k\,(n-1),$$

we estimated k by linear regression of $\ln(Y_n)$ against $n-1$ for each dataset, and then averaged:

$$k_{\text{irrigated}} \;=\; 0.145.$$

This value will be used in our model to simulate typical ratoon-yield decay under irrigated conditions.

3.3.2 Derivation of Planting-Date Productivity Multipliers

To quantify the yield penalty associated with shifting the sugarcane planting date by approximately ±30 days, we adapt the controlled "dry-off" experiment of Araújo *et al.* (2016)[56]. In their drip-irrigated trial on the CTC4 variety (cane-plant cycle), five irrigation-cut treatments were imposed at 90, 60, 30, 15 and 0 days before the scheduled harvest. Sugar yield (total recoverable sugar, kg t^{-1}) was measured at each evaluation date, revealing a clear optimum when irrigation ceased 30 days pre-harvest. Relative to this optimum:

$$\begin{aligned} \text{Yield at 60 days dry-off:} &\quad \approx Y_{30} \times (1 - 0.11) \quad (\text{–}11\%)\,, \\ \text{Yield at 0 days dry-off:} &\quad \approx Y_{30} \times (1 - 0.05) \quad (\text{–}5\%), \end{aligned}$$

where Y_{30} denotes the sugar yield under the 30 day dry-off treatment.

Because a ± 30 day planting shift similarly relocates the critical 30 day maturation window into hotter/drier (early-plant) or cooler/wetter (late-plant) seasonal regimes, we define three dimensionless multipliers F_E, F_N, and F_L by direct analogy:

$$\begin{aligned} F_E &= 1 - 0.11 = 0.89 \qquad (\text{early planting analogue})\,, \\ F_N &= 1.00 \qquad (\text{baseline, “normal” planting})\,, \\ F_L &= 1 - 0.05 = 0.95 \qquad (\text{late planting analogue})\,. \end{aligned} \tag{3.4}$$

Thus, for any baseline yield $\overline{Y}$ under a normal planting date, the expected yields under shifted plantings become

$$Y_{\text{early}} \;=\; F_E\,\overline{Y} \;=\; 0.89\,\overline{Y}, \qquad Y_{\text{late}} \;=\; F_L\,\overline{Y} \;=\; 0.95\,\overline{Y}.$$

This method assumes “average-year” climate conditions and is most directly applicable to single-year ratoon cycles, in which the 30 day maturation period dominates final sugar accumulation [56].

3.3.3 Pesticide-Use Factors for Volume and Cost Adjustments

Percentage Yield Improvements as Pre-Knowledge

A recent meta-analysis of over two hundred field trials in subtropical sugarcane systems demonstrates that the relationship between pesticide dose and yield gain is highly non-linear. In particular, Virk et al. (2024) fit mixed-effects curves for each pesticide class-herbicide, insecticide and fungicide-and report that:

- **Herbicides** at 0.21 kg ha^{-1}, 0.22 kg ha^{-1} and 1.00 kg ha^{-1} active ingredient correspond, respectively, to yield improvements of approximately +30%, +31% and +15% over unsprayed controls.
- Similar sigmoidal dose–response patterns occur for **insecticides** and **fungicides**, with optimum yield gains near the base-case dose and diminishing returns at higher rates (Virk et al., 2024).

We take these three "Low-Use / Base-Use / High-Use" points per class as given. From here, we derive multiplicative factors to adjust both (a) total cane volume (t ha^{-1}) and (b) pesticide costs (R$ ha^{-1}) in our financial model.

Model Inputs: Herbicide Usage and Costs

Herbicides used	Amount used	R$/Kg	% Of costs
Hexazinona D	0,06	100	0%
Plateau	0,16	685	4%
Total	0,22	525	4%

Inseticides Used	Amount used	Price/Kg	% Of costs
Curavial	0,02	3550	3%
Certero	0,1	244	1%
Belt	0,1	686	3%
Regent 800 WG	0,02	870	1%
Actara 250	0,33	162	2%
Total	0,57	412	9%

Fungicides Used	Amount used	Price/Kg	% Of costs
Priori Xtra	0,1	201	8%
Provence	0,17	415	3%
Total	0,27	336	11%

Table 3.1: Herbicide, insecticide and fungicide quantities and unit costs used in the base case

Table 3.1 shows that our base-case herbicide mix uses 0.22 kg ha^{-1} at an average R$ 525 kg^{-1}, totaling R$ 116 ha^{-1}.

From % Yield to Multiplicative Factors

We convert the reported percentage yield changes into dimensionless "volume" (F_v) and "cost" (F_c) factors via six steps:

1. **Baseline use & cost.** From Figure 3.1, herbicide use = 0.22 kg ha^{-1}, cost = R$ 525 kg^{-1}, so $C_{\text{base}} = 0.22 \times 525 = 116$ R$ ha^{-1}.

2. **Scenario costs.** $C_{\text{dose}} = (\text{kg ha}^{-1})_{\text{dose}} \times 525$. E.g. at 1.00 kg ha^{-1}, $C_{\text{high}} = 525$ R$ ha^{-1}.

3. **Absolute yield change.** $\Delta V = 77$ t/ha $\times$ (%gain). For 31%: $\Delta V_{\text{base}} = 24$ t ha^{-1}.

4. **Volume factor.**
$$F_v = 1 \; - \; \left(1 - \frac{\Delta V_{\text{dose}}}{\Delta V_{\text{base}}}\right) \times \frac{\Delta V_{\text{base}}}{77}.$$
For the low-use herbicide (23 vs. 24 t): $F_v = 1 - (1 - 23/24) \times (24/77) \approx 0.99$.

5. **Cost factor.**
$$F_c = 1 \; - \; \left(1 - \frac{C_{\text{dose}}}{C_{\text{base}}}\right) \times \frac{C_{\text{base}}}{C_{\text{total}}}.$$
Here C_{total} is total pesticide cost per hectare (aroun R$ 500).

6. **Repeat for each class.** We apply these formulae identically to insecticides and fungicides.

Herbicides	Use (Kg/ha)	% Yield Improve	Costs/ha	Vol inc. (ton/ha)	Factor (vol)	Factor (costs)
Low Use	0,21	30%	110	23	0,99	1,00
Base case	0,22	31%	116	24	1,00	1,00
High Use	1	15%	525	12	0,84	1,16

Table 3.2: Herbicide scenario doses, yield gains, costs, and resulting factors F_v, F_c (Andrade, 2024)

Figure 3.2 illustrates the computed F_v and F_c for the low-, base- and high-use herbicide scenarios. In the financial model, baseline volume and cost are multiplied by these factors to simulate the impact of reduced or increased pesticide rates on both output and expenditure.

By anchoring on the rigorously derived Virk et al. (2024) dose–response data and normalizing to our plantation's baseline, we embed real agronomic non-linearities into our economic projections.

3.3.4 Sugarcane Price Adjustment Factor from Ethanol and Sugar variations

To quantify how fluctuations in the market prices of crystal sugar and hydrated ethanol propagate to the price of sugarcane, we adopted a three-stage procedure: (i) data acquisition and annual aggregation; (ii) definition of growth scenarios for sugar and ethanol; and (iii) estimation of elasticities and assembly of the adjustment factor.

Data acquisition and annual aggregation

Weekly price series for crystal sugar were obtained from CEPEA, while weekly sugarcane prices were sourced from CONAB. To smooth out high-frequency noise, each weekly series $P_{t,w}$ (week w of year t) was aggregated into an annual series $\bar{P}_t$ via arithmetic mean:

$$\bar{P}_t = \frac{1}{52} \sum_{w=1}^{52} P_{t,w}.$$

The same aggregation was applied to the ethanol price series.

Definition of growth scenarios

For each annual series $\{\bar{P}_t\}_{t=2015}^{2025}$, we computed the Compound Annual Growth Rate (CAGR):

$$g_{\text{CAGR}} = \left(\frac{\bar{P}_{2025}}{\bar{P}_{2015}}\right)^{\frac{1}{10}} - 1.$$

For example, if $\bar{P}_{2015} = 78.8$ and $\bar{P}_{2025} = 146.2$ for sugar, then $g_{\text{CAGR}}^{\text{sugar}} \approx 6.4\%$. From this base rate, three growth scenarios were constructed by applying a $\pm 25\%$ sensitivity rule:

$$\begin{aligned} g_{\text{pessimistic}} &= 0.75\, g_{\text{CAGR}}, \\ g_{\text{base}} &= 1.00\, g_{\text{CAGR}}, \\ g_{\text{optimistic}} &= 1.25\, g_{\text{CAGR}}. \end{aligned}$$

This $\pm 25\%$ range is widely adopted in scenario analysis because it is (a) straightforward to communicate, (b) anchored within historical volatility, and (c) sufficiently conservative to avoid unrealistic extremes. For each scenario c, the projected price h years ahead is given by geometric compounding:

$$\hat{P}_{t+h}^{(c)} = \bar{P}_t \left(1 + g_c\right)^h.$$

Estimation of Elasticities

To measure how variations in sugar and ethanol prices translate into changes in the sugarcane price, we first convert each annual price series $\{\bar{P}_t^X\}$ into year-over-year logarithmic returns:

$$r_t^X = \ln\left(\bar{P}_t^X\right) - \ln\left(\bar{P}_{t-1}^X\right), \quad X \in \{\text{cane, sugar, ethanol}\}.$$

This transformation approximates the percentage change and renders multiplicative effects additive, which permits straightforward linear regression.

We then estimate the following multivariate regression model over the sample of annual returns:

$$r_t^{\text{cane}} = \alpha + \beta_{\text{sugar}}\, r_t^{\text{sugar}} + \beta_{\text{ethanol}}\, r_t^{\text{ethanol}} + \varepsilon_t.$$

Here, α captures any average drift in cane returns not explained by sugar or ethanol, while the coefficients β_{sugar} and β_{ethanol} are elasticities. Each β indicates the percent-change in sugarcane price associated with a 1 % change in the corresponding input price, holding the other constant. These elasticities form the core link between input markets and the sugarcane price.

Projection of Sugarcane Price

Once elasticities are obtained, we construct our scenario projections by layering an inflation baseline with an elasticity-weighted adjustment:

1. Let P_0^{cane} be the current sugarcane price and π the cumulative inflation factor over the projection horizon. The inflation–only forecast is

$$P_{\text{baseline}} = P_0^{\text{cane}} \times \Big(1 + \pi\Big).$$

2. For each scenario $c \in \{\text{pessimistic}, \text{base}, \text{optimistic}\}$, denote by $g_{\text{sugar}}^{(c)}$ and $g_{\text{ethanol}}^{(c)}$ the scenario CAGRs for sugar and ethanol, and by $g_{\text{sugar}}^{\text{base}}$, $g_{\text{ethanol}}^{\text{base}}$ their base-case CAGRs. Compute the excess growth rates

$$\Delta g_{\text{sugar}} = g_{\text{sugar}}^{(c)} \;-\; g_{\text{sugar}}^{\text{base}}, \quad \Delta g_{\text{ethanol}} = g_{\text{ethanol}}^{(c)} \;-\; g_{\text{ethanol}}^{\text{base}}.$$

3. Weight these deviations by the estimated elasticities to form the adjustment factor

$$A^{(c)} = 1 \;+\; \beta_{\text{sugar}}\, \Delta g_{\text{sugar}} \;+\; \beta_{\text{ethanol}}\, \Delta g_{\text{ethanol}}.$$

4. The final projected sugarcane price under scenario c is

$$\hat{P}_{(c)}^{\text{cane}} = P_{\text{baseline}} \;\times\; A^{(c)}.$$

This approach cleanly separates a conservative inflation baseline from the incremental impacts of sugar and ethanol market dynamics, grounded in the empirically estimated elasticities.

3.3.5 Projecting Oil Price Evolution for Cost Adjustment

To estimate the factor representing the impact of oil price changes on our pesticide-application costs and transportation costs, we first need to project the expected evolution of Brent crude prices. For that, we employ Holt's linear trend exponential smoothing to capture both underlying trends and recent volatility in the 2000–2025 historical series. Below is our step-by-step methodology.

Data Collection

We gathered annual FOB Brent prices (US$ per barrel) for 2000–2025 from the LiteFinance report.

Method Selection

Given oil's pronounced trend and volatility, a simple CAGR is inappropriate. Instead, we apply Holt's double exponential smoothing:

$$\begin{cases} \ell_t = \alpha\, y_t + (1-\alpha)\,(\ell_{t-1} + b_{t-1}) \\ b_t = \beta\,(\ell_t - \ell_{t-1}) + (1-\beta)\, b_{t-1} \\ \hat{y}_{t+h} = \ell_t + h\, b_t \end{cases}$$

where ℓ_t is the estimated level, b_t the trend component, and α, β are smoothing parameters optimized by maximum likelihood.

Projection Fitting

Using Python's `statsmodels`, we fit an additive-trend model (no seasonality) to the 2000–2025 series. The optimized smoothing parameters ($\alpha \approx 0.75$, $\beta \approx 0.10$) reflect strong responsiveness to recent price changes and moderate trend updating.

Oil Price Forecasting

We then forecast Brent prices for 2026–2034. Table 3.3 and Figure 3.4 display the historical data alongside the 8-year projection.

Table 3.3: Brent Price Forecast (Holt's Linear Trend, 2026–2034)

Year	Forecasted Price (US$ /bbl)
2026	76.85
2027	78.70
2028	80.56
2029	82.41
2030	84.26
2031	86.11
2032	87.96
2033	89.82
2034	91.67

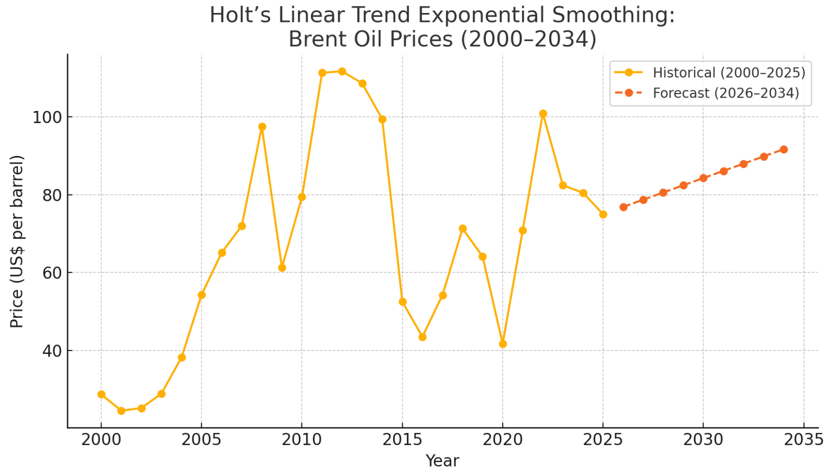

Figure 3.4: Historical vs. Holt's linear trend forecasts for Brent prices.

These forecasts, reflecting the anticipated trajectory of oil prices, will be considered as our base case and variations will be transformed into a multiplicative cost factor in the costs of our model, ensuring that changing fuel prices are properly accounted for in scenario analyses.

Applying to the model

To quantify how fluctuations in global oil prices translate into our model's per-hectare costs, we first project the future Brent curve, then convert those projections into year-on-year (YoY) changes, define stressed scenarios around that base case, and finally weight the incremental impacts by the share of costs directly tied to oil

1. Project the future Brent curve and compute year-on-year (YoY) growth rates.
2. Define low- and high-growth stress scenarios around that base case.
3. Identify the share of total costs directly tied to oil.
4. Compute, for each scenario, the incremental oil-price cost factor.
5. Apply those factors multiplicatively to the base per-hectare cost.

Projecting Brent Price Growth

From our Holt-smoothed historical Brent series (2000–2025), extended through 2034, let P_t denote the forecast price in year t. The base-case YoY growth rate is

$$\Delta_{\text{base},t} = \frac{P_t - P_{t-1}}{P_{t-1}} \times 100\%, \quad t = 2001, \ldots, 2034.$$

Defining Stress Scenarios

To capture downside and upside risk, we scale each year's base-case growth by fixed multipliers:

$$\Delta_{\text{low},t} = 0.75\,\Delta_{\text{base},t}, \quad \Delta_{\text{high},t} = 1.25\,\Delta_{\text{base},t}.$$

Identifying Oil-Sensitive Cost Shares

Within our total cost base, only transportation and pesticide inputs move materially with oil prices:

Costs involved	Value (R$)	% Total
Transportation	990	16%
Pesticides	441	7%
Total	1 431	24%

Table 3.4: Share of total unit costs sensitive to oil-price changes.

Hence the combined oil-dependency weight is

$$w_{\text{oil}} = 0.16 + 0.07 = 0.24\ (24\%).$$

Oil-Price Cost Factor Calculation

For each scenario $s \in \{\text{low}, \text{base}, \text{high}\}$ and year t, define the incremental cost factor as the deviation of that scenario's YoY growth from the base case, scaled by w_{oil}:

$$F_{s,t} = \Big(\Delta_{s,t} - \Delta_{\text{base},t}\Big) \times w_{\text{oil}}.$$

By construction, $F_{\text{base},t} = 0$; $F_{\text{low},t} < 0$ and $F_{\text{high},t} > 0$ capture relative cost relief or pressure.

Adjusting Per-Hectare Costs

Finally, apply these factors multiplicatively to the base per-hectare cost:

$$C_{s,t} = C_{\text{base}} \times (1 + F_{s,t}), \quad C_{\text{base}} = 6{,}022$$

This yields three parallel cost trajectories-low, base, and high-that feed into our scenario analysis.

3.3.6 Water Availability Factor

To translate soil moisture into an adjustment of projected cane volume (sheet "3. Volume"), we define a dimensionless *water availability factor* $f_{\text{water}} \in [0,1]$. Rather than assume a one-to-one response, we adopt the FAO water-production function, which relates relative yield reduction to evapotranspiration deficit via a crop-specific *yield response factor* k_y [57, 58].

1. Soil moisture thresholds. Permanent wilting point θ_{wp} is the volumetric moisture below which plants can no longer extract water and wilt irreversibly. Field capacity θ_{fc} is the moisture remaining 24–48 h after excess gravitational water has drained. Maulana et al. measured these for tropical sugarcane soils as $\theta_{\text{wp}} = 27\%$ and $\theta_{\text{fc}} = 40\%$ (vol. basis) using pressure-plate methods [59]. These values align with documented ranges for medium-textured tropical loams and are thus appropriate for our Brazilian model.

