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Impact of yield forecast on the fair value of sugarcane

Impacto da previsão de produtividade no valor justo da cana-de-açúcar

Impacto de la previsión de productividad en el valor razonable de la caña de azúcar

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Abstract
The aim is to identify the impact of yield forecast on measuring sugarcane at fair value. Previous research identifies a certain subjectivity related to the fair value of biological assets without an active market, which is the case with sugarcane. Therefore, this study focused on alternatives to determine sugarcane yield following a quantitative and descriptive approach. The sample is from a plant in the state of São Paulo with 12 farms analyzed using the Wilcoxon test, comparing the fair value according to real data with: i) fair value with historical data; ii) fair value with agrometeorological model. The results demonstrate that the fair value with historical data is close to that of actual data in half of the harvest years, while the agrometeorological model did not show proximity to the fair value of real data, despite being useful when calculating the ton of sugarcane and the cost.
Keywords: Biological Assets; Fair Value; Productivity; Discounted Cash Flow; Sugarcane

Resumo
O objetivo é identificar o impacto da previsão de produtividade na mensuração da cana a valor justo. Pesquisas anteriores identificam certa subjetividade relacionada ao valor justo dos ativos biológicos sem mercado ativo, o que é o caso da cana-de-açúcar. Então, esse estudo teve enfoque em alternativas para determinar a produtividade da cana-de-açúcar seguindo abordagem quantitativa e descritiva. A amostra é de uma usina do estado de São Paulo com 12 fazendas analisadas através do teste de Wilcoxon, comparando o valor justo segundo dados reais com: i) valor justo com dados históricos; ii) valor justo com modelo agrometeorológico. Os resultados demonstram que o valor justo com dados históricos é aproximado ao de dados efetivos em metade dos anos-safras, enquanto o modelo agrometeorológico não apresentou proximidade ao valor justo de dados reais, apesar de ser útil ao calcular a tonelada de cana e o custo.
Palavras-chave: Ativos Biológicos; Valor justo; Produtividade; Fluxo de Caixa Descontado; Cana-de-Açúcar

Resumen
El objetivo es identificar el impacto de las proyecciones de productividad en la medición de la caña de azúcar a valor razonable. Investigaciones anteriores identifican cierta subjetividad relacionada con el valor razonable de los activos biológicos sin un mercado activo, como es el caso de la caña de azúcar. Por lo tanto, este estudio se centró en alternativas para determinar la productividad de la caña de azúcar siguiendo

un enfoque cuantitativo y descriptivo. La muestra proviene de una planta en el estado de São Paulo con 12 fincas analizadas mediante la prueba de Wilcoxon, comparando el valor razonable según datos reales con: i) valor razonable con datos históricos; ii) valor razonable con modelo agrometeorológico. Los resultados demuestran que el valor razonable con datos históricos se acerca al de datos reales en la mitad de los años de cosecha, mientras que el modelo agrometeorológico no mostró proximidad al valor razonable de datos reales, a pesar de ser útil a la hora de calcular la tonelada de caña de azúcar y el costo.
Palabras clave: Activos Biológicos; Valor razonable; Productividad; Flujo de Caja Descontado; Caña de Azúcar

1 Introduction

In 2009, in the accounting field, agribusiness was affected by the implementation of CPC 29 - Biological Assets and Agricultural Product, which is internationally known as *IAS 41 - Agriculture*. Thus, there was a change in the process of measuring biological assets. In the period prior to implementation of the standard, these assets were measured based on historical costs (Hadiyanto et al., 2018; Silva Filho et al., 2013), but currently *IFRS 13 – Fair Value Measurement* suggests the use of a fair value for this purpose. This scenario generated an academic discussion regarding which measurement method would be best according to the relevance of the information to users (Argilés et al., 2011; Huffman, 2018; Gonçalves et al., 2017; Hadyianto et al., 2018; Wukich, 2019; Silva Filho et al., 2013; Martins et al., 2014).

One of the recurring concerns in research is the use of fair value when there is no active market because it can be difficult to measure biological assets (Machado et al., 2014; Santos et al., 2015). This scenario often occurs because biological assets are measured via discounted cash flows (Figueira & Ribeiro, 2016; Moura et al., 2024; Santos et al., 2015; Santos & Silva, 2018). That is, biological asset estimates are subjective, depending on the judgement of the managers regarding the assumptions used, and this process generates uncertainty in their measurement (Bohusova & Svoboda, 2017; Morozova et al., 2019; Martins et al., 2014; Silva et al., 2022), which may indicate unreliable accounting information (Eilifsen et al., 2020; Machado et al., 2014; Cretu et al., 2014).