2. Soil-water balance. On a monthly timestep, volumetric moisture θ_t in the active root zone is simulated by a simple bucket model:

$$\theta_t = \theta_{t-1} + \frac{P_t + I_t - ET_c(t) - L_t}{Z\,\rho_b},$$

where P_t is precipitation, I_t irrigation, $ET_c = ET_o \times K_c$ crop evapotranspiration (FAO-56), L_t losses (runoff/percolation), Z rooting depth, and ρ_b bulk density.

3. Computing relative extractable water.

$$\text{RAW}_t = \frac{\theta_t - \theta_{\text{wp}}}{\theta_{\text{fc}} - \theta_{\text{wp}}}\,,$$

with RAW_t unconstrained.

4. Yield response function. We then calculate the water factor as

$$\frac{Y_a}{Y_{\text{m}}} = 1\ -\ k_y\Big(1 - \text{RAW}_t\Big),$$

so that

$$f_{\text{water},t} = \max\Big(0, \min\Big(1,\ 1 - k_y\,(1 - \text{RAW}_t)\Big)\Big).$$

5. Choice of k_y. FAO data for sugarcane typically report $k_y \approx 0.75$ [58]. To reflect high tolerance to moderate deficits, we select a sightly smaller $k_y = 0.70$.

6. Example scenarios.

Scenario	RAW_t	$f_{\text{water},t} = 1 - 0.70\,(1 - \text{RAW}_t)$
Dry	0.75	$1 - 0.70 \times 0.25 = 0.83$
Base	0.90	$1 - 0.70 \times 0.10 = 0.93$
Wet	1.00	$1 - 0.70 \times 0.00 = 1.00$

7. Volume adjustment. Finally, assuming that the factor for our base case is 1, we have the following:

$$Wn(f_{\text{water},t}) = f_{\text{water},t}/0.93$$

so that,

$$W_n(0.83) = \frac{0.83}{0.93} \approx 0.89,$$
$$W_n(0.93) = \frac{0.93}{0.93} = 1.00,$$
$$W_n(0.75) = \frac{0.75}{0.93} \approx 0.81.$$

and the unstressed volume $V_{0,t}$ from sheet "3. Volume" is scaled:

$$V_t = V_{0,t} \times Wn.$$

This approach embeds empirically observed buffering of sugarcane yield under water stress into our financial model.

3.3.7 Currency Exposure Factor

To capture currency risk in both revenues and imported-input costs, we introduce two related factors per scenario s: a sugar-price factor $f_{\text{price},s}$ and a pesticide-cost factor $f_{\text{pest},s}$.

Exchange-rate scenarios. Let USD_{base} be the Itaú BBA forecasts for USD/BRL (average of the year). The forecast goes up to 2028, so in order to extend it to the followying years, we assume the same YoY growth sequence (for example, if YoY Growth from 2024 to 2025 is equal to 7%, we assume this same growth for YoY Growth from 2028 to 2029). We define "low" and "high" cases by adjusting this forecast by ±25%, a range that reflects yearly forecasting errors spanning 20–30% for USD/BRL over the past decade (Central Bank of Brazil data).

This Factor is different from the others, as even in the Base Case, we will take into the account the currency exchange variation, while in the other factors the base case is always 1.

Thus:

$$\text{YoY}_{\text{low}} = \text{YoY}_{\text{base}} \times 0.75, \quad \text{YoY}_{\text{high}} = \text{YoY}_{\text{base}} \times 1.25.$$

We then compute the exchange-rate variation

$$\Delta_{\text{YoY},s} = \frac{\text{YoY}_s - \text{YoY}_{\text{base}}}{\text{YoY}_{\text{base}}} \quad (s \in \{\text{low, base, high}\}).$$

Sugar-price factor. Since roughly 80 % of Brazil's sugar (35.8 / 44.7 = 0.80) is exported (USDA FAS 2025), domestic sugar prices move with USD/BRL by that share. We set

$$X_{\text{price},s} = 1 + Ep \times YoY_s, \quad Ep = 0.80.$$

Pesticide-cost factor. Pesticides are almost entirely imported, so their BRL-costs move one-for-one with USD/BRL:

$$f_{\text{pest},s} = 1 + \Delta_{\text{USD},s}.$$

In order to turn this factor, which is only related to the costs of pesticides, in a factor we can use to multiply our entire cost, we simply multiply it by the weight of pesticide costs to total costs. We have already calculated that weight, and it is equal to 7%.

With that, we have:

$$X_{\text{cost},s} = 1 + Ec \times YoY_s, \quad Ec = 0.07,$$

and

$$X_{\text{price,low}} = 1 + 0.80 \times YoY_{low}, \quad X_{\text{cost,low}} = 1 + 0.07 \times YoY_{low},$$
$$X_{\text{price,base}} = 1 + 0.80 \times YoY_{base}, \quad X_{\text{cost,base}} = 1 + 0.07 \times YoY_{base},$$
$$X_{\text{price,high}} = 1 + 0.80 \times YoY_{high}, \quad X_{\text{cost,high}} = 1 + 0.07 \times YoY_{high}.$$

Chapter 4

Financial Model Proposition

4.1 Financial Model Design

Building on the assumptions and worksheet overviews presented earlier, this section explains how the modules interact to generate the key outputs. By tracing the flow of data from inputs through calculations to the three financial statements and finally to valuation, we ensure continuity with the preceding methodology.

This model is organized as a seamless pipeline, carrying user-defined assumptions through successive layers of calculation until the final valuation outputs are produced. Figure 4.1 illustrates the overall flow.

1. Input Layer At the very beginning, all scenario levers-agronomic drivers, market prices, macroeconomic variables and cost indices-are entered into the input sheets (e.g. Macroeconomic Inputs, Internal Agronomic Factors, External Price & Cost Factors, Volume Projection, Cane Market Data).

2. Calculation Layer Once the inputs are in place, the model computes:

- *Volume Projection:* combines planted area, yield-decay curves and planting-date multipliers to forecast cane production over time.
- *Revenue Streams:* applies scenario price curves for sugar and ethanol to the volume forecasts, yielding annual sugar and ethanol revenues.
- *Cost Breakdown:* allocates planting, ratoon maintenance and replanting costs-adjusted for fuel, fertilizer and FX multipliers-to derive total operating costs by year.

Each sub-calculation is performed on a dedicated sheet, maintaining auditability and allowing targeted sensitivity checks.

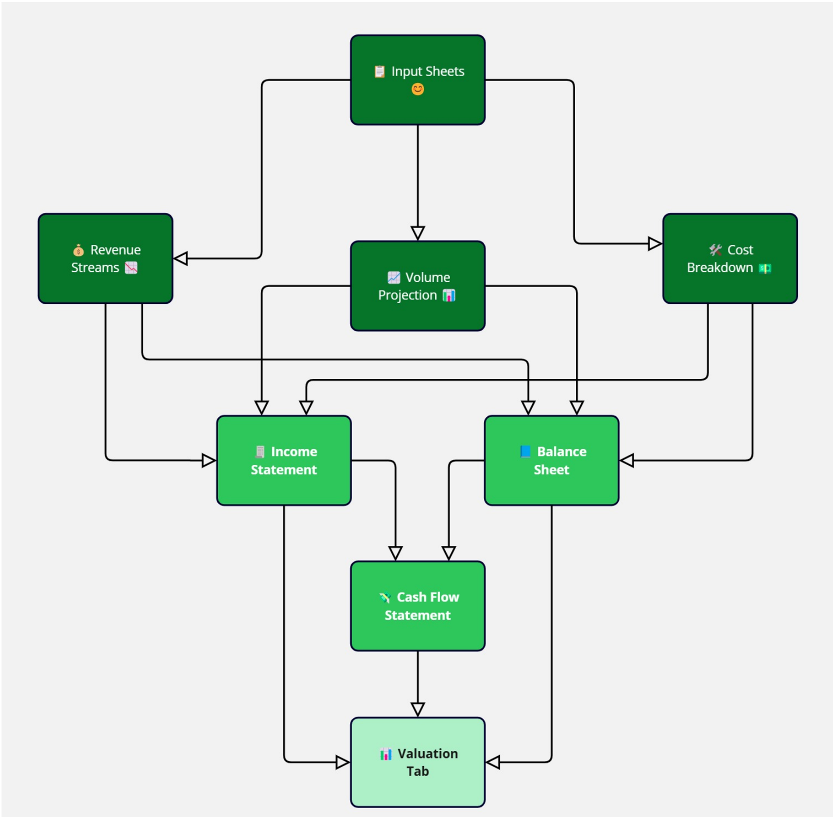

Figure 4.1: Flowchart of the financial model architecture

3. Financial Statement Layer The output from the Calculation Layer feeds directly into the three core statements:

- *Income Statement:* consolidates revenues and costs into operating profit, net income and margin ratios.
- *Balance Sheet:* uses net income (rolled into retained earnings), depreciation schedules and working-capital balances (receivables, inventory, payables) to project assets and liabilities.
- *Cash-Flow Statement:* transforms net income into Free Cash Flow to the Firm by adding back non-cash charges, incorporating working-capital movements and subtracting planned CAPEX.

4. Valuation Layer Finally, the projected FCFF series and cost-of-capital inputs converge in the Valuation tab, where NPV, IRR, payback period and EV/EBITDA are calculated for each scenario. An Acquisition Analysis section then uses these results to estimate a maximum bid price consistent with target returns and debt-service metrics.

4.1.1 Interdependencies of Financial Statements and Cash-Flow Calculation

The three core statements are fully integrated: each period's result in one feeds directly into the next, ultimately generating the cash-flow series used for valuation (see Figure 4.2).

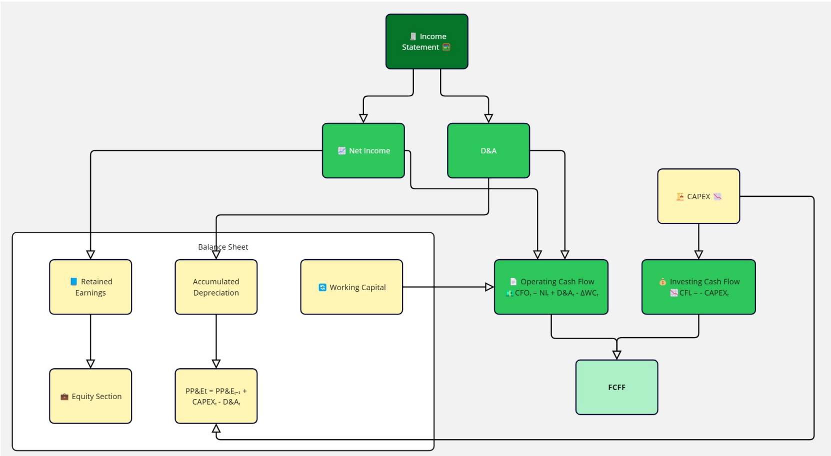

Figure 4.2: Linkages among Income Statement, Balance Sheet and Cash-Flow Statement

1. **From Income Statement to Balance Sheet and Cash-Flow**

   - **Net Income to Retained Earnings:**

     $$\text{RE}_t = \text{RE}_{t-1} + \text{NI}_t - \text{Div}_t$$

     Net Income (NI_t) from the Income Statement is added to last period's retained earnings, after subtracting dividends, and appears in Equity on the Balance Sheet.

   - **Depreciation to PP&E:**

     $$\text{PP\&E}_t = \text{PP\&E}_{t-1} + \text{CAPEX}_t - \text{D\&A}_t$$

     Depreciation & amortization ("D&A" on the Income Statement) reduces net income and accumulates in the contra-asset Accumulated Depreciation on the Balance Sheet.

2. Working Capital and Operating Cash Flow Changes in working capital accounts on the Balance Sheet drive the operating section of the Cash-Flow Statement:

$$\Delta \text{WC}_t = (\Delta \text{AR}_t + \Delta \text{Inv}_t) - \Delta \text{AP}_t$$

$$\text{CFO}_t = \text{NI}_t + \text{D\&A}_t - \Delta \text{WC}_t$$

where:

- $\Delta \text{AR}_t,\ \Delta \text{Inv}_t,\ \Delta \text{AP}_t$ are changes in receivables, inventory and payables.
- CFO_t is the net cash generated from operations in period t.

3. Investing Cash Flow and CAPEX Capital expenditures purchased in each period appear as an increase in PP&E on the Balance Sheet and as an outflow in the Cash-Flow Statement:

$$\text{CFI}_t = -\,\text{CAPEX}_t$$

This ensures that additions to the asset base are mirrored by cash outflows.

4. Free Cash Flow to the Firm and Valuation The Free Cash Flow to the Firm (FCFF) is computed by combining operating and investing cash flows:

$$\text{FCFF}_t = \text{CFO}_t - \text{CAPEX}_t = \Big(\text{NI}_t + \text{D\&A}_t - \Delta \text{WC}_t\Big) - \text{CAPEX}_t$$

This FCFF series feeds directly into the Valuation tab (3.2.1) to calculate NPV, IRR, payback period and other metrics under each scenario.

5. Financing Cash Flow (optional) While the model focuses on FCFF for valuation, the Cash-Flow Statement also includes a financing section:

$$\text{CFF}_t = \text{New Debt}_t - \text{Debt Repayments}_t - \text{Dividends}_t$$

showing how equity and debt movements reconcile the net change in cash to the opening balance.

By structuring the statements in this linked fashion, any change-whether in revenue drivers, cost inputs or investment timing-propagates automatically from the Income Statement through to the Cash-Flow Statement and into the valuation outputs.

4.2 Scenario Analysis

Scenario analysis lies at the heart of this study: by systematically varying key drivers, we explore how different futures-both in terms of external market and macro conditions and in terms of management decisions on the farm-affect financial performance and ultimately valuation. Rather than relying on a single "most likely" forecast, scenario analysis allows us to bracket outcomes under optimistic, base-case and pessimistic environments and, separately, under "good," "basic" and "bad" operational regimes. This two-dimensional approach not only deepens our understanding of which factors most strongly influence NPV, IRR and payback, but also provides the basis for the acquisition analysis: if our farm operates in its optimum internal scenario, can it still afford to acquire a peer that is running in a sub-optimal internal scenario, under each external environment?

We therefore define two parallel sets of scenarios:

- **External-Factor Scenarios:** Three cases reflecting possible futures for prices (sugar, ethanol), input-cost inflation, exchange rates, interest rates and other macro drivers:

  1. *Optimistic*-Favorable commodity prices, low inflation and supportive FX.
  2. *Base Case*-Best estimate drawn from consensus forecasts.
  3. *Pessimistic*-Adverse price shocks, high inflation and currency weakness.

- **Internal-Factor Scenarios:** Three cases capturing alternative management and agronomic outcomes on the farm:

  1. *Good Management*-High yields, efficient ratoon cycles, optimized harvest timing and cost control.
  2. *Basic (Base Case)*-Expected operational performance as calibrated in our default drivers.
  3. *Poor Management*-Lower yields, sub-optimal cycle decay, harvest delays and higher per-unit costs.

By crossing these two dimensions, we generate a matrix of nine scenario outputs, each producing its own set of financial statements and valuation metrics. This matrix underpins our acquisition analysis: for each external case, we compare the buyer-farm in its Good-Management scenario against a target-farm in its Poor-Management scenario, thereby testing deal feasibility under the widest range of possible conditions.

Base Case

In the Base Case, all factors are set to their default ("0") values, representing the expected operational and market conditions under consensus forecasts. This configuration serves as the benchmark against which both the optimistic/pessimistic external scenarios and the good/poor-management internal scenarios are compared.

Internal-Factor Base Case

- **Herbicide Use:** Base level (0), corresponding to the standard application rate calibrated in the Internal Agronomic Factors sheet (Section 3.3.3).
- **Insecticide Use:** Base level (0), reflecting the average protection program under normal pest pressure (Section 3.3.3).
- **Fungicide Use:** Base level (0), representing the typical disease-management regimen derived from historical yield data.
- **Planting Window:** Normal planting-date window, per the agronomic driver multipliers described in Section 3.3.3.

External-Factor Base Case

- **Sugar Price:** Consensus forecast curve as documented in the Macroeconomic Inputs sheet (Section 3.3.4).
- **Ethanol Price:** Base-case trajectory drawn from market consensus.
- **Oil Price:** Baseline futures curve used for input-cost indexing.
- **Water Availability:** Median historical water-availability factor (0), capturing typical climatic conditions.
- **Dollar Variation:** Base exchange-rate path from consensus forecasts.

Crop Cycle Duration In the Base Case we assume a 5-year crop cycle-comprising one plant-cane harvest followed by four ratoon cycles-reflecting Brazilian practice where consecutive ratooning for 4–5 years is generally adopted before replanting becomes necessary.

National statistics report an average of 3.77 ratoon crops per planting, which, when combined with the initial plant-cane cycle, corresponds to an effective five-year cultivation period.[60]. This duration represents a balance between declining yields in successive ratoons, due to factors such as nutrient depletion and pest buildup, and the costs associated with field renewal, including land preparation and replanting operations.

Optimistic External and Good-Management Internal Scenarios

In the Optimistic/Good-Management combined case, both external drivers and internal practices are set to their most favorable levels to illustrate an upside bound on financial performance.

External-Factor Settings

- **Sugar Price:** Optimistic price curve from the Cane Market Data sheet (Section 3.3.4).
- **Ethanol Price:** Upside trajectory as defined in the Macroeconomic Inputs (Section 3.3.4).
- **Oil Price:** Low-cost index case to minimize fuel and energy expenses.
- **Water Availability:** Wet-season multiplier (2) to reflect above-average rainfall (Section 3.3.6).
- **Dollar Variation:** Low-volatility exchange-rate scenario (1) to stabilize imported-input costs.

Internal-Factor Settings

- **Herbicide Use:** High-use regimen (2) to maximize weed control and support yield potential (Section 3.3.3).
- **Insecticide Use:** High-use regimen (2) for optimal pest management.
- **Fungicide Use:** High-use regimen (2) to reduce disease losses.
- **Planting Window:** Narrowest feasible window to ensure uniform crop establishment and maximize early growth.

Crop Cycle Duration The optimal cycle length is determined by running the base-case inputs across a range of ratoon durations and selecting the cycle that maximizes NPV and IRR. In this upside scenario, we adopt that optimum cycle length. The calculation with the actual values will be shown in the Results Section.

Pessimistic External and Poor-Management Internal Scenarios

In the Pessimistic/Poor-Management combined case, both external factors and farm practices are set to their least favorable levels to illustrate a downside bound on financial performance.

External-Factor Settings

- **Sugar Price:** Pessimistic price curve from the Cane Market Data sheet (Section 3.3.4).
- **Ethanol Price:** Downside trajectory from consensus forecasts.
- **Oil Price:** High-cost index case, increasing energy and fuel expenses.
- **Water Availability:** Dry-season multiplier (1) to reflect below-average rainfall (Section 3.3.6).
- **Dollar Variation:** High-volatility exchange-rate scenario (2), amplifying imported-input cost swings.

Internal-Factor Settings

- **Herbicide Use:** Low-use regimen (1), reflecting under-application or budget constraints.
- **Insecticide Use:** Low-use regimen (1) with increased pest-related yield risk.
- **Fungicide Use:** Low-use regimen (1), elevating disease vulnerability.
- **Planting Window:** Widest allowable window, leading to uneven crop emergence and yield variability.

Crop Cycle Duration The "bad" cycle length is set to the next worse duration after the base-case five-year cycle, as determined by the same NPV/IRR sweep described above (see placeholder for cycle duration selection procedure).

4.3 Acquisition Analysis

In this section we establish the discount rate (WACC) and the cycle-average perpetuity for our DCF valuations, and extend the model to assess acquisition feasibility. In this section, we develop a two-stage framework that answers, for each external scenario (Optimistic, Base, Pessimistic) and for both bad and base-management targets:

1. **Return Test:** Compute the fixed-price IRR against the target's intrinsic DCF valuation and derive the break-even bid price that exactly meets our minimum IRR hurdle (TIR_{min}).

2. **Financing Test:** Introduce our debt–equity structure and calculate both unlevered and levered IRRs-after accounting for annual debt service-to determine whether the acquisition can be sustainably financed (e.g. DSCR $\geq 1.3\times$).

By comparing pure investment returns with balance-sheet capacity under each scenario, this acquisition analysis delivers clear "Yes/No" decision criteria and negotiation ceilings, ensuring that any proposed bid is both value-creating and financeable.

Minimum IRR Hurdle (TIR_{min})

To ensure that any acquisition generates sufficient value net of both the time value of money and deal-specific risks, we set a minimum IRR hurdle as:

$$\text{TIR}_{\text{min}} = \text{WACC} + \Delta_{\text{deal}},$$

where:

- WACC is the weighted average cost of capital which will be calculated.
- Δ_{deal} is an acquisition risk premium, reflecting:
  - *Integration and execution risk*-the uncertainty of realizing synergies and embedding best practices.
  - *Valuation and negotiation risk*-the danger of overpaying due to imperfect information.
  - *Size and market-cycle risk*-small bolt-on deals in cyclic commodities typically command higher returns.

Thus, in each scenario s, an acquisition is deemed acceptable only if the computed IRR (whether unlevered or levered) meets or exceeds our minimum IRR. This buffer ensures that the project compensates investors for both routine operational risk and the specific uncertainties inherent in M&A execution.

4.3.1 Calculation the Weighted Average Cost of Capital

The Weighted Average Cost of Capital (WACC) represents the opportunity cost of investing in the combined farm, reflecting the blended required returns of both equity and debt providers. Accurately estimating WACC is critical to our acquisition analysis, as it serves both as the discount rate for valuing future cash flows and as the baseline hurdle against which the Internal Rate of Return (IRR) is measured. In the subsections that follow, we decompose WACC into its constituent elements: the cost of equity (via the CAPM), the after-tax cost of debt, and the target debt–to–equity ratio, before synthesizing these inputs into the final WACC calculation.

Defining our Cost of Equity

We estimate the cost of equity r_e via the CAPM:

$$r_e \;=\; r_f \;+\; \beta_{\text{ag}}\Big(E[R_m] - r_f\Big) \;+\; \text{CRP},$$

where:

- **Risk-free rate (r_f).** Nominal yield on 10-year Brazilian government bonds as of 31 December 2024:
$$r_f = 14.193\%.$$
- **Equity beta (β_{ag}).** Averaged 5-year levered betas of three sugar-energy peers:
$$\beta_{\text{ag}} = \frac{1.09 + 0.69 + 0.64}{3} \approx 0.81.$$
- **Equity risk premium ($E[R_m] - r_f$).** Set at 6 % based on Damodaran's emerging-markets survey.
- **Country-risk premium (CRP).** Set at 3 % to capture Brazil's sovereign-risk spread.

Assuming an equity-heavy capital structure (60 % equity, 40 % debt), and substituting:

$$r_e = 14.193\% \;+\; 0.81 \times (6\%) \;+\; 3\% = 14.193\% + 4.86\% + 3\% = 22.053\%.$$

Defining the Cost of Debt

Brazil's federal rural–credit schemes (*Plano Safra 2024/25* and BNDES investment lines) offer nominal interest rates between 7 % and 12 % a year to medium- and large-scale producers. To keep the model conservative we anchor the pre-tax cost of debt to the project's own risk-free rate, applying the average 15 % subsidy (i.e. a 0.85 multiplier) observed in those programmes:

1. Pre-tax cost of debt. With the 10-year NTN-F yield already used in the CAPM ($r_f = 14.193\%$; see Section 4.3.1),
$$r_{d,\text{gross}} = 0.85 \times r_f = 0.85 \times 14.193\% \approx 12.06\%.$$
2. **After-tax cost of debt ($r_{d,\text{after–tax}}$).** Applying the Lucro Real corporate tax rate $T_c = 34\%$,
$$r_{d,\text{after–tax}} = r_{d,\text{gross}}\,(1 - T_c) = 12.06\% \times 0.66 \approx 7.96\%.$$

Policy-continuity risk. On 21 Feb 2025 Brazil's National Treasury *temporarily suspended* the granting of new subsidized loans under the 2024/25 Crop Plan, citing budget constraints and the absence of an approved 2025 fiscal framework. Although similar suspensions in the past were reversed once additional funding was negotiated, the episode highlights a non-trivial risk that future rural-credit subsidies could be curtailed. For tractability, and to avoid compounding uncertainties across model parameters, we retain the $0.85 \times r_f$ rule in the all cases.

Target Capital Structure: Debt-to-Equity Proportion

We adopt a conservative, equity-heavy financing mix of 30% debt and 70% equity for the combined farm acquisition, motivated by the following considerations:

- **Agronomic and commodity-price volatility.** Sugarcane yields and prices exhibit multi-year cycles and sharp swings, which can strain debt-service capacity if leverage is too high. A 30/70 structure preserves ample headroom against covenant breaches (e.g., DSCR$\geq 1.3\times$) under pessimistic scenarios.
- **Empirical sector practice.** Long-term debt lines typically finance 40–60% of fixed assets in Brazilian sugarcane operations, while land acquisition is often funded predominantly by equity [30, 43]. Our chosen 30% debt share thus sits below the historical midpoint, enhancing financial flexibility.
- **Preservation of optionality.** Lower leverage allows the buyer to redirect future free cash flows toward agronomic investments (e.g., replanting, drainage, productivity enhancements) or opportunistic bolt-on acquisitions, rather than servicing high interest and principal loads.
- **Risk-management alignment.** By capping debt at 30%, we target an interest-coverage ratio above 6× in the Base Case and maintain robust balance-sheet resilience, consistent with best practices in agricultural finance.

Weighted Average Cost of Capital (WACC)

Having estimated the cost of equity ($r_e = 22.053\%$, Section 4.3.1) and the after-tax cost of debt ($r_{d,\text{after–tax}} = 7.96\%$, Section 4.3.1), and set the target capital structure at 70% equity and 30% debt, we calculate WACC as:

$$\text{WACC} = \frac{E}{V}\, r_e + \frac{D}{V}\, r_{d,\text{after–tax}} = 0.70 \times 22.053\% + 0.30 \times 7.96\% = 17.8\%.$$

Where:

- $E/V = 0.70$ (equity share)

- $D/V = 0.30$ (debt share)

This WACC serves as the discount rate in our acquisition valuation and as the basis for solving the maximum bid price that meets our IRR hurdle [46].

4.3.2 Terminal Value via Cycle-Average Perpetuity

To capture the long-run value of the combined farm beyond our explicit projection horizon (10 years), we calculate a terminal (perpetuity) value that reflects the underlying agronomic cycle-one replant year plus $X - 1$ ratoon years-rather than simply capitalizing the final year's cash flow.

1. **Define cycle duration X.** As detailed in Section 3.3.1, we assume an X-year planting cycle (e.g. 5 years in the Base Case), comprising one plant-cane harvest followed by $X - 1$ ratoon cycles.

2. **Compute the cycle-average cash flow $\overline{CF}$.** Let $CF_{t-X+1}, \ldots, CF_t$ be the model's Free Cash Flows to the Firm (FCFF) in the final X years of the explicit forecast (with t the last projection year, e.g. 2030). We then set

$$\overline{CF} = \frac{1}{X} \sum_{i=0}^{X-1} CF_{t-i}\,.$$

3. **Apply a perpetual growth rate.** We assume a long-run nominal growth rate $g = 5\%$, aligned with consensus inflation expectations, to carry $\overline{CF}$ into perpetuity.

4. **Calculate the terminal value.** Using the Gordon–Growth formula, the terminal value at t is

$$TV_t = \frac{\overline{CF}\left(1 + g\right)}{WACC - g}\,,$$

   where $WACC$ is the weighted average cost of capital.

5. **Discount back to present.** Finally, TV_t is discounted to time 0 at the buyer's $WACC$ and appended to the NPV calculation in the acquisition analysis.

Rationale

By averaging the final X cash flows, we preserve a realistic representation of one full replant-plus-ratoon cycle, rather than over- or under-stating terminal cash flow simply because the projection ended on a high- or low-yield year. The 5 % growth aligns the perpetuity with expected inflation and avoids assuming unrealistic real growth beyond the explicit forecast. Embedding this cycle-average perpetuity ensures consistency between our agronomic assumptions (cycle duration) and financial valuation, delivering a more robust and realistic terminal value.

4.3.3 Acquisition Decision Framework

Building on the WACC and terminal value methodologies described above, we now develop a simple, "flip"-style framework to evaluate whether the good-management farm can acquire a peer under each external scenario. We compare two target types-bad-management and base-management farms-across the Optimistic, Base and Pessimistic scenarios, using both a fixed-price IRR test and a break-even-price analysis. Transitional outlays are omitted, and we assume an immediate post-acquisition switch to the good-management cash-flow profile.

Fixed-Price IRR Analysis

Let P_0 denote the purchase price, set equal to the target's DCF valuation under its intrinsic management quality. Post-acquisition, the combined farm generates the good-management free cash-flow stream, denoted $\{CF^G_{t,s}\}^T_{t=1}$ (where the superscript "G" stands for Good-Management), under scenario $s \in \{\text{Opt}, \text{Base}, \text{Pess}\}$. We compute the internal rate of return:

$$\text{IRR}_s = \text{IRR}\Big(\{-P_0,\, CF^G_{1,s},\, \ldots,\, CF^G_{T,s}\}\Big).$$

Acquisition is deemed attractive in scenario s if

$$\text{IRR}_s \;\geq\; \text{TIR}_{\min}\,.$$

Break-Even-Price Analysis

To establish a maximum bid threshold, we solve for the highest price P_0^* that exactly meets our IRR hurdle:

$$P_0^* = \arg\Big\{P:\; \text{IRR}(\{-P,\, CF^G_{1,s},\, \ldots,\, CF^G_{T,s}\}) = \text{TIR}_{\min}\Big\}.$$

The value P_0^* represents the ceiling price the acquirer can pay to achieve the minimum acceptable return. We test feasibility by comparing P_0^* to the target's intrinsic DCF valuation under its own management state.

Scenario & Target Comparison

For each combination of external scenario s and target management quality (bad or base), we perform:

- **Fixed-Price IRR:** compute IRR_s for $P_0 = \mathrm{DCF}_{\mathrm{target}}$ and check $\mathrm{IRR}_s \geq \mathrm{TIR}_{\mathrm{min}}$.
- **Break-Even Price:** solve for P_0^* and verify $P_0^* \geq \mathrm{DCF}_{\mathrm{target}}$.

Results are summarized in a matrix of "Yes/No" flags, accompanied by the corresponding IRRs and maximum bid prices for each target–scenario pair. This dual analysis delivers both a snapshot of returns at prevailing valuations and a clear negotiation ceiling, ensuring a robust acquisition decision framework.

Financing Sustainability Analysis

While the fixed-price IRR and break-even-price tests determine whether the acquisition "makes sense" on a pure-return basis, they do not guarantee that the buyer can service the required debt. To close this gap, we perform two complementary IRR calculations:

Unlevered IRR (Project-Level Return) We first isolate the investment's intrinsic economics by assuming an all-cash purchase of price P_0 and ignoring financing. The cash flows are

$$\{-P_0,\ CF^G_{1,s},\ CF^G_{2,s},\ \ldots,\ CF^G_{T,s}\},$$

where $CF^G_{t,s}$ is the good-management FCFF in year t under scenario s. We compute

$$\mathrm{IRR}^{\mathrm{U}}_s = \mathrm{IRR}\Big(\{-P_0,\ CF^G_{1,s}, \ldots, CF^G_{T,s}\}\Big).$$

If $\mathrm{IRR}^{\mathrm{U}}_s \geq \mathrm{TIR}_{\mathrm{min}}$, the project generates sufficient cash-flow to justify the investment before any debt service.

Levered IRR (Equity Return After Financing) Next, we introduce our target capital structure: a debt share λ (e.g. 30 %) and equity share $1 - \lambda$. At $t = 0$:

$$D_0 = \lambda\, P_0, \quad E_0 = (1 - \lambda)\, P_0.$$

Debt is amortized over N years at rate r_d, producing a constant annual debt service

$$DS \ = \ \frac{r_d\, D_0}{1 - (1 + r_d)^{-N}}$$

Let $CF^G_{t,s}$ denote the Good-Management free cash-flow before debt service, and let $CF^{G,E}_{t,s}$ denote the Good-Management free cash-flow to equity after debt service (superscripts "G,E" stand for Good-Management and Equity). Then, in year t:

$$CF^{G,E}_{t,s} = CF^G_{t,s} \ - \ DS.$$

We compute the equity-level IRR:

$$\mathrm{IRR}^{\mathrm{L}}_{s} = \mathrm{IRR}\Big(\{-E_0,\ CF^{G,E}_{1,s}, \ldots, CF^{G,E}_{T,s}\}\Big).$$

Acquisition is financeable in scenario s if $\mathrm{IRR}^{\mathrm{L}}_{s} \geq \mathrm{TIR}_{\min}$ and if standard debt-service ratios (e.g. DSCR $\geq 1.3\times$) hold across the projection.

Interpretation and Decision Criteria

- If $\mathrm{IRR}^{\mathrm{U}}_{s} < \mathrm{TIR}_{\min}$, the acquisition lacks sufficient value in scenario s and should be rejected outright.
- If $\mathrm{IRR}^{\mathrm{U}}_{s} \geq \mathrm{TIR}_{\min}$ but $\mathrm{IRR}^{\mathrm{L}}_{s} < \mathrm{TIR}_{\min}$, the project is intrinsically attractive but over-leveraged; options include reducing debt share λ, negotiating a lower P_0, or extending the amortization term N.
- If both $\mathrm{IRR}^{\mathrm{U}}_{s}$ and $\mathrm{IRR}^{\mathrm{L}}_{s} \geq \mathrm{TIR}_{\min}$, the acquisition is both value-creating and sustainably financed under scenario s.

We apply this dual analysis to both bad- and base-management targets across the Optimistic, Base and Pessimistic scenarios, yielding a robust, finance-aware acquisition decision framework.

4.4 Financial Metrics Used

To evaluate the outputs of our model, we calculate the following metrics using the formulas below.

Net Present Value (NPV) The NPV is the sum of discounted net cash flows minus the initial investment:

$$\mathrm{NPV} \;=\; \sum_{t=0}^{T} \frac{CF_t}{(1+WACC)^t} \;-\; I_0$$

where CF_t is the net cash flow in year t, $WACC$ is the weighted average cost of capital, and I_0 is the initial outlay.

Internal Rate of Return (IRR) The IRR is the discount rate r that makes the NPV zero:

$$0 \;=\; \sum_{t=0}^{T} \frac{CF_t}{(1+IRR)^t} \;-\; I_0$$

We solve this equation numerically for IRR.

Payback Period The (undiscounted) payback period P is the smallest integer P such that

$$\sum_{t=0}^{P} CF_t \;\geq\; I_0.$$

This gives the number of years required to recover the initial investment.

Enterprise Value / EBITDA (EV/EBITDA) Enterprise Value is defined as:

$$EV \;=\; E_{mkt} \;+\; D \;-\; C$$

where E_{mkt} is market capitalization, D is total debt, and C is cash on hand. The valuation multiple is then

$$\frac{EV}{\text{EBITDA}}.$$

Example: If a sugarcane farm has a market capitalization of R\$30 million, outstanding debt of R\$10 million, and R\$2 million in cash, then $EV = 30{+}10{-}2 = R\$38$ million. If its EBITDA is R\$7.6 million, the multiple is $EV/EBITDA = 38/7.6 \approx 5.0$. In practice, this means the farm is valued at five times its annual EBITDA.

Free Cash Flow to the Firm (FCFF) FCFF for year t is:

$$\text{FCFF}_t = \Big(EBIT_t \times (1-T)\Big) + \text{Dep}_t - \text{CapEx}_t - \Delta\text{WC}_t,$$

where $EBIT_t$ is earnings before interest and taxes, T is the corporate tax rate, Dep_t is depreciation, CapEx_t is capital expenditure, and ΔWC_t is the change in working capital.
Example: Consider a farm with EBIT of R\$5 million, a tax rate of 34%, depreciation of R\$1 million, capital expenditures of R\$2 million, and a R\$0.5 million increase in working capital. Then:

$$\text{FCFF} = (5 \times (1-0.34)) + 1 - 2 - 0.5 = 1.8 \text{ million}.$$

This represents the cash available to both debt and equity holders after operational reinvestments.

Debt Service Coverage Ratio (DSCR) The DSCR measures the ability to cover debt obligations:

$$\text{DSCR} = \frac{\sum_{t=1}^{T} \text{FCFF}_t}{\sum_{t=1}^{T}\Big(\text{Principal}_t + \text{Interest}_t\Big)}.$$

A DSCR greater than 1 indicates sufficient cash flow to meet debt service.

Example: If the farm generates cumulative FCFF of R$12 million over the next 5 years and its total debt service (principal + interest) over the same period is R$10 million, then:

$$\text{DSCR} = \frac{12}{10} = 1.2.$$

A DSCR above 1.0 indicates the farm produces enough cash to meet its debt obligations with a 20% safety margin.