These changes in accounting standards significantly impact Brazil, given that agribusiness is crucial to the Brazilian economy, employing approximately 21% of Brazilians (CEPEA[i], 2020a), creating the most jobs in 2020 (CNA[ii], 2020), and accounting for 20.9% of the national GDP (CEPEA, 2020b). In 2019, it is noteworthy that among primary crops, 51% of global production is divided among sugarcane, corn, wheat, and rice (FAO, 2021), with sugarcane holding the largest share at 21% of this total, while the remaining 30% is split among corn, rice, wheat, potatoes, soybeans, and others.

In the sugarcane industry, there are some studies on biological assets and their fair values (Rabassi et al., 2020; Silva et al., 2022; Cavalheiro, Gimenes, Binotto & Fietz, 2019; Moura et al., 2024). However, only Silva et al. (2022) and Cavalheiro, Gimenes, Binotto and Fietz (2019) have addressed the process of constructing the discounted cash flow of developing sugarcane and not its measured result. Silva et al. (2022) focused on a fictitious company to identify the divergences that originated due to the uncertainty inherent to the estimates. Cavalheiro, Gimenes, Binotto and Fietz (2019) investigated the use of the model developed by Doorenbos and Kassam (1979) to crop yield prediction, noting that agrometeorological models can be useful for evaluating assets more effectively.

Based on this scenario, there is still room for discussion about evaluating standing sugarcane, mainly related to the information used to measure this asset since its assumptions must be defined with caution to decrease the level of uncertainty, which may affect the relevance of the accounting information (Conceptual Framework for Financial Reporting). Factors such as price, future productivity, and discount rate can significantly influence discounted cash flow and are defined subjectively, which may impact the discounted cash flow calculation and generate distortions in fair value (Rech & Pereira, 2012; Silva et al., 2022). Thus, this study aims to identify the impact of yield forecast on determining the fair value of standing sugarcane using real data from a plant located in the interior of São Paulo.

This research is different because it applies a process-based model, based on Marin (2014), to observe direct impacts on fair value. This model relies on more variables to crop yield prediction than Doorenbos and Kassam (1979) used by Cavalheiro, Gimenes, Binotto and Fietz (2019), demonstrating to be more robust and recent. In addition, a new perspective is used to identify how the practice of using historical data can affect calculating plant biological assets, which has not yet been addressed by previous studies. By comparatively analysing yield data with harvest data from the field, it is possible to identify the likely divergences in the data and their impacts on fair value for a real company and determine the estimate that provides more significant results through the rank comparison test (Wilcoxon).

The contribution of this research to the literature is its discussion of sugarcane yield in estimating fair value through different approaches, showing regulatory agents how the comprehensiveness of standards can affect the calculation of fair value. The individual analysis allowed a deeper understanding of the subjectivity intrinsic to measuring sugarcane. In addition, the findings reflect how the current models for evaluating sugarcane in development are used by sugarcane mills based on which sources of information may be more useful in the measurement process. Furthermore, this research contributes to expanding fair value studies in the sugar-energy sector, an important sector in the national and international scenario, for which there is a lack of research in relation to fair value. Finally, the results highlight the actual scenario of a single biological asset, considering its market specificities, which can be useful for the producers that need accounting information in the sugar-alcohol sector.

2 Theoretical framework

2.1 Studies on biological assets

There is a debate in the literature regarding which method of measuring biological assets is most relevant to the external user: the fair value method or historical cost method (Argilés et al., 2011; Wukich, 2019; Silva et al., 2013; Hadiyanto et al., 2018; Huffman, 2018; Argilés-Bosch et al., 2018; Silva Filho et al., 2013; Martins et al., 2014). This debate is justified by the change outlined in the IFRS 13 standard, which strongly recommends using fair value for the valuation of biological assets when fair value can be measured reliably.