Sensitivity Analysis Sensitivity analysis identifies which inputs most affect our financial outputs (NPV, IRR, FCFF). We proceed as follows:

1. **Select drivers:** e.g. ratoon decay rate, sugar-price growth.
2. **Vary each input** X_i by $\pm 10\%$, holding others constant.
3. **Compute normalized sensitivity:**

$$S_i = \frac{Y(X_i + \Delta) - Y(X_i - \Delta)}{2\,\Delta} \times \frac{X_i}{Y(X_i)}.$$

4. **Rank and report:** Order $|S_i|$ in a tornado chart.

By systematically applying sensitivity analysis, we ensure that our financial model is not only scenario-aware but also pinpointed to the variables that matter most for decision-makers.

4.5 Software and Tools

The development, analysis and presentation of the financial model leveraged a combination of spreadsheet, programming, diagramming and typesetting tools, each selected for its strengths in different stages of the workflow.

Microsoft Excel All core modeling was performed in Microsoft Excel (Office 365). Excel's grid interface and formula engine allow transparent linkages across sheets, while built-in features such as:

- `INDEX/MATCH` for dynamic data retrieval;
- Data Tables and the Scenario Manager for sensitivity and what-if analysis;
- Linear Regression analysis for data interpretation and the Yield Factor 'k' estimation

- Conditional formatting and data validation for input control and auditability;
- PivotTables and basic charting for exploratory data analysis;

were used extensively to build, test and visualize the model.

Miro Miro (miro.com) served as the collaborative diagramming platform for flowcharts and process maps. Its infinite canvas and real-time co-editing capabilities facilitated the design of the overall model architecture and the inter-statement linkage diagrams, later exported as high-resolution images for inclusion in the thesis.

LaTeX The manuscript, including all equations, tables and references, was composed in LaTeX (TeX Live 2024). Packages such as `amsmath` and `booktabs` ensured professional formatting of mathematical expressions and tables, while `hyperref` and `cleveref` streamlined cross-referencing of sections, figures and equations throughout the document.

Chapter 5

Application & Results

5.1 Yield Decay Simulation Results

This section explores how the interval between replantings ("cycle duration") affects the aggregate yield profile under the same exponential-decay law ($k = 0.145$, $V_0 = 23{,}167$ t). We compare four scenarios—4, 5, 6 and 10-year cycle durations—to illustrate the trade-off between longer ratoon series and more frequent resets to full productivity.

Practical meaning of k and V_0.

- $\mathbf{V_0}$: post-renewal, full-productivity output level (the reset point immediately after replanting). It anchors the yield path at renewal.

- **k**: speed of decline between harvests (how quickly ratoon yields fall as the stand ages). Higher k implies faster decay; lower k implies more persistent yields.

With $k = 0.145$, the model retains about $e^{-0.145} \approx 86.5\%$ of the previous harvest each subsequent year, yielding a half-life of roughly $\ln(2)/0.145 \approx 4.78$ harvests.

Implication for cycle duration: Shorter cycles (e.g., 4–5 years) reset to V_0 more frequently, preserving higher average yields but incurring more frequent replanting costs. Longer cycles (e.g., 6–10 years) reduce renewal frequency and costs but operate longer on the decayed segment of the curve. The scenarios below quantify this trade-off.

5.1.1 5-year Cycle (Base Case)

Using the exponential decay model described in Section 3.3.1, we compute yield factors

$$f_c = e^{-k\,(c-1)},$$

and project volumes $V_t = V_0 \times f_c$. Table 5.1 and Figure 5.1 repeat the results for the 5-year (plant-cane + 4 ratoons) cycle.

Table 5.1: Yield factors and projected volumes for a 5-year cycle (2024–2034)

Year	Cycle	Factor	Volume (t)
2024	Plant-cane	1.00	23 167
2025	Ratoon 1	0.90	20 040
2026	Ratoon 2	0.70	17 335
2027	Ratoon 3	0.60	14 995
2028	Ratoon 4	0.60	12 971
2029	Plant-cane	1.00	23 167
2030	Ratoon 1	0.90	20 040
2031	Ratoon 2	0.70	17 335
2032	Ratoon 3	0.60	14 995
2033	Ratoon 4	0.60	12 971
2034	Plant-cane	1.00	23 167

5.1.2 4-year Cycle (Plant-Cane + 3 Ratoons)

Applying the same exponential decay model ($k = 0.145$, $V_0 = 23\,167$ t), but resetting every four years, yields the results in Table 5.2 and Figure 5.2.

5.1.3 6-year Cycle (Plant-Cane + 5 Ratoons)

Applying the exponential decay model ($k = 0.145$, $V_0 = 23\,167$ t) with a six-year rotation (replanting every 6th year) yields the factors and volumes in Table 5.3 and the corresponding yield path in Figure 5.3.

5.1.4 10-year Cycle (Plant-Cane + 9 Ratoons)

Applying the exponential decay model ($k = 0.145$, $V_0 = 23\,167$ t) with a ten-year rotation (nine consecutive ratoon cycles before replanting) yields the factors and projected volumes shown in Table 5.4 and Figure 5.4.

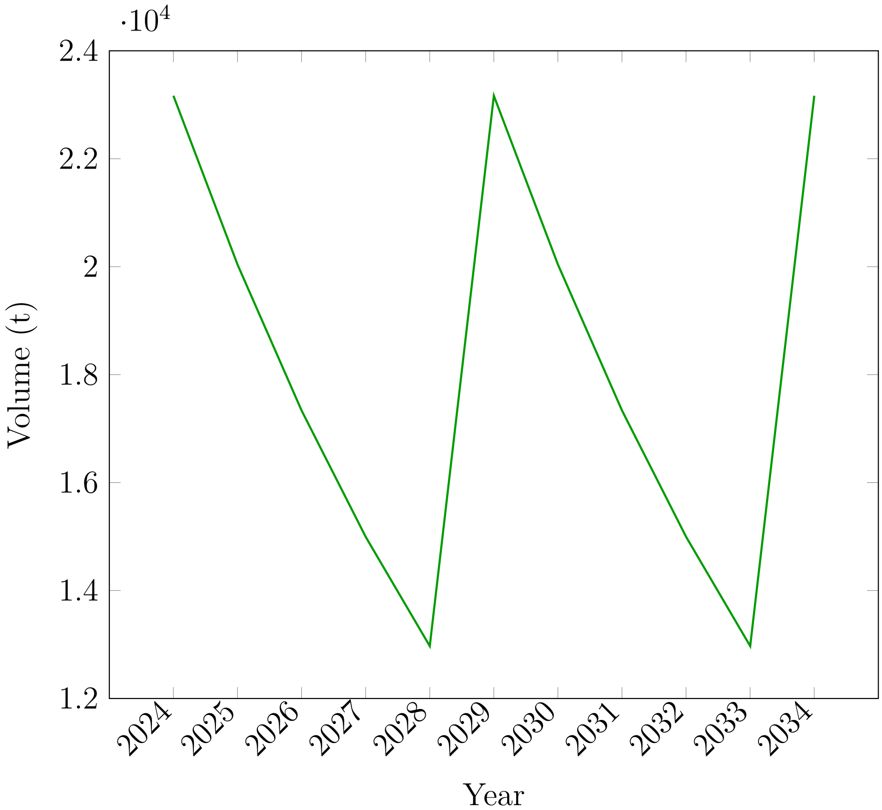

Figure 5.1: Projected yield factor path for the 5-year cycle (plant-cane + 4 ratoons).

Table 5.2: Yield factors and projected volumes for a 4-year cycle (2024–2034)

Year	Cycle	Factor	Volume (t)
2024	Plant-cane	1.00	23 167
2025	Ratoon 1	0.90	20 040
2026	Ratoon 2	0.70	17 335
2027	Ratoon 3	0.60	14 995
2028	Plant-cane	1.00	23 167
2029	Ratoon 1	0.90	20 040
2030	Ratoon 2	0.70	17 335
2031	Ratoon 3	0.60	14 995
2032	Plant-cane	1.00	23 167
2033	Ratoon 1	0.90	20 040
2034	Ratoon 2	0.70	17 335

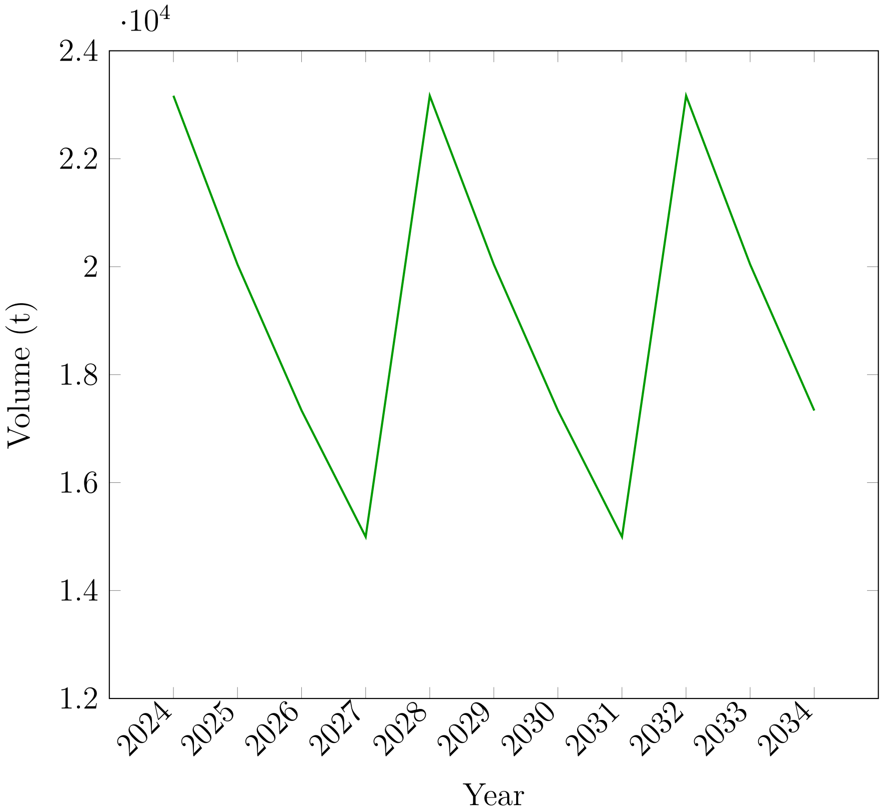

Figure 5.2: Projected yield factor path for the 4-year cycle (plant-cane + 3 ratoons).

Table 5.3: Yield factors and projected volumes for a 6-year cycle (2024–2034)

Year	Cycle	Factor	Volume (t)
2024	Plant-cane	1.00	23 167
2025	Ratoon 1	0.90	20 040
2026	Ratoon 2	0.70	17 335
2027	Ratoon 3	0.60	14 995
2028	Ratoon 4	0.60	12 971
2029	Ratoon 5	0.50	11 220
2030	Plant-cane	1.00	23 167
2031	Ratoon 1	0.90	20 040
2032	Ratoon 2	0.70	17 335
2033	Ratoon 3	0.60	14 995
2034	Ratoon 4	0.60	12 971

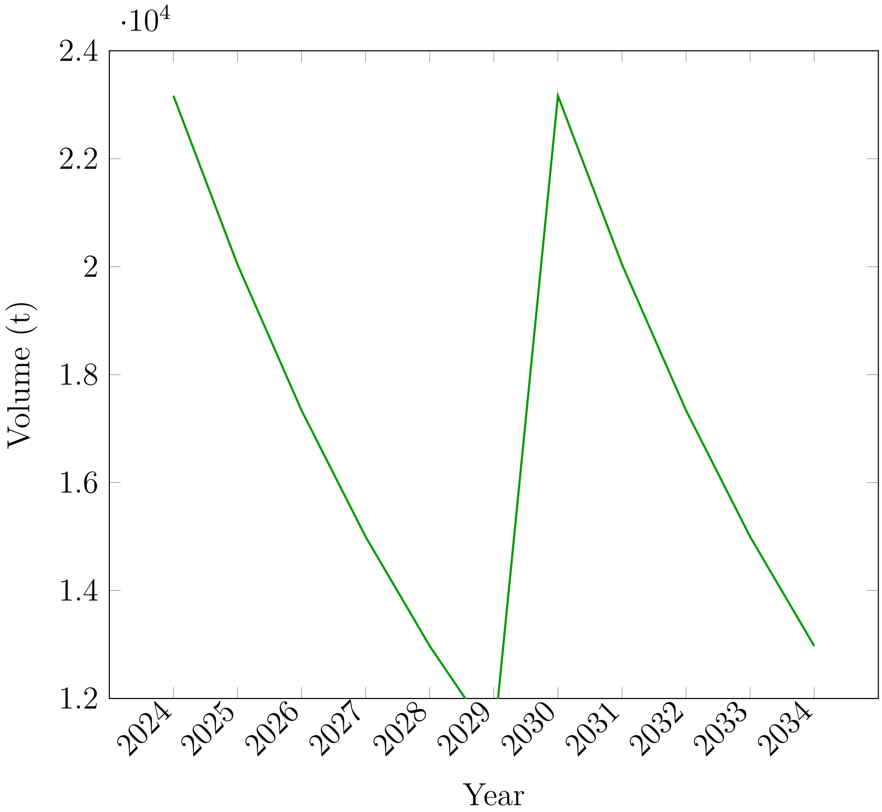

Figure 5.3: Projected yield factor path for the 6-year cycle (plant-cane + 5 ratoons).

Table 5.4: Yield factors and projected volumes for a 10-year cycle (2024–2034)

Year	Cycle	Factor	Volume (t)
2024	Plant-cane	1.00	23 167
2025	Ratoon 1	0.90	20 040
2026	Ratoon 2	0.70	17 335
2027	Ratoon 3	0.60	14 995
2028	Ratoon 4	0.60	12 971
2029	Ratoon 5	0.50	11 220
2030	Ratoon 6	0.40	9 706
2031	Ratoon 7	0.40	8 396
2032	Ratoon 8	0.30	7 262
2033	Ratoon 9	0.30	6 282
2034	Plant-cane	1.00	23 167

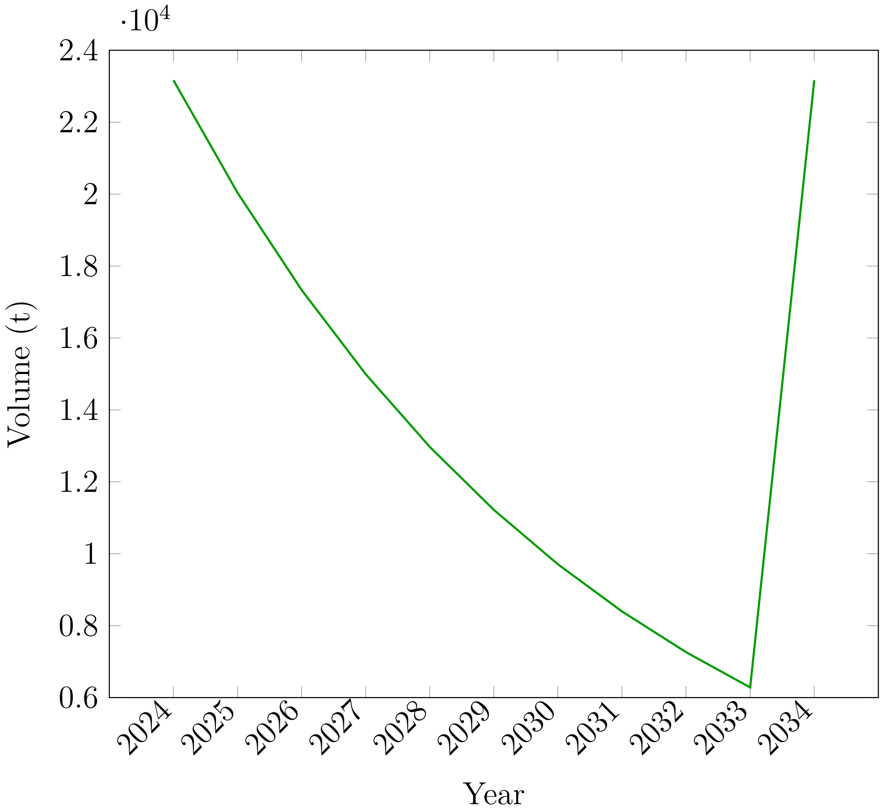

Figure 5.4: Projected yield factor path for the 10-year cycle (plant-cane + 9 ratoons).

5.1.5 Discussion of Decay Simulation Results

Tables 5.2–5.4 and Figures 5.2–5.4 highlight the trade-offs between cycle length, yield troughs and replant frequency. The 4-year rotation limits the deepest trough to 14 995 t (35 % drop from plant-cane) and requires two replant events (2028, 2032). The 5-year base case deepens the trough to 12 971 t (44 %) with two replants (2029, 2034). Extending to a 6-year cycle lowers the trough further to 11 220 t (52 %) but reduces replanting to a single event (2030). The 10-year rotation exhibits an extreme trough of 6 282 t (73 % drop) with only one replant (2034), shown here solely as a boundary case to illustrate maximum decay loss.

Under the base-case decay parameter $k = 0.145$, the 5-year interval remains the optimal compromise between maintaining throughput and minimizing replant costs. A 4-year rotation may be justified in regimes prioritizing yield stability if marginal replanting costs are low, whereas longer cycles (6 years or beyond) defer establishment expenses at the expense of substantially lower average volumes. These results feed directly into the revenue projections in Section 3.2.2 and the investment-timing considerations of the acquisition analysis in Section 4.3. The cost trade-off between replanting expenses and throughput loss will be analyzed in detail further down in this chapter.

Economic trade-off (illustrative). Using the replanting cost of R$ 9,231/ha (farm total R$ 2,769,291), which corresponds to $\sim$ 300 ha, the annualized replant burden is approximately:

$$\begin{aligned} \text{4-year}: &\quad \text{R\$ 2,308/ha} \cdot \text{yr (farm } \approx \text{R\$ 692k/yr)} \\ \text{5-year}: &\quad \text{R\$ 1,846/ha} \cdot \text{yr (farm } \approx \text{R\$ 554k/yr)} \\ \text{6-year}: &\quad \text{R\$ 1,538/ha} \cdot \text{yr (farm } \approx \text{R\$ 462k/yr)} \\ \text{10-year}: &\quad \text{R\$ 923/ha} \cdot \text{yr (farm } \approx \text{R\$ 277k/yr)} \end{aligned}$$

Given $k = 0.145$ and $V_0 = 23{,}167$ t (total farm), the *average annual production over the cycle* is approximately:

4-year	:	18,884 t/yr (≈ 62.95 t/ha)
5-year (base)	:	17,702 t/yr (≈ 59.01 t/ha)
6-year	:	16,621 t/yr (≈ 55.40 t/ha)
10-year	:	13,138 t/yr (≈ 43.79 t/ha)

From these, simple *break-even* rules of thumb follow (incremental replant cost divided by incremental tons):

$$\begin{aligned} \textbf{4y vs 5y:} &\quad +\,1{,}183 \text{ t/yr but } +\text{R\$ 138k/yr} \Rightarrow \text{ break-even} \approx \text{R\$ 117/t.} \\ \textbf{6y vs 5y:} &\quad -\,1{,}080 \text{ t/yr but } -\text{R\$ 92k/yr} \Rightarrow \text{ break-even} \approx \text{R\$ 85/t.} \\ \textbf{10y vs 5y:} &\quad -\,4{,}564 \text{ t/yr but } -\text{R\$ 277k/yr} \Rightarrow \text{ break-even} \approx \text{R\$ 61/t.} \end{aligned}$$

These thresholds are *illustrative*: they intentionally isolate only two levers, cycle length (renewal frequency) and replanting cost, holding all other drivers constant (commodity prices, ATR/recovery, operating costs, logistics, financing, risk, etc.). The full model reintroduces these factors, which jointly determine the optimal renewal policy; the purpose here is to build intuition before layering on the complete economics in the sections that follow.

5.2 Base Case Scenario Results

Just as a reminder, the Base Cas Scenario is where we consider the "Basic" management regime under medium market conditions, with sugar and ethanol prices, inflation and FX aligned to reference forecasts. All other parameters follow the definitions from Chapter 3.

5.2.1 Revenue and Cost Profiles

Gross Revenue

Annual gross revenue R_t is calculated as

$$R_t = V_t \times P_t,$$

where V_t is volume sold and P_t is the unit price. Table 5.5 summarizes the base-case volumes, prices and resulting gross revenues for 2024–2034.

Table 5.5: Volume, unit price and gross revenue in the base case (2024–2034)

Year	Volume (t)	Price (R$/t)	Gross Revenue (R$'000)
2024	23 167	165	3 820 441
2025	19 038	183	3 492 018
2026	16 468	190	3 128 919
2027	14 245	200	2 846 668
2028	12 323	211	2 604 114
2029	22 008	232	5 116 665
2030	19 038	241	4 584 637
2031	16 468	253	4 171 070
2032	14 245	268	3 815 668
2033	12 323	295	3 631 065
2034	22 008	305	6 717 621

Net Revenue

As detailed before, the following deductions apply to gross revenue:

Returns and cancellations:	1.0% R_t,
PIS/Cofins:	1.8% R_t,
Funrural:	1.2% R_t,

Accordingly, net revenue is computed as

$$\begin{aligned} R_t^{\text{net}} &= R_t - 0.01\,R_t - 0.018\,R_t - 0.012\,R_t \\ &= R_t\Big(1 - 0.01 - 0.018 - 0.012\Big). \end{aligned}$$

Table 5.6 shows the resulting net revenues for 2024–2034.

Table 5.6: Net revenue in the base case (2024–2034)

Year	Net Revenue (R$'000)
2024	3 667 623
2025	3 352 337
2026	3 003 763
2027	2 732 802
2028	2 499 950
2029	4 911 999
2030	4 401 251
2031	4 004 227
2032	3 663 041
2033	3 485 823
2034	6 448 916

Overall, net revenue retains the same cyclical profile as gross revenue but at roughly 94 % of its level, reflecting the fixed deduction rates. These net revenue figures will feed directly into the free cash flow projections.

Operating Costs

Table 5.5 presents the breakdown of operating costs for ratoon (Cana-soca) and plant-cane (Cana-planta) phases. All figures are in R$'000 (except the last row, which is percent of net revenue).

Ratoon costs start at R$1.67 m in 2024 and rise to R$1.95 m in 2028 as yield per hectare declines, driving the cost-to-net-revenue ratio from 45.6 % up to

		dez/24	dez/25	dez/26	dez/27	dez/28	dez/29	dez/30	dez/31	dez/32	dez/33	dez/34
	Units	2024A	2025E	2026E	2027E	2028E	2029E	2030E	2031E	2032E	2033E	2034E
Costs	**R$ '000**	**1.673**	**1.944**	**1.938**	**1.944**	**1.949**	**2.275**	**1.954**	**1.962**	**1.967**	**1.980**	**2.290**
Cana-soca Costs	**R$ '000**	**1.673**	**1.944**	**1.938**	**1.944**	**1.949**	**-**	**1.954**	**1.962**	**1.967**	**1.980**	**-**
Treatment of *Cana-soca*		775	896	898	900	902	-	906	908	910	913	-
Harvest		898	1.038	1.040	1.042	1.045	-	1.049	1.052	1.054	1.057	-
% Net Revenue	%	*45,6%*	*58,0%*	*64,5%*	*71,1%*	*78,0%*	-	*44,4%*	*49,0%*	*53,7%*	*56,8%*	-
Cana-planta Costs	**R$ '000**	**-**	**-**	**-**	**-**	**-**	**2.275**	**-**	**-**	**-**	**-**	**2.290**
Treatment of Cana-planta		-	-	-	-	-	693	-	-	-	-	702
Harvest		-	-	-	-	-	1.570	-	-	-	-	1.590
% Net Revenue	%	-	-	-	-	-	*46,3%*	-	-	-	-	*35,5%*

Figure 5.5: Operating cost breakdown in the base case (2024–2034).

78.0 %. After each replanting (2029 and 2034), plant-cane costs spike to about R$2.28 m–2.29 m but represent a lower share of net revenue (46.3 % and 35.5 %, respectively) thanks to restored productivity.

5.2.2 Projected Income Statement (2024–2034)

Figure 5.6 presents the projected Income Statement for the sugar-cane operation over the 2024–2034 horizon. Overall, revenues and earnings exhibit an initial contraction-reflecting conservative yield and price assumptions from Chapter 3 and 4, followed by a strong rebound from 2029 onward as commodity prices recover and efficiency gains materialize. Margins trend similarly: gross and EBITDA margins narrow in the early years, then expand markedly in the outer forecast period. Net income turns positive in 2027 and accelerates thereafter, driven by both higher operating leverage and stable tax treatment under *Lucro Real*.

	12	12	12	12	12	12	12	12	12	12	12
R$ '000	2024	2025E	2026E	2027E	2028E	2029E	2030E	2031E	2032E	2033E	2034E
Gross Revenue	**3.820**	**3.492**	**3.129**	**2.847**	**2.604**	**5.117**	**4.585**	**4.171**	**3.816**	**3.631**	**6.718**
% YoY Growth		*(8,6%)*	*(10,4%)*	*(9,0%)*	*(8,5%)*	*96,5%*	*(10,4%)*	*(9,0%)*	*(8,5%)*	*(4,8%)*	*85,0%*
(-) Cancellations	(38)	(35)	(31)	(28)	(26)	(51)	(46)	(42)	(38)	(36)	(67)
% Gross Revenue	*1,0%*	*1,0%*	*1,0%*	*1,0%*	*1,0%*	*1,0%*	*1,0%*	*1,0%*	*1,0%*	*1,0%*	*1,0%*
(=) Gross Revenue net of cancellations	**3.782**	**3.457**	**3.098**	**2.818**	**2.578**	**5.065**	**4.539**	**4.129**	**3.778**	**3.595**	**6.650**
% YoY Growth		*(8,6%)*	*(10,4%)*	*(9,0%)*	*(8,5%)*	*96,5%*	*(10,4%)*	*(9,0%)*	*(8,5%)*	*(4,8%)*	*85,0%*
(-) Deductions	(115)	(105)	(94)	(85)	(78)	(153)	(138)	(125)	(114)	(109)	(202)
% Gross Revenue	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*
(=) Net Revenue	3.668	3.352	3.004	2.733	2.500	4.912	4.401	4.004	3.663	3.486	6.449
% YoY Growth		*(8,6%)*	*(10,4%)*	*(9,0%)*	*(8,5%)*	*96,5%*	*(10,4%)*	*(9,0%)*	*(8,5%)*	*(4,8%)*	*85,0%*
(-) COGS	(1.673)	(1.944)	(1.938)	(1.944)	(1.949)	(2.275)	(1.954)	(1.962)	(1.967)	(1.980)	(2.290)
% Net Revenue	*45,6%*	*58,0%*	*64,5%*	*71,1%*	*78,0%*	*46,3%*	*44,4%*	*49,0%*	*53,7%*	*56,8%*	*35,5%*
Gross Profit	1.995	1.408	1.066	789	551	2.637	2.447	2.043	1.696	1.506	4.159
% Gross Margin	*54,4%*	*42,0%*	*35,5%*	*28,9%*	*22,0%*	*53,7%*	*55,6%*	*51,0%*	*46,3%*	*43,2%*	*64,5%*
(-) Operational expenses	(101)	(92)	(83)	(75)	(69)	(135)	(121)	(110)	(101)	(96)	(178)
% Net Revenue	*2,8%*	*2,8%*	*2,8%*	*2,8%*	*2,8%*	*2,8%*	*2,8%*	*2,8%*	*2,8%*	*2,8%*	*2,8%*
(+) Other operational revenues	20	18	16	15	14	27	24	22	20	19	35
% Net Revenue	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*
EBITDA	1.914	1.334	1.000	728	495	2.529	2.350	1.954	1.615	1.429	4.016
% EBITDA Margin	*52,2%*	*39,8%*	*33,3%*	*26,6%*	*19,8%*	*51,5%*	*53,4%*	*48,8%*	*44,1%*	*41,0%*	*62,3%*
(-) Depretiation	(185)	(222)	(255)	(289)	(319)	(346)	(371)	(420)	(464)	(504)	(484)
% Net Revenue	*5,0%*	*6,6%*	*8,5%*	*10,6%*	*12,8%*	*7,0%*	*8,4%*	*10,5%*	*12,7%*	*14,5%*	*7,5%*
(-) Amortization of Biological Assets	-	(609)	(609)	(609)	(609)	(646)	(646)	(646)	(646)	(646)	(654)
% Net Revenue	-	*18,2%*	*20,3%*	*22,3%*	*24,4%*	*13,2%*	*14,7%*	*16,1%*	*17,6%*	*18,5%*	*10,1%*
EBIT	1.729	503	135	(170)	(433)	1.537	1.333	888	505	279	2.878
% EBIT Margin	*47,1%*	*15,0%*	*4,5%*	*(6,2%)*	*(17,3%)*	*31,3%*	*30,3%*	*22,2%*	*13,8%*	*8,0%*	*44,6%*
(+/-) Resultado financeiro	(152)	(106)	(87)	(72)	(62)	(56)	(84)	(54)	(28)	(4)	17
% Net Revenue	*(4,1%)*	*(3,2%)*	*(2,9%)*	*(2,6%)*	*(2,5%)*	*(1,1%)*	*(1,9%)*	*(1,4%)*	*(0,8%)*	*(0,1%)*	*0,3%*
EBT	1.577	397	48	(241)	(495)	1.480	1.249	834	477	275	2.895
% EBT Margin	*43,0%*	*11,8%*	*1,6%*	*(8,8%)*	*(19,8%)*	*30,1%*	*28,4%*	*20,8%*	*13,0%*	*7,9%*	*44,9%*
(-) IRPJ/CSLL	(536)	(135)	(16)	-	-	(503)	(425)	(283)	(162)	(94)	(984)
% EBT	*34,0%*	*34,0%*	*34,0%*	-	-	*34,0%*	*34,0%*	*34,0%*	*34,0%*	*34,0%*	*34,0%*
Net Income	1.041	262	32	(241)	(495)	977	824	550	315	182	1.911
% Net Margin	*27,2%*	*7,5%*	*1,0%*	*(8,5%)*	*(19,0%)*	*19,1%*	*18,0%*	*13,2%*	*8,3%*	*5,0%*	*28,4%*

Figure 5.6: Projected Income Statement (2024–2034)

General Dynamics

- **Revenue profile:** Gross Revenue falls from R$3,820 k in 2024 to R$2,604 k in 2028 (–8 % CAGR), then jumps to R$5,117 k in 2029 (+96.5 %), ultimately reaching R$6,718 k by 2034. The rebound in 2029 is driven largely by higher prices, though partial yield reductions from replanting moderate the full upside of that price recovery.
- **Replanting year (2029):** As detailed in Section 5.1.1, the base-case 5-year cycle resets yields from 12 971t in 2028 back to full plant-cane volume of 23 167t in 2029. This scheduled replanting drives a discrete spike in CAPEX in 2029, leading to higher depreciation expense in that year, which in turn elevates per-ton COGS and tempers margin expansion despite the favorable price environment.
- **Margin evolution:** Gross margin narrows from 54.4 % in 2024 to 22.0 % in 2028 before recovering to 64.5 % by 2034. EBITDA margins follow suit (52.2 % $\rightarrow$ 19.8 % $\rightarrow$ 62.3 %). The dip in 2029 EBITDA margin (to 35 %) reflects both replanting-related cost absorption and elevated depreciation.
- **Profitability turning point:** EBIT, after dipping into a R$433 k loss in 2028, climbs to R$2,878 k by 2034. Net Income break even occurs in 2027, with R$32 k of profit, and rises to R$2,911 k in 2034.

Discussion of Key Sections of the IS

1. **Gross Revenue & Cancellations/Deductions.** Driven by tonnage × price assumptions (Section 3.2.2). A uniform 1 % cancellation rate and 3 % deduction rate are applied across the forecast.
2. **Cost of Goods Sold (COGS).** Comprises field-level production costs and mill-processing expenses, each indexed to oil and FX multipliers (Section 3.3.5). The replanting cycle in 2029 increases per-hectare field costs (higher seed, labor for planting), so COGS as a percentage of Net Revenue peaks that year before declining as the new plantings reach full productivity.
3. **Gross Profit & Operating Expenses.** Gross Profit reflects the combined effect of price recovery and replanting yield drag. SG&A expenses remain at 2.8 % of Net Revenue, while other operating revenues (0.5 %) provide a modest offset. The additional site-preparation costs for replanting are capitalized rather than expensed, thus showing up in depreciation.
4. **EBITDA, Depreciation & Amortization.** EBITDA is Gross Profit less SG&A and other operating items. Depreciation of fixed assets scales with

the CAPEX schedule, while biological-asset amortization remains constant at R$609 k per year over the 4 first years, and increases after the second replanting, following the accumulated inflation increase for 5 years.

5. **EBIT & Financial Result.** Subtracting non-cash charges yields EBIT, which turns negative in 2028 (–17.3 % margin) and remains subdued in 2029 (–2.5 %) due to elevated depreciation. Interest expense on gross debt at 8 % produces a net financial charge declining from R$152 k in 2024 to near zero by 2033 as debt is paid down.

6. **Taxes & Net Income.** EBT is taxed at 34 % (IRPJ/CSLL under *Lucro Real*). Cash taxes mirror earnings volatility: the muted pre-tax profit in 2029 results in minimal tax outflow that year, supporting positive free cash flow despite low EBIT.

5.2.3 Projected Balance Sheet (2024–2034)

Figure 5.7 presents the projected Balance Sheet for the sugar-cane operation over the 2024–2034 horizon. Assets, Liabilities and Equity are shown in current and non-current groupings, automatically linked to the Income Statement and Cash-Flow modules via working-capital balances and retained-earnings roll-forwards.

R$ '000	2024	2025E	2026E	2027E	2028E	2029E	2030E	2031E	2032E	2033E	2034E
Balance Sheet											
Assets	**24.931**	**26.207**	**26.163**	**25.852**	**25.282**	**26.303**	**27.011**	**27.516**	**27.782**	**27.917**	**29.922**
Current Assets	**2.096**	**2.784**	**3.262**	**3.508**	**3.569**	**2.090**	**3.578**	**4.656**	**5.594**	**6.484**	**5.991**
Cash and Cash Equivalents	103	573	1.099	1.370	1.453	(613)	1.235	2.352	3.325	4.225	3.093
Accounts Receivable	380	347	311	283	259	509	456	415	380	361	668
Stock - Grown Crop	1.474	1.713	1.707	1.713	1.717	2.004	1.722	1.728	1.733	1.744	2.018
Stock - Supplies	90	105	104	105	105	122	105	106	106	107	123
Pre-paid expenses	50	46	41	37	34	67	60	55	50	48	88
Non-current Assets	**22.835**	**23.423**	**22.901**	**22.344**	**21.714**	**24.213**	**23.433**	**22.860**	**22.188**	**21.432**	**23.931**
Tangible Assets	21.450	21.595	21.682	21.735	21.714	21.629	21.495	21.568	21.542	21.432	21.316
Land (owned)	19.800	19.800	19.800	19.800	19.800	19.800	19.800	19.800	19.800	19.800	19.800
Buildings and infrastructure	300	326	342	352	348	333	308	321	317	297	276
Improvements (e.g., irrigation systems, drainage)	100	109	114	117	116	111	103	107	106	99	92
Machinery and Equipment	1.000	1.088	1.141	1.173	1.160	1.109	1.027	1.071	1.056	989	919
Vehicles	250	272	285	293	290	277	257	268	264	247	230
Biological Assets	1.385	1.828	1.218	609	-	2.584	1.938	1.292	646	-	2.616
Rootsock Value	1.385	1.828	1.218	609	-	2.584	1.938	1.292	646	-	2.616
Liabilities and Stockholders Equity	**24.931**	**26.207**	**26.163**	**25.852**	**25.282**	**26.303**	**27.011**	**27.516**	**27.782**	**27.917**	**29.922**
Current Liabilities	**640**	**690**	**688**	**687**	**684**	**802**	**756**	**763**	**765**	**769**	**904**
Accounts payable (input suppliers, service providers)	300	344	341	340	340	408	351	350	349	350	419
Wages and benefits payable	30	27	25	22	20	40	36	33	30	29	53
Short-term loans (e.g., working capital lines)	200	218	230	239	245	274	297	313	324	333	371
Current portion of long-term debt	100	92	85	78	72	66	61	56	51	47	43
Taxes payable	10	9	8	7	7	13	12	11	10	10	18
Non-Current Liabilities	**1.000**	**920**	**846**	**779**	**716**	**659**	**606**	**558**	**513**	**472**	**434**
Long-term debt (e.g., PRONAF, BNDES rural credit lines)	1.000	920	846	779	716	659	606	558	513	472	434
Owner's Equity	**23.291**	**24.597**	**24.628**	**24.387**	**23.882**	**24.842**	**25.648**	**26.195**	**26.504**	**26.676**	**28.584**
Share Capital	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000
Retained earnings	2.250	3.291	3.553	3.584	3.343	2.848	3.825	4.649	5.200	5.514	5.696
Net income (or loss) for the year	1.041	262	32	(241)	(495)	977	824	550	315	182	1.911
Dividends	-	1.044	1.044	1.044	1.034	1.017	999	996	989	980	977
Revaluation surplus (e.g., land appreciation, if marked to market)	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000

Figure 5.7: Projected Balance Sheet (2024–2034)

General Dynamics

- **Total Assets:** Grow from R$24,931 k in 2024 to R$29,922 k in 2034, driven by incremental CAPEX and the replanting cycle.
- **Current Assets:** Fluctuate with working-capital needs-cash dips in 2029 due to the replanting outlay, while receivables and inventories reflect the yield cycle.
- **Non-Current Assets:** Increase steadily with property, plant & equipment additions being higher than depreciation of these assets.
- **Liabilities:** Short-term borrowings and the current portion of long-term debt rise in replant years to fund CAPEX, then decline as repayments resume. The short-term borrowings are assumed to be 1% of net revenue.
- **Equity:** Retained earnings accumulate net income, turning positive after 2027; a constant share capital and any revaluation surplus complete the owner's equity section.