While advocates of the historical cost method argue that its application is associated with reliability and objectivity, its negative aspect is linked to its low relevance for users of accounting information. On the other hand, the fair value method stands out for its relevance, representing the timelier biological transformation of the asset. However, this method has been criticized due to its inherent subjectivity and lack of reliability in measuring fair value without an active market, in addition to its complexity, with some stating that fair value can be very academic and impractical (Wukich, 2019; Herbohn & Herbohn, 2006; Rech & Pereira, 2012; Jana & Marta, 2014).

Argilés et al. (2011) argued that measuring biological assets in agriculture based on fair value rather than historical cost results in greater predictive power of future gains, noting that the historical cost has the main barrier to calculating biological assets with precision and reliability on the small farms studied. In contrast, He et al. (2021) determined that the fair value of biological assets does not increase the forecast of future operating cash flows and that this effect remains independent of the level of the fair value hierarchy.

Silva Filho et al. (2013) found that fair value is more relevant than historical cost in valuing biological assets since fair value provides more relevant information to adjust the stock price. Martins et al. (2014) also confirmed that short and long-term biological assets are relevant but can be measured with certain conservatism when compared to the market. However, the authors added that there is reliability in fair value measurements.

Regarding the positive attributes of using the fair value of biological assets, Gonçalves et al. (2017) stated that fair value is relevant; however, relevance is greater when there is a higher level of disclosure. Nonetheless, they also found that in comparison to carrier biological assets, consumable biological assets do not have greater relevance with greater disclosure. The authors argued that this scenario can be justified because the prices of biological assets are usually available in the market, thus failing to signal what the situation of the biological assets would be without an active market.

Huffman (2018) evaluated which measurement method is most relevant considering consumable and carrier biological assets. The results showed that the consumable biological assets measured based on fair value and the carrier biological assets measured based on historical cost are relevant to investors and creditors, influencing the prediction of the future performance of companies. It is notable that sugarcane that is in development is characterized as a consumable biological asset, which would indicate its greater relevance when determined by the fair value method. This study also supports the Review of Technical Pronouncements 08, which changed the accounting classification of plants to fixed assets, which were then measured at historical cost.

2.2 Studies of the sugarcane industry

Rabassi et al. (2020) compared statements with and without a fair value effect, and through a case study of a sugarcane company, they demonstrated that the economic and financial performance indicators of organizations are affected by the fair value of sugarcane, showing that this accounting information can impact the decision-making process of agroindustrial organization managers.

Regarding disclosure, Moura et al. (2024) investigated the process of measuring and disclosing information on sugarcane at 13 plants and identified differences in the measurements and assumptions disclosed by them. This information can affect the comparability and thus the comparison process between the plants, making it difficult for investors to evaluate them.

On the other hand, Silva et al. (2022) demonstrated through a hypothetical sugarcane mill that fair value is uncertain and subjective, which can generate distortions in financial statements. It is expected that the *inputs* from internal and external sources of a company can be determined effectively such that a fair value compatible with reality can be measured, providing investors information on the state of the biological assets of the company.

An evaluation of sugarcane at fair value according to an interdisciplinary methodology, considering agronomic, economic and accounting elements, showed that it is possible to measure biological assets with greater reliability, despite the complexity of the methodology. Cavalheiro, Gimenes, Binotto and Fietz (2019) conducted a study by considering data from a family-run sugarcane agroindustry using the agrometeorological model. In addition, an agronomic variable that calculates the sugarcane yield as a function of the model by Doorenbos and Kassam (1979), which estimates production according to the water stress of the plant, was presented.

In another context, Lento et al. (2018) investigated the reduction of uncertainty in the fair value estimation of a salmon farm based on its salmon productivity. The authors found that while market prices are easily identified, salmon productivity remains uncertain. This uncertainty arises because measuring salmon biomass is prohibited by regulatory restrictions. Therefore, they developed a statistical regression model to estimate productivity using data on fish feed consumption, water temperature, water quality, and mortality rates.

2.3 Presentation of the research hypotheses

In 2009, CPC 29 - Biological Assets and Agricultural Products was published, corresponding to *IAS 41 - Agriculture*. Thus, organizations began to adopt the fair value method more frequently to adapt accounting guidelines (Figueira & Ribeiro, 2016). The fair value method allows the visualization of living animal and plant biological transformations since this method can reflect the growth, degeneration, procreation and production processes of agricultural products in financial statements (IAS 41). By definition, fair value is the market value of an asset or liability that is determined by market participants in a transaction not forced under current market conditions (IFRS 13).