Discussion of Key Sections of the BS

1. **Cash & Cash Equivalents.** Maintained at roughly 3–5 % of annual revenue; the 2029 replanting spike in CAPEX causes a temporary cash outflow, reflected as a negative opening balance before financing inflows restore liquidity.
2. **Accounts Receivable & Inventory.** Tied to volume projections (Section 5.1.1) and priced at expected mill prices; receivables lag by 1.1 months of sales, while standing-cane inventory swings with the ratoon cycle.
3. **Biological Assets (Rootstock).** Capitalized at planting and amortized over the 5-year base cycle; in 2029 the rootstock value resets to the full plant-cane level (R$2,584 k) before subsequent amortization.
4. **Property, Plant & Equipment.** Land remains constant at R$19.8 m; buildings, improvements and machinery track the CAPEX schedule, with depreciation reducing net book values each year. The 2029 replanting outlay adds to field development and boosts accumulated depreciation.
5. **Working-Capital Liabilities.** Accounts payable and wages payable align with input-cost timing; short-term loans peak in replant years to bridge cash gaps, then amortize on the current portion of long-term debt.
6. **Long-Term Debt & Equity.** Target debt share of 30 % finances fixed assets; principal repayments reduce non-current liabilities over time. Retained

earnings carry net income from the Income Statement into equity, supporting balance-sheet growth after profitability turns in 2027.

5.2.4 Cash–Flow Statement and Free Cash Flow to the Firm (FCFF)

Figure 5.8 presents the projected Cash–Flow Statement for the sugar-cane operation over the 2024–2034 horizon, and the derivation of Free Cash Flow to the Firm (FCFF).

In R$ '000 (except if said otherwise)	2024	2025E	2026E	2027E	2028E	2029E	2030E	2031E	2032E	2033E	2034E
Cash Flow											
EBITDA		**1.334**	**1.000**	**728**	**495**	**2.529**	**2.350**	**1.954**	**1.615**	**1.429**	**4.016**
(-) D&A		(831)	(864)	(898)	(928)	(992)	(1.017)	(1.066)	(1.110)	(1.150)	(1.138)
EBIT		**503**	**135**	**(170)**	**(433)**	**1.537**	**1.333**	**888**	**505**	**279**	**2.878**
(-) Taxes		(171)	(46)	–	–	(522)	(453)	(302)	(172)	(95)	(978)
% effective rate		34%	34%	0%	0%	34%	34%	34%	34%	34%	34%
(=) NOPLAT		**332**	**89**	**(170)**	**(433)**	**1.014**	**879**	**586**	**333**	**184**	**1.899**
(+) D&A		831	864	898	928	992	1.017	1.066	1.110	1.150	1.138
(+/-) Working Capital Variation		(177)	40	22	20	(493)	297	34	30	9	(537)
Capital de giro		*1.830*	*1.790*	*1.768*	*1.748*	*2.241*	*1.944*	*1.909*	*1.879*	*1.871*	*2.408*
(=) Operational Cash Flow		**986**	**994**	**750**	**515**	**1.513**	**2.194**	**1.687**	**1.473**	**1.343**	**2.500**
(-) CAPEX		(367)	(335)	(335)	(300)	(3.503)	(250)	(491)	(440)	(400)	(3.636)
(=) Investments Cash Flow		**(367)**	**(335)**	**(335)**	**(300)**	**(3.503)**	**(250)**	**(491)**	**(440)**	**(400)**	**(3.636)**
(=) Free Cash Flow to Firm (FCFF)		**619**	**659**	**415**	**215**	**(1.990)**	**1.944**	**1.195**	**1.033**	**943**	**(1.136)**
% Cash Conversion (over EBITDA)		*46,4%*	*65,9%*	*57,0%*	*43,3%*	*-78,7%*	*82,7%*	*61,2%*	*64,0%*	*65,9%*	*-28,3%*

Figure 5.8: Projected Cash–Flow Statement and FCFF (2024–2034)

General Dynamics

- **EBITDA & Depreciation:** EBITDA declines from R$1,334 k in 2024 to R$495 k in 2027 before surging post-2029. Depreciation and amortization rise steadily with accumulated CAPEX, peaking in replant years.
- **Taxes & NOPLAT:** Cash taxes are 34 % of positive EBIT; negative EBIT years (2026–2027) incur zero tax, so NOPLAT equals EBIT in those years.
- **Working-Capital Variation:** Changes in receivables, inventory and payables generate swings of up to ±R$1.8 m; the 2029 replant cycle drives a R$493 k increase in net working capital.
- **CAPEX and Investments:** Field and equipment investments run R$300–350 k annually, except for a discrete R$3.503 m outlay in 2029 for the 5-year replanting cycle.
- **Free Cash Flow to the Firm (FCFF):** FCFF is positive in most years but turns negative in 2029 (–R$1.990 m) and again in 2034 (–R$1.136 m) due to replanting and end-of-cycle maintenance.
- **% Cash Conversion:** The ratio of FCFF to EBITDA ranges from 43 % to 83 %, dropping to –78.7 % in the heavy-investment year 2029.

Derivation of FCFF

1. **EBIT to NOPLAT.** Start with EBIT (e.g., R$503 k in 2024), subtract cash taxes at 34% to obtain NOPLAT (R$332 k). Zero cash tax is applied in years with negative EBIT.

2. **Add back Depreciation & Amortization.** Non-cash D&A is added to NOPLAT (e.g., +R$831 k in 2024) to arrive at Operating Cash Flow before working capital.

3. **Working-Capital Effects.** Subtract the change in net working capital, which is +R$177 k in 2024 (a cash outflow) and +R$493 k in 2029 due to replant-driven inventory build-up.

4. **Capital Expenditures.** Deduct cash CAPEX (–R$367 k in 2024; –R$3.503 m in 2029 for replanting) to yield FCFF.

5. **Resulting FCFF Series.** The resulting FCFF sequence (e.g., R$619 k in 2024; –R$1.990 m in 2029) is the input to the Valuation module, discounted at the model WACC.

5.2.5 Key Outputs

The following key performance and valuation metrics are summarized in the following tables.

EBITDA and Net Income as of 2034 are shown alongside their 5-year cycle averages. Because year-on-year values swing significantly due to the 5-year replanting cycle, the point estimate for 2034 can be misleading; the 5-year average better reflects sustainable performance. We omit the Debt Service Coverage Ratio here, since scheduled debt repayments are materially below the firm's repayment capacity throughout the forecast, making DSCR analysis uninformative at this stage.

	At 2034	**Average last 5 years**
EBITDA (R$ '000)	4 016	2 273
EBITDA margin (%)	62	52
Net Income (R$ '000)	1 911	756
Net margin (%)	30	17

Table 5.7: EBITDA and Net Income: 2034 vs. Last 5-Year Average

NPV and Enterprise Value

Table 5.8 summarizes the discounted value of the forecast cash flows and the terminal perpetuity, as well as the resulting enterprise value (EV). The NPV of cash flows reflects the value generated over the explicit forecast period, while the perpetuity NPV captures the residual value beyond the projection horizon. The EV of R$3,941 m represents the total firm value before accounting for financing structure.

Metric	**Value**
NPV – Cash Flows	R$ 2,030 ’000
NPV – Perpetuity	R$ 1,911 ’000
Enterprise Value	R$ 3,941 ’000

Table 5.8: NPV and Enterprise Value

Equity Value Calculation

Table 5.9 shows the bridge from enterprise value to equity value by adding cash and subtracting debt. The resulting equity value of R$2.743 m represents the residual claim available to shareholders after satisfying all obligations.

Adjustment	**Amount**
(+) Cash	R$ 103 ’000
(–) Debt	R$(1 300 ’000)
Equity Value	**R$ 2 743 ’000**

Table 5.9: Equity Value Calculation

Table 5.10 reports the current debt-to-equity ratio of 0.5×. A ratio of 0.5× means the firm has R$0.50 of debt for every R$1.00 of equity, reflecting a conservative leverage position. This low level of debt relative to equity reduces financial risk and interest-service requirements, and is below typical agribusiness benchmarks (around 1.0–1.5×), indicating ample capacity to support future growth or weather commodity-price volatility.

Metric	Value
Current Debt-to-Equity Ratio	0.5 x

Table 5.10: Capital Structure Ratio

5.3 Multi-Scenario Analysis

As mentioned before, to capture both external market uncertainty and internal execution risk, we analyze three external scenarios (Optimistic, Base, Pessimistic), each under three management regimes (Good, Base, Bad). With that, we have organized the results in three tables, one for each external scenario.

5.3.1 Optimistic Scenario Results

Table 5.11 below shows the key valuation metrics under the *Optimistic* external scenario.

	Case 1	Case 2	Case 3
Scenario	Optimistic	Optimistic	Optimistic
Management	Good	Base	Bad
NPV - Cash Flows	4.543	3.376	914
NPV - Perpetuity	4.321	3.253	742
Enterprise Value	**8.864**	**6.630**	**1.656**
(+) Cash	103	–	–
(-) Debt	(1.300,0)	(1.300,0)	(1.300,0)
Equity Value	**7.667**	**5.432**	**459**
Equity/Debt	**0,2x**	**0,2x**	**2,8x**
Average EBITDA	**3.155**	**2.462**	**1.223**
Average EBITDA Margin	50%	48%	31%
Average Net Revenue	**1.370**	**919**	**92**
Average Net Margin	20%	16%	0%

Table 5.11: Valuation Metrics under the Optimistic External Scenario

Under optimistic market conditions, superior execution ("Good" regime) roughly doubles both NPV and Enterprise Value relative to the "Bad" regime, illustrating the value of operational excellence when prices and yields are favorable. Conversely, even under strong external tailwinds, a poor management regime delivers only modest equity-value creation (R$459 m). The steep decline in Debt to Equity from 0.2× to 2.8× across regimes further highlights how internal performance drives the firm's leverage metrics, leaving the firm more vulnerable to financial stress.

It is important to note that under both the "Good" and "Base" regimes, the 5-year crop cycle length remains unchanged, so differences in valuation metrics stem solely from variations in operational efficiency and cost management. In the "Bad" regime, however, we assume a lengthened cycle (6 years) due to suboptimal field practices and delayed replanting, which depresses average yields and exacerbates the decline in NPV, Enterprise Value, and other metrics relative to the Good and Base cases.

5.3.2 Base Scenario Results

Table 5.12 presents the key valuation metrics under the *Base* external scenario, across three management regimes. Note that while "Good" and "Base" regimes maintain the 5-year cycle, the "Bad" regime assumes a lengthened cycle, driving the steeper declines and even negative equity in Case 6.

	Case 4	Case 5	Case 6
Scenario	Base	Base	Base
Management	Good	Base	Bad
NPV - Cash Flows	2.902	2.030	(9)
NPV - Perpetuity	2.649	1.911	167
Enterprise Value	**5.551**	**3.941**	**157**
(+) Cash	–	–	–
(-) Debt	(1.300,0)	(1.300,0)	(1.300,0)
Equity Value	**4.353**	**2.743**	**(1.040)**
Equity/Debt	**0,3x**	**0,5x**	**(1,2x)**
Average EBITDA	**2.258**	**1.745**	**759**
Average EBITDA Margin	44%	42%	23%
Average Net Revenue	**770**	**432**	**(236)**
Average Net Margin	14%	9%	-10%

Table 5.12: Valuation Metrics under the Base External Scenario

Under the Base external assumptions, the Good regime yields an NPV of R$2.902 m and EV of R$5.551 m, while the Bad regime (with a longer cycle) produces a negative equity of R$1.040 m and effectively zero leverage capacity. The mid-case (Base management) provides a moderate outcome (NPV = R$2.030 m, EV = R$3.941 m), illustrating the sensitivity to execution quality even when external conditions are unchanged.

5.3.3 Pessimistic Scenario Results

Table 5.13 presents the key valuation metrics under the *Pessimistic* external scenario, across three management regimes. As before, only the "Bad" regime assumes a lengthened cycle, compounding the negative market effects.

Under pessimistic market conditions, the Good regime still produces a modest positive EV (R$2.823 m) and equity value (R$1.723 m), whereas the Base regime

	Case 7	Case 8	Case 9
Scenario	Pessimistic	Pessimistic	Pessimistic
Management	Good	Base	Bad
NPV - Cash Flows	1.506	876	(765)
NPV - Perpetuity	1.318	847	(650)
Enterprise Value	**2.823**	**1.723**	**(1.415)**
(+) Cash	3.086	–	–
(-) Debt	(1.300,0)	(1.300,0)	(1.300,0)
Equity Value	**1.626**	**526**	**(2.612)**
Equity/Debt	**0,8x**	**2,5x**	**(0,5x)**
Average EBITDA	**1.502**	**1.144**	**388**
Average EBITDA Margin	38%	35%	14%
Average Net Revenue	**252**	**(1)**	**(534)**
Average Net Margin	6%	-1%	-24%

Table 5.13: Valuation Metrics under the Pessimistic External Scenario

yields thin value and the Bad regime results in negative enterprise and equity values, underscoring the dual impact of adverse prices and suboptimal management on firm valuation.

5.3.4 Scenario Matrix

To visualize the combined impact of external market conditions and internal execution quality, Figures 5.14 and 5.15 present heat-map–style matrices of Enterprise Value (EV) and Average Net Margin, respectively, across the nine scenario–regime combinations.

	Good	**Base**	**Bad**
Optimistic	8 864	6 630	1 656
Base	5 551	3 941	157
Pessimistic	2 823	1 723	(1 415)

Table 5.14: Enterprise Value Matrix (R$ ’000) across External Scenarios and Management Regimes

Several key insights emerge from these matrices:

- **EV Sensitivity to Market vs. Management.** Under Optimistic markets, even a “Bad” regime yields positive EV (R$1.656 m), but under Pessimistic markets a “Bad” regime destroys value (EV = –R$1.415 m). This underscores

	Good	**Base**	**Bad**
Optimistic	20 %	16 %	0 %
Base	14 %	9 %	–10 %
Pessimistic	6 %	–1 %	–24 %

Table 5.15: Average Net Margin Matrix (%) across External Scenarios and Management Regimes

that strong external conditions can partially offset poor execution, whereas adverse markets amplify the impact of suboptimal management.

- **Management Impact within a Scenario.**
  - In the Optimistic case, shifting from Good to Bad management cuts EV by ∼81 % (8 864 → 1 656).
  - In the Base case, the drop is even more severe: EV falls from R$5.551 m to just R$0.157 m (–97 %) when moving from Good to Bad.
  - In the Pessimistic case, only the Good regime maintains positive EV, highlighting a critical "buffer" provided by superior execution.
- **Net Margin Dynamics.**
  - Margins remain strongly positive in Optimistic/Good (20 %) but plunge into negative territory under any Bad regime (–10 % to –24 %), indicating that poor operations both reduce volume and inflate unit costs.
  - Even under Base markets, a Good regime delivers a healthy 14 % margin, compared to –10 % under Bad management.
- **Correlations and Thresholds.**
  - There is a clear, roughly linear relationship between Net Margin and EV across regimes, but the slope steepens under worse external scenarios, signalling non-linear downside risk.
  - The negative EV and margin in the Pessimistic/Bad cell signifies a breach of a "viability threshold," suggesting that this combination should be avoided or mitigated through hedging, cost controls, or capital injections.

Together, these matrices and their interpretation guide strategic decisions on where to focus managerial improvement efforts (e.g. cost reduction, yield optimization) and how to position the firm under varying market outlooks.

5.4 Acquisition Analysis

As outlined in Section 4.3, for each external environment (Optimistic, Base-Case, Pessimistic) we first set the acquisition price equal to the target farm's enterprise value under its current (poor/base) management regime. We then assume that, upon closing in 2024, the target immediately operates under the optimized ("good-management") regime, while the external scenario used to value the farm remains unchanged.

Building on this framework, we now apply our acquisition-analysis toolkit to assess whether an optimized 300 ha sugarcane farm can afford to acquire a peer operating under (a) poor-management and (b) base-management regimes across the three external scenarios.

Our acquisition evaluation applies two hurdle-rate criteria and a debt service requirement:

- **Unlevered IRR** $\geq 20.8\%$, calculated on the project's free cash flows before financing.
- **Levered IRR** $\geq 20.8\%$, calculated on the equity cash flows after debt service.
- **DSCR** $\geq 1.0\times$, where DSCR in each forecast year is

$$\text{DSCR}_t = \frac{\text{Cash Flow Available for Debt Service}_t}{\text{Debt Service}_t}.$$

In the end we will show a summary table, with all the conditions for each case, showing in which cases we can or cannot perform the acquisition.

Replanting CapEx as Initial Investment for Bad-Management In the Bad-management scenarios, the target farm follows a different, less efficient cane cycle and will require a full replanting before any "good-management" practices can take effect. To capture this one-time adjustment cost and avoid assuming a frictionless transition, we therefore treat the replanting capital expenditure as an additional initial investment in these cases. This approach aligns the post-acquisition cash-flow timing with the optimized regime's cycle and ensures that our IRR calculations reflect both the difference in agronomic cycle length and the up-front cost of rebuilding the stand-rather than implicitly granting a costless switch to "good" practices.

Analysis of Acquisition - Case 1 example To better understand how we performed this analysis for each case, Table 5.16 shows the detailed cash-flow build-up, discount factors, IRR and DSCR metrics for the first case, which serves as the template for all other combinations.

Case 1: Optimistic Scenario & Bad Management													
Unlevered		**Initial Investment**											
Initial Investment and cashflows		(4.425)	470	918	718	608	(1.159)	3.052	2.055	1.878	1.836	812	13.608
Discount factor			*91%*	*75%*	*62%*	*52%*	*43%*	*35%*	*29%*	*24%*	*20%*	*17%*	*17%*
IRR	24,2%												
Max. Price	6.289												
Levered		**Initial Investment**											
Initial Investment and cashflows		(4.425)	470	918	718	608	(1.159)	3.052	2.055	1.878	1.836	812	13.608
Discount factor			*91%*	*75%*	*62%*	*52%*	*43%*	*35%*	*29%*	*24%*	*20%*	*17%*	*17%*
Debt Principal Repayment			(310)	(310)	(310)	(310)	(310)	(310)	(310)	(310)	(310)	(310)	
Debt Interest			(496)	(459)	(422)	(384)	(347)	(310)	(272)	(235)	(198)	(160)	
Previous Debt Service			(109)	(104)	(99)	(94)	(91)	(89)	(87)	(85)	(83)	(83)	
Debt Service Coverage Ratio			**2,1x**	**1,8x**	**1,5x**	**1,3x**	**5,7x**	**5,7x**	**5,3x**	**5,1x**	**5,2x**	**13,8x**	
Equity Cashflows		(1.328)	(446)	45	(112)	(180)	(1.907)	2.344	1.385	1.248	1.245	260	13.608
IRR	25,5%												
Max. Price	2.743												

Table 5.16: Example of Acquisition Analysis for the Optimistic and Bad Management Case

In Table 5.16 we report both the unlevered and levered analyses for Case 1, under the Optimistic external scenario with the target still in its "bad-management" regime at acquisition. The two panels correspond to:

1. Unlevered cash-flow valuation.

- We treat the acquisition price as the enterprise value of the target under its existing (poor) regime, then project its free cash-flow to the firm (FCFF) for years 1–10.
- Each FCFF is discounted back at the unlevered discount factors implied by our WACC estimate (cf. Section 4.3).
- Solving for the purchase price P_0^* that delivers the IRR hurdle of 20.8 % yields a "break-even" unlevered price of R$ 6,289 m, corresponding to an unlevered IRR of 24.2 % at the original enterprise value of R$ 1,656, + R$ 2,769m of CAPEX.

2. Levered financing-and-debt-service test.

- We assume a 30 %-debt / 70 %-equity financing package, 10-year amortization at 12 % p.a., and a DSCR covenant of 1.0×.
- In each forecast year we deduct scheduled principal and interest to arrive at residual equity cash flows. The resulting average DSCR exceeds 1.0× throughout (peaking at 5.7× in year 5 and never falling below 1.5×).
- Discounting these equity cash flows at the 20.8 % hurdle produces a levered levered break-even price of R$ 2.743 m.

Interpretation. Under optimistic market conditions, even a target acquired at its full poor-management enterprise value can (i) meet the minimum unlevered IRR hurdle, and (ii) comfortably service debt while delivering a levered IRR above 20.8

%. This confirms viability in Case 1 and validates our methodology for decomposing acquisition value into unlevered valuation and subsequent leverage-driven equity returns.

5.4.1 IRR and Max Bid Prices Results

Scenario	Management	Unlevered IRR	Levered IRR
Optimistic	Bad	24,2%	25,5%
Optimistic	Base	19,1%	18,3%
Base	Bad	24,0%	23,9%
Base	Base	19,9%	18,3%
Pessimistic	Bad	16,3%	11,2%
Pessimistic	Base	12,5%	7,6%

Table 5.17: Unlevered and Levered IRRs by Scenario and Management Regime

Table 5.17 reports both unlevered and levered equity IRRs for all six combinations of external scenario (Optimistic, Base-Case, Pessimistic) and target management regime (Bad, Base). In each case we compare the levered IRR against our 20.8 % hurdle.

Scenario	Management	Unlevered Bid	Levered Bid
Optimistic	Bad	6.289	2.743
Optimistic	Base	7.102	2.008
Base	Bad	4.029	1.544
Base	Base	4.419	1.221
Pessimistic	Bad	2.600	234
Pessimistic	Base	3.198	(380)

Table 5.18: Unlevered and Levered Maximum Bid Price

From another view, Table 5.18 reports, for each combination of external market scenario (Optimistic, Base-Case, Pessimistic) and target management performance (Bad, Base), the highest acquisition price-expressed both as total enterprise value and as price per share-that the acquirer can pay while still delivering our 20.8%

levered-equity IRR hurdle. To arrive at these bid ceilings, we invert the IRR calculations from Table 5.17: using the projected free-cash-flow streams, assumed debt financing terms, and exit multiple under each scenario, we solve for the maximum purchase price consistent with a 20.8% return.

Now, we will look furhter into the results of the IRR Results:

Unlevered IRR Performance

- **Optimistic**: Acquiring a poorly run asset (“Bad”) produces an unlevered IRR of 24.2 %, clearing the 20.8 % hurdle, whereas buying the same farm under “Base” operations now returns only 19.1 %, *below* the target. Even in buoyant markets, over-paying for an adequately managed asset erodes the upside.
- **Base-case**: Turning around a Bad operation delivers 24.0 %, comfortably above the hurdle, while a straight purchase of a Base-managed farm yields 19.9 %, under the cut-off-underscoring the value captured through operational improvement in mid-cycle conditions.
- **Pessimistic**: Neither Bad (16.3 %) nor Base (12.5 %) reaches the hurdle, confirming that adverse commodity prices dominate unlevered value creation.

Levered IRR and Debt-Service Viability

- Adding 30 % debt gives only a modest boost in one instance-Optimistic/Bad rises from 24.2 % to 25.5 % (+1.3 pp)-and *reduces* equity IRRs everywhere else (e.g. Optimistic/Base falls from 19.1 % to 18.3 %).
- **Base-case + Bad management**: leverage is slightly dilutive (24.0 % → 23.9 %) yet still above the hurdle; by contrast, **Base-case + Base management** drops further below the target (19.9 % → 18.3 %), showing that leverage cannot salvage a fairly priced, adequately run farm.
- Under Pessimistic conditions leverage backfires: equity IRR declines by roughly 5 pp (Bad: 16.3 % → 11.2 %; Base: 12.5 % → 7.6 %) and would likely push DSCRs below covenant levels, reinforcing the need to curb debt in downside scenarios.

Drivers of IRR Variation

1. **External scenario** dominates overall: moving from Pessimistic to Base-Case lifts levered IRR by over 12 pp (from 12.5% to 24.2 % in the Bad-management case).

2. **Management regime.** Operating quality shapes returns in every market environment, but the size of the effect now varies markedly: in the *Optimistic* scenario the levered IRR on a poorly run target (25.5 %) exceeds that of a reasonably managed peer (18.3 %) by 7.2 pp; the gap narrows to 5.6 pp in the *Base* case (23.9 % vs. 18.3 %) and to 3.6 pp in the *Pessimistic* downturn (11.2 % vs. 7.6 %).

3. **Interaction effect.** The upside of "buying low" and executing a turnaround grows with market tailwinds: strong external prices boost post-acquisition cash flows while the entry discount remains locked in, so the spread is largest in the Optimistic scenario and progressively compressed as conditions deteriorate.

Underlying Mechanisms

- **Cash-flow timing and magnitude.** Good-management practices deliver more front-loaded free cash flow (higher early-year yields, lower inputs, shorter cycles), which debt magnifies into higher equity IRRs in favourable scenarios.
- **Debt amortisation profile.** The 10-year level-payment structure concentrates interest and principal in early years-sustainable in strong cash-flow regimes but straining DSCR under mid-cycle stress (e.g. Base–Base's 1.1× in 2028).
- **Leverage as double-edged sword.** Debt amplifies upside when FCFF comfortably covers service, but in a downturn (Pessimistic) fixed obligations erode returns and breach covenants.
- **Valuation entry-point ("buy-low" effect).** Acquiring underperformers at a discount widens the spread between purchase price and post-turnaround cash flows; the payoff is greatest when external conditions add further tailwinds (Optimistic/Bad reaches the top IRR at 25.5 %, while Base/Bad remains attractive at 23.9 %).
- **Scenario sensitivity.** External price and yield assumptions drive the largest swings (around 11–14 pp) in IRR, whereas operational improvements contribute up to 7 pp.

Implications

- **Role of leverage in up-markets.** With 30 % debt, only the *turnaround* case clears the 20.8 % equity-IRR hurdle in buoyant markets (Optimistic/Bad 25.5 %); a fully-priced, adequately run farm (Optimistic/Base 18.3 %) still falls short, demonstrating that leverage alone cannot offset paying a fair price for average operations. In the mid-cycle Base scenario the pattern repeats (23.9 % vs. 18.3 %).

- **Down-market discipline.** In a Pessimistic downturn, leverage destroys equity value, IRRs drop to 11.2 % (Bad) and 7.6 % (Base), far below the hurdle, and would likely trigger covenant breaches, reinforcing the case for lower gearing and/or contingent pricing (earn-outs).
- **Strategic takeaway.** The pronounced IRR uplift from acquiring poorly managed peers (a 7.2 pp spread in Optimistic, 5.6 pp in Base) supports a "buy-low, fix-up" strategy, *especially when external conditions are supportive*; however, covenant headroom must be preserved to keep that upside from being wiped out in adverse scenarios.

Deal Viability Decision Table

Scenario	Management	Unlevered IRR OK?	Levered IRR OK?	DSCR OK?
Optimistic	Bad	Yes	Yes	Yes
Optimistic	Base	No	No	Yes
Base	Bad	Yes	Yes	Yes
Base	Base	No	No	Yes
Pessimistic	Bad	No	No	No
Pessimistic	Base	No	No	No

Table 5.19: Decision Table: Unlevered IRR, Levered IRR and DSCR Covenant Tests

Table 5.19 synthesizes our three viability tests-unlevered IRR >= 20.8 %, levered IRR >= 20.8 %, and DSCR >= 1.0×-across all scenario–management combinations. Green cells signal a pass, red cells indicate failure.

Fully viable deals.

- **Optimistic environment + Bad management**: only the poorly managed target clears both the unlevered and levered IRR hurdles of 20.8% and meets the DSCR covenant (>1.0×), demonstrating that acquiring undervalued assets under robust market conditions can deliver both high returns and secure debt service.
- **Base-Case + Bad management**: even in mid-cycle markets, buying a low-valuation, poorly run farm passes the 20.8% IRR tests (unlevered and levered) and maintains DSCR above 1.0×, validating the "buy-low, fix-up" strategy when external conditions are neither exceptionally strong nor weak.

Borderline and failed cases.

- **Optimistic environment + Base management**: although debt service is secure (DSCR >1.0×), the elevated 20.8% IRR hurdle is not met, signaling that-even in strong markets-well-managed farms trading at full value cannot generate the extra return premium.
- **Base-Case + Base management**: both unlevered and levered IRRs fall below 20.8%, yet DSCR holds at roughly 1.1×, indicating adequate coverage but insufficient return, and highlighting a stressed capital structure.
- **Pessimistic environment**: no combination clears the 20.8% IRR hurdle; only well-managed targets sustain DSCR above 1.0×, but their sub-threshold returns render the deal uneconomic.

Key takeaway. Under the hurdles (IRR >20.8% and DSCR >1.0×), only acquisitions of poorly managed farms at low valuations-either in mid-cycle (Base Case) or any farm in an Optimistic environment-can simultaneously deliver the required returns and debt-service coverage. Deals on well-managed assets in mid-cycle markets or any asset in a downturn demand either lower leverage, purchase-price discounts, or additional contractual protections to become viable.

5.5 Sensitivity Tests

Building on the methodology in Section 4.4, we now present the outcomes of our two-way sensitivity tables. Each small matrix shows the impact on enterprise value (EV) of varying one commodity or resource factor alongside FX rate, while the larger table explores the joint effect of WACC and crop-cycle duration. Below we discuss each in turn.

1. Oil Price vs. FX Rate

Enterprise Value (EV) [R$ MM] by changing Oil Price and FX Rate

		Oil Price		
	3.941	Pessimistic	Base	Optimistic
FX Rate	Pessimistic	3.439	3.452	3.465
	Base	3.928	3.941	3.954
	Optimistic	4.430	4.443	4.456

Figure 5.9: EV Sensitivity to Oil Price and FX Rate

As shown in Figure 5.9, EV is remarkably insensitive to oil-price variations, exhibiting shifts of less than 0.8% across scenarios within each Oil-price case. By contrast, EV responds strongly to FX-rate movements: moving from a pessimistic to a base FX rate increases EV by approximately 14%, and from base to optimistic by a further 13%, irrespective of the oil-price environment. In practice, this demonstrates that currency risk far outweighs oil-price volatility in its impact on enterprise value.

2. Water Availability vs. FX Rate

Enterprise Value (EV) [R$ MM] by changing **Water Availability and FX Rate**

	3.941	Water Availability: Pessimistic	Base	Optimistic
FX Rate	Pessimistic	3.001	3.452	3.767
	Base	3.438	**3.941**	4.293
	Optimistic	3.887	4.443	4.833

Figure 5.10: EV Sensitivity to Water Availability and FX Rate

As shown in Figure 5.10, variation in water availability has a moderate impact on EV: relative to the base-case water assumption, a shift to pessimistic availability reduces EV by approximately 13%, whereas moving to optimistic availability increases EV by about 9%. In contrast, exchange-rate movements produce larger effects: upgrading the FX rate by one tier boosts EV by roughly 14.6% from pessimistic to base and by another 12.7% from base to optimistic, consistently across water scenarios. This underscores that, even when agronomic risks such as water shortage are well controlled, currency exposure remains the primary driver of valuation variability.

3. Sugar Price vs. Ethanol Price

Enterprise Value (EV) [R$ MM] by changing **Sugar and Ethanol price**

	3.941	Sugar Price: Pessimistic	Base	Optimistic
Ethanol Price	Pessimistic	2.490	3.509	4.597
	Base	2.893	**3.941**	5.072
	Optimistic	3.304	4.387	5.564

Figure 5.11: EV Sensitivity to Sugar and Ethanol Prices

In Figure 5.11, commodity prices both matter, but sugar price swings drive the largest EV variation. A move from pessimistic to optimistic ethanol prices (holding sugar constant) boosts EV by around 25%, whereas an equivalent shift in sugar price changes EV by over 75%. This suggests that, while both markets are important, sugar margins are the prime lever for value. We should recall in the methodology, we have estimated pass-through elasticities, and that they satisfy $\beta_{\text{sugar}} > \beta_{\text{ethanol}}$. In other words, mills transmit a larger fraction of a given sugar-price change into the cane price than they do of an equivalent ethanol-price change.

With that, it is indeed expected that, for identical relative shocks, sugar-price variation produces a bigger adjustment in projected cash flows-and hence enterprise value-than ethanol-price variation.

4. WACC vs. Cycle Duration

Enterprise Value (EV) [R$ MM] by changing **WACC** and **Cycle Duration**

		WACC				
	3.941	**15,8%**	**16,8%**	**17,8%**	**18,8%**	**19,8%**
Cycle Duratio	**3**	4.392	3.952	3.585	3.274	3.009
	4	4.590	4.179	3.833	3.538	3.285
	5	4.819	4.338	**3.941**	3.608	3.327
	6	3.663	3.382	3.144	2.939	2.761
	7	3.384	3.119	2.896	2.704	2.539

Figure 5.12: EV Sensitivity to WACC and Crop-Cycle Duration

Figure 5.12 compares the effect on enterprise value of varying WACC (columns) and ratoon-cycle length (rows). A one-percentage-point change in WACC around the 17.8 % base shifts EV by roughly ±10 %. By contrast, modifying the crop cycle yields an asymmetric impact: shortening from 5 to 4 years reduces EV by only 2.8 % (to R$ 3.833 mm) and to 3 years by 9.9 % (R$ 3.585 mm), whereas extending the cycle to 6 or 7 years slashes EV by 25.3 % (R$ 3.144 mm) and 36.0 % (R$ 2.896 mm), respectively. Thus, while shorter cycles modestly erode value, lengthening the cycle inflicts a far larger decline than equivalent WACC movements.

Summary of Sensitivities Across all two-way tests, FX rate and WACC remain key drivers of EV. However, extended ratoon cycles present an even stronger downside risk than a 1 pp rise in WACC, whereas shortened cycles produce milder losses. Among commodity factors, sugar-price variation clearly outweighs ethanol-price swings-consistent with our higher β_{sugar} pass-through-making sugar the principal driver of cash-flow and valuation volatility. Agronomic cycle timing and resource availability exert important but secondary influence on enterprise value.

Chapter 6

Conclusions and Discussion

6.1 Summary of Key Findings

This thesis was set up to **build, calibrate and stress test an integrated financial model for a representative 300-ha sugar-energy farm in the center-south of Brazil**. By explicitly linking agronomic cycles (ratoon decline and replanting) to full financial statements and valuation logic, the model enabled multi-factor "what-if" simulations and an acquisition module not yet offered in the literature.

- **Yield-cycle economics**. With the calibrated decay constant $k = 0.145$, a *5-year rotation* (plant-cane + 4 ratoons) maximised NPV. Shorter cycles (4 years) preserved volumes but destroyed value through replant CAPEX, while longer cycles ($\geq$ 6 years) saved CAPEX yet lost more in revenue, confirming the agronomic rule-of-thumb that four to five harvests per planting are optimal for irrigated fields (Tables 5.1–5.4).
- **Cost and margin dynamics**. Under the base external outlook, net revenue fell in the yield trough (year 5) but rebounded sharply post-replant, driving gross margins from 22% back to 65% by 2034 (Fig. 5.6). Pesticide indexation and oil-linked inputs even amplified those swings.
- Management quality is as important as commodity conditions. Crossing three external scenarios with three management regimes shows that moving from "bad" to "good" practices increases EV from R$ 1.6 m to R$ 8.9 m in optimistic markets and turns a strongly negative EV (–R$ 1.8 m) into a modest positive one (+ R$ 3.0 m) even under pessimistic prices. Average net-margin spreads of 24 pp confirm the operational leverage of better agronomy and cost control.
- **Acquisition analysis-conditions for meeting the IRR hurdle**. The

dedicated module (Section 5.4) tested what an optimised farm could pay to acquire a poorly run neighbour while still clearing the *20.8 % equity IRR* minimum. Results show the bid ceiling ranges from R$ 7,102 m in a optimistic macro to R$ 234 m in an pessimistic one, with debt-service coverage achieving it's lowest at 0.5x, in the Pessimistic and Base Management scenario. Practically, an acquisition remains viable provided (i) we are in the Optimistic or Base Scenario; and (ii) that we acquire a Bad Management peer.

Collectively, these findings demonstrate that *agronomic excellence is a prerequisite for sustained value creation.* They also provide investors, producers and policy-makers with quantitative guard-rails for capital deployment and sectoral consolidation. Another important factor is opportunistic acquisitions, where you seek to find the bad management peer, at a better price (lower price) than in other cases of management.

6.2 Research questions and objectives

In our introduction, we brought up two fundamental questions regarding the resilience and valuation of a Brazilian sugarcane farm under varying agronomic and market conditions, which we will try and answer, with the results got:

6.2.1 RQ1: Under what combination of internal and external conditions can an optimized farm finance a baseline or worst-case farm?

Our acquisition analysis (5.4) evaluates, for each external environment (Optimistic, Base-Case, Pessimistic) and target-farm quality (Bad, Base), whether a good-management acquirer can (i) achieve a minimum 20.8 % levered IRR and (ii) maintain a debt-service coverage ratio (DSCR) of at least 1.0×. Key results (5.19) show that:

- **Optimistic external scenario:** Only poorly managed targets can be acquired at their full enterprise-value asking prices while exceeding the 20.8 % IRR hurdle and sustaining DSCR >= 1.0×. For example, acquiring a Bad-regime target valued at R$ 4.425 m yields a 24.2 % levered IRR with average DSCR = 3.7×
- **Base-Case scenario:** Only the poorly managed target meets all criteria when acquired below its base-management enterprise value. Acquiring a Base-regime peer at full mid-cycle ask actually respects the DSCR hurdle, but does not clear the IRR hurdle.

- **Pessimistic scenario:** Neither target can achieve a 20.8 % levered IRR under adverse market conditions, even with debt financing, and DSCR tests fail.

Thus, the boundary conditions for a viable acquisition are: (a) an Optimistic or Base market *combined* with a discounted (Bad-regime) target. This delivers practical guidance to investors on the pricing and timing of M&A in sugarcane, underscoring the value of buying low and enhancing operational performance post-deal.

6.2.2 RQ2: How do multi-variable scenarios affect key financial metrics (NPV, IRR, FCFF)?

Crossing three external scenarios with three internal management regimes yields nine "what-if" cases whose financial outcomes are summarized in the EV and Net-Margin matrices (Tables 5.14–5.15). The key takeaways are the following.

- **Internal drivers dominate variability:** While keeping the management scenario as Good, moving from Pessimistic to Optimistic markets shifts EV by up to +214 %, whereas internal improvements (Bad to Good management) change EV by +435% in the Optimistic Case. This internal impact is heavily due to the effects of changing the cycle duration, which brings significant changes to our Revenue, and consequently, to the Cash Flows and EV.

- **Management matters most mid-cycle:** Under Base-Case prices, upgrading from Bad to Good execution increases EV from 157K to 5,551 M and lifts average net margin from –10 % to +14 %.

- **Sensitivity confirms sugar price and FX as key risks:** Two-way sensitivities reveal enterprise value is most exposed to sugar-price shocks (±30 % EV swing) and FX movements (±13 %), while oil-price and water-stress effects are secondary (±14 %). Furthermore, increasing the project duration by 1 year can shift EV by -25 % and decreasing by the same amount can decrease EV by 3%, reflecting the compounding impact of additional ratoon cycles (with declining yields) or earlier replanting. This duration sensitivity underscores the strategic importance of planning cycle length and renewal timing alongside market hedges to manage downside risk.

These multi-variable analyses demonstrate the model's power to dissect both upside potential and downside risk, informing producers of which levers (price hedging, currency risk management, agronomic optimization) yield the greatest impact on returns and resilience.

Related to the questions just answered, objectives were also set to be achieved, so now we will review the four objectives defined in the Introduction and evaluate if each one was met by the work presented.

1. **Develop a flexible financial model for a typical mid-sized sugarcane plantation in Brazil (around 300 ha).** This objective was fully achieved through the creation of a modular spreadsheet model comprising an input layer (control panel for agronomic, operational, and market assumptions), a calculation layer (automated volume forecasts, cost–revenue breakdowns, and composite factor computations), and an output layer (dynamically linked financial statements and valuation metrics). The model architecture and inter-tab linkages are detailed in Section 3.2.1 and illustrated in 4.1, ensuring transparency, auditability, and real-time scenario updating .

2. **Explicitly include multiple ratoon cycles and replanting costs in cash-flow projections.** The model incorporates semi-perennial cultivation dynamics by applying a negative exponential yield-decline function, calibrated with decay constant $k = 0.145$ for irrigated fields, and by scheduling establishment costs after a user-defined number of ratoon cycles. This approach captures both declining yields across successive ratoons and the renewal expense upon replanting.

3. **Integrate agronomic, operational, and market variables into a unified scenario-analysis framework.** Achievement of this objective is evidenced by the construction of seven composite factors, four internal (ratoon decay, planting-date multipliers, pesticide adjustments, water availability) and three external (price elasticity, oil-cost indexing, currency exposure)-which are multiplicatively combined to simulate multi-driver scenarios. The resulting two-dimensional matrix (Optimistic, Base-Case, Pessimistic crossed with Good, Basic, Poor management) provides comprehensive stress-testing of profitability outcomes.

4. **Evaluate an optimized farm's capacity to finance or acquire a baseline or adverse-scenario farm.** The acquisition-analysis module computes the maximum bid price a Good-management farm can pay under each external scenario while satisfying target IRR and DSCR thresholds. 5.4 identifies the boundary conditions (market outlook and target quality) under which such acquisitions remain viable, delivering actionable benchmarks for investors and producers.

In summary, all four objectives were met. The model's modular design and explicit treatment of ratoon cycles establish a robust foundation; the unified scenario framework enables nuanced multi-variable analysis; and the acquisition module translates insights into clear financial benchmarks.

6.3 Contributions and Implications

This thesis advances both methodology and practice in the financial evaluation of perennial-crop operations. Its main contributions and their implications are as follows:

1. Methodological innovation through a modular, ratoon-aware model. We develop a fully modular spreadsheet model-comprising input, calculation and output layers-that explicitly captures semi-perennial ratoon cycles and scheduled replanting costs (Section 3.2–3.3). This architecture enhances transparency, auditability and ease of scenario updates, offering researchers a reusable framework for other perennial crops or geographies.

2. Integrated multi-driver scenario-analysis framework. By combining four (seven if you separate the pesticide factor in three) internal composite factors (ratoon decay, planting-date timing, pesticide use) with five external factors (sugar price, ethanol price, oil-cost indexing, FX exposure, water availability), we deliver a two-dimensional stress-test matrix across nine distinct management–market regimes. This unified approach permits clear decomposition of upside potential and downside risk, informing future research on compound-driver interactions.

3. Acquisition-analysis module for resilient deal-making. The bid-pricing tool (Section 4.3) computes the maximum price an optimized (Good-management) farm can pay for a peer under baseline or adverse conditions, subject to IRR and DSCR constraints. This yields practical "go/no-go" criteria for M&A in volatile commodity sectors, bridging academic valuation with real-world investment decision rules.

4. Quantification of key risk sensitivities. Two-way sensitivity analyses establish sugar-price swings, FX moves, oil-price and water-stress, and project-duration shifts as primary value drivers. This highlights the need for targeted hedging strategies and optimal crop-cycle planning to mitigate financial downside.

Implications for practice and policy:

- **For investors:** The acquisition benchmarks and risk-sensitivity results provide a structured due-diligence checklist-covering market outlook, execution quality and covenant thresholds-tailored to sugarcane M&A.
- **For producers:** Quantified returns on agronomic improvements and cycle-length decisions inform prioritization of capital investments (e.g., irrigation upgrades, optimized replant timing).

- **For policymakers:** Insights into the relative impact of water stress and input-cost inflation can guide subsidy design and resource-allocation policies to bolster sector resilience.

6.3.1 Environmental Impacts

A life-cycle assessment for Brazilian sugarcane ethanol production shows total fossil energy inputs of approximately 14 283.8 MJ ha^{-1} yr^{-1}, against an ethanol energy output of 151 008 MJ ha^{-1} yr^{-1}-an energy balance ratio of 10.57 : 1. Scaling to the 300 ha plantation yields annual fossil energy consumption of 4.285 TJ and renewable energy output of 45.302 TJ [61].

Total greenhouse gas emissions from the production stage average 2 360 kg CO_2-eq ha^{-1} yr^{-1}, with harvest emissions (pre-harvest burning) accounting for 44 % of the total and soil emissions (N_2O, CH_4) comprising 63 % of cultivation-phase impacts. For 300 ha, this equates to around 708 t CO_2-eq emitted annually. On the other hand, by substituting gasoline, sugarcane ethanol avoids roughly 14.3 t CO_2-eq per hectare per year-totaling around 4,288 t CO_2-eq avoided for the entire plantation each year[61].

These findings underscore that, while the 300 ha operation delivers a strong net energy yield and significant end-use emissions reductions, on-field practices such as pre-harvest burning and intensive nitrogen fertilization remain critical hotspots. Adoption of green-harvest techniques, precision nutrient management, and enhanced cogeneration can further lower the carbon footprint and improve the environmental sustainability of mid-sized sugarcane plantations.

6.4 Main Limitations

Despite its comprehensive scope, this study has several limitations that should be kept in mind when interpreting and generalizing the results:

- **Homogeneous farm context and scale sensitivity.** All calibrations assume a **300 ha irrigated plantation** as the representative unit. This choice reflects the empirical range of commercial operations in Brazil: as shown in detail before, most commercial farms fall broadly in the **200 to 500 ha** band, with Embrapa clusters showing cane areas $\approx$ 98 to 362 ha; larger units ($>$ 1,000 ha) exist and outliers $>$ 3,000 ha are reported but are not tha 'average' brazilian commercial sugar-cane farm. ORPLANA's $\sim$ 74 ha average pertains to a broader pool of independent suppliers and does not reflect larger commercial operations. The 300 ha anchor was therefore chosen as a mid-range proxy for financial modeling [30, 2, 36, 44].

This implies that results are *sensitive to area* through: (i) fixed-cost dilution (administration, machinery overhead), (ii) logistics and utilization (equipment scheduling, field distances), and (iii) commercial terms (bargaining power, service pricing). In contexts *smaller than* $\sim 200\,ha$, unit costs are likely higher and covenants harder to meet; in contexts *larger than* $\sim 500\,ha$, per-ton fixed costs likely fall while investment scale rises. While revenue and most variable costs scale roughly with area, **per-unit profitability does not**; hence conclusions should be read as **conditional on the 300 ha specification**. For representativeness, the most likely deviations lie within $\sim \pm 100$ to 200 ha around the base, whereas $> 1{,}000$ ha operations represent a different managerial/industrial paradigm.

- **Deterministic scenario framework.** The analysis uses three discrete external scenarios (Optimistic, Base, Pessimistic) crossed with internal regimes, but does not capture *probability distributions* for prices, climate, FX, or water stress; as such, *tail risks* remain unexplored.

- **Simplified financing structure.** Debt terms (rate, amortization, covenants) are static within each run; there is no refinancing, prepayment, or rate-path uncertainty. In practice, interest rates, credit spreads, and liquidity evolve; *refinancing risk* and *covenant headroom* matter for survivability.

- **Limited environmental integration** Although a standalone LCA (Life-Cycle Assessment) of sugarcane ethanol informs the environmental discussion, *carbon emissions and energy balances are not endogenous* to the cash-flow engine (e.g., no shadow carbon price, credit revenue, or emissions-linked capex/opex). With that, reported economics do not change if the carbon context changes, which is a recurring matter in out environmentally evolving context.

- **No real-options or dynamic replanting decisions.** Ratoon-cycle length is user-defined and fixed *ex ante*; the model does not endogenously *re-optimize replant timing* when yields, prices, or water conditions change. With that, the value of *managerial flexibility* (e.g., threshold rules "replant when marginal tonnage falls below X") is not captured.

6.5 Future Research Recommendations

To extend and deepen the analytical framework, future work could:

- **Extend to heterogeneous farm portfolios** Rather than a single "representative" 300 ha unit, future work should consider a *portfolio of farm archetypes* that mirrors the realities of Brazilian cane supply. Heterogeneity is not an edge case; most producers manage a mosaic of fields with different soils, water regimes, distances, and operational constraints. The economic consequences are material: average productivity, volatility, and financing resilience can look very different once the portfolio mix is made explicit.

- *Rain-fed vs. irrigated (widespread).* Irrigation tends to lift average yields and dampen downside volatility, but it also introduces capital and water-security risks (energy for pumping, legal/seasonal restrictions, drought curtailments). Rain-fed fields carry greater weather sensitivity; dry spells can compress throughput and weaken DSCR precisely when prices or costs may be unfavorable.
- *Soil classes and water-holding capacity (ubiquitous, often decisive).* Sandy or shallow soils can drive faster productivity decay and shorter profitable ratoon series, while deep, well-structured soils support more stable yields and lower input intensity per ton. Soil constraints also interact with mechanization losses and compaction risk, affecting both cost and recovery over time.
- *Distance to mill and road quality (common, economically material).* Longer hauls raise t-km costs and cut-to-crush times, which can erode ATR and strain harvest scheduling near mill capacity. Wet-season road degradation adds operational fragility: small logistics shocks can spill into lower annual volumes and tighter covenant headroom.
- *Topography and field layout (regional, non-rare).* Slope and fragmentation reduce effective machine speeds, raise fuel and maintenance, and increase harvest losses. In steeper or highly fragmented areas, the same nominal hectares can produce meaningfully different margins and risk profiles.
- *Farm size and fragmentation (prevalent).* Larger units benefit from fixed-cost dilution and stronger bargaining power, but also face coordination and downtime risks if layout is dispersed. Smaller or fragmented suppliers may bear higher unit costs and more volatile cash flows, affecting credit capacity and investment timing.
- *Varietal mix, maturity windows, and ATR (management-driven, common).* Cultivar choices and maturation scheduling can smooth supply and reduce exposure to weather risks-or amplify them if mismatched. Differences in ATR and ratoon longevity cascade into revenue consistency and the economics of replanting.
- *Pest and disease pressure; rotation history (episodic but not rare over multi-year horizons).* Outbreaks can create localized yield shocks and spike

OPEX (controls, rework), with lingering effects on subsequent ratoons and replant timing.

– *Water rights, inputs, and labor markets (regional heterogeneity, non-rare).* Variation in water availability, seasonal labor, and input prices (diesel, fertilizer, custom services) drives dispersion in costs and operational reliability across otherwise similar hectares.

Why this matters. A heterogeneous-portfolio lens will typically show fatter downside tails and different "weak links" than a single-farm analysis. It helps identify where value is created (e.g., good soils near the mill) and where risk concentrates (e.g., rain-fed sandy fields far from the mill), guiding targeted interventions in irrigation, soil improvement, logistics, and varietal planning rather than one-size-fits-all policies.

- **Incorporate stochastic programming or Monte Carlo simulation** Replace discrete scenarios with probability distributions for key drivers (sugar/ethanol prices, rainfall/water stress, FX). Draw *correlated* paths and report P10/P50/P90 for NPV/IRR, VaR/CVaR for equity returns, and the *probability of DSCR breach* by year. Practically, begin with calibrated distributions (e.g., mean-reverting price, rainfall anomalies) and a rank-correlation matrix; 5–10k runs usually stabilize tail estimates.

- **Integrate real-options analysis** Allow *endogenous timing* of replanting/expansion via trigger rules (e.g., "replant when marginal tonnage $<$ threshold" or "defer if price $< X$ and soil moisture $< Y$"). A binomial/trinomial price tree with a Markov yield state (wet/normal/dry) can quantify the *option value of waiting vs. acting*, turning fixed cycles into adaptive policies under uncertainty.

- **Embed environmental economics** Link the LCA layer to cash flows by adding *shadow prices* or credits for carbon and *charges for water use*, plus optional revenue from *energy co-generation* (bagasse) and penalties for high-emission practices. Then present *NPV sensitivity to carbon/water prices* and a *social-NPV* alongside private NPV, aligning sustainability with finance.

- **Model dynamic financing** Let interest rates and credit spreads *evolve stochastically*; include *refinancing/rollover risk* and *covenant headroom dynamics*. Report *DSCR distributions*, *time-to-breach curves*, and *expected recapitalization needs* under stress to test robustness beyond point assumptions.

- **Apply machine-learning techniques,** for dynamic calibration of agronomic parameters (e.g. decay constant k) using historical yield and weather datasets.

6.6 Final Concluding Remarks

This thesis has presented a novel, modular financial model tailored to the semi-perennial nature of sugarcane cultivation in Brazil, integrating agronomic, operational, and market drivers into a cohesive scenario-analysis framework. By explicitly modeling ratoon cycles, replanting costs, and composite risk factors, the work delivers both theoretical insights and practical tools for investment decision-making in a volatile commodity environment.

Key outcomes include:

- A transparent, auditable model architecture that supports real-time "what-if" analysis across nine management–market scenarios.
- An acquisition module that translates optimal-management performance into clear bid-price benchmarks under varying external outlooks, informing disciplined M&A strategies.
- Identification of the most sensitive value drivers-sugar-price volatility, currency movements, and project duration-guiding targeted hedging and crop-cycle planning.

By bridging detailed agronomic decay functions with rigorous financial metrics (NPV, IRR, DSCR, EV), this thesis provides a replicable blueprint for analyzing semi-perennial crop investments. The insights gained resonate beyond sugarcane, offering a template for other bioenergy and semi-perennial agriculture contexts.

As global agricultural systems confront climate variability and market uncertainty, tools that marry agronomy with finance become ever more valuable. It is my hope that the model and findings here will aid stakeholders-producers, investors, and policymakers, in crafting resilient, sustainable, and profitable strategies for the next generation of bioenergy and crop-production enterprises.

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