Companies can use various techniques to measure fair value, depending on the production stage of the plantation in question and the type of biological asset (Figueira & Ribeiro, 2016; Bohusová et al., 2012; Silva & Santos, 2018). However, the constant use of the revenue approach technique has been highlighted, using cash flow to measure the assets (Camargo et al., 2019; Silva et al., 2015; Santos et al., 2015; Santos & Silva, 2018) and this approach is also used to evaluate sugarcane crops in their development phase (Moura et al., 2024; Cavalheiro, Gimenes & Binotto,2019).

Consequently, there are some data that are estimated to value an asset at this stage, and this process involves a certain subjectivity, such as that related to future price, rate of return and future productivity (Morozova et al., 2019; Eilifsen et al., 2020; Machado et al., 2014), making investors suspicious of its results and decreasing its reliability (Rech & Pereira, 2012; Eilifsen et al., 2020; Herbohn & Herbohn, 2006).

Depending on the judgement of the accounting information manager, calculating these important variables to the model can be influenced by bias or imprecision (Silva et al., 2022; Eilifsen et al., 2020; Herbohn & Herbohn, 2006), which can generate distorted accounting information (Silva et al., 2022). This distortion is due to the use of estimates, and productivity is one of the critical factors in determining the fair value of biological assets (Cavalheiro, Gimenes, Binotto & Fietz, 2019; Rech & Pereira, 2012; Silva et al., 2022; Morozova et al., 2019; Bohusová et al., 2012). Additionally, the lack of experience among professionals in the evaluation process can impact measurement (Biljon & Wingard, 2020; Cavalheiro, Gimenes & Binotto, 2019) and may require professionals from technical fields related to crops to effectively signal potential biological transformation (Machado et al., 2014).

Cavalheiro, Gimenes and Binotto (2019) state that it is common practice to estimate yield according to the averages of previous harvests, ignoring the climatic effects that can affect sugarcane cultivation. Moreover, it is necessary to note that crops experience climatic effects, directly impacting productivity, that is, the quality and yield of biological assets that are subject to biological transformation. Furthermore, crops also face risk of diseases that can affect the biological transformation of assets (Morozova et al., 2019). Herbohn and Herbohn (2006) add that the volatility of biological asset fair value can be influenced by meteorological and biological conditions, such as rain, hail, pests and disease effects.

Thus, there is concern about the adequacy of using historical data to estimate future sugarcane yield since the main limitation of this method is that it does not consider climatic effects and specific plant factors that may contribute to the increase/decrease in sugarcane productivity; this limitation generates additional uncertainty about productivity, which may be different from the actual scenario (Cavalheiro, Gimenes & Binotto, 2019; Rech & Pereira, 2012), thus affecting the fair value (Silva et al., 2022). Thus, the first research hypothesis is formed:

H1: The fair value of sugarcane yield based on historical data differs significantly from the fair value of sugarcane using actual yield.

Research in agronomy has evolved over time, leading to the development of systems that detect these conditions and assist in prediction and control related to soil, plant, and atmospheric conditions in which the plant is located (Vianna et al., 2017). Thus, crop yield depends on agronomic and environmental factors, and understanding the interaction between these factors is necessary to create more efficient crop prediction models (Ferraro et al., 2009). In this context, process-based crop models, broadly referred to in this work as agrometeorological models of plant production, seek to represent plant development through equations and programming code based on soil and climatic factors, enabling future predictions (Marin, 2014; Pilau & Marin, 2019).

The information from these models could contribute to calculating fair value to address the effects of uncertainty linked to the determination of this *input.* This scenario has already been observed by Cavalheiro, Gimenes, Binotto and Fietz (2019) in a study in which a sugarcane evaluation was performed using the agrometeorological model of Doorenbos and Kassam (1979). This model is from 1979 and reflects sugarcane yield considering that "... water deficits in the plantations and the resulting water stress on the plant have an effect on crop evapotranspiration and crop yield" (Doorenbos and Kassam, 1979, p. 10).

Considering that this model is restricted to the variable water stress, it may not capture all the effects that may interfere with productivity. The agrometeorological model SAMUCA is a more recent and more complex alternative that captures the effect of other variables for crop yield forecasting (Marin, 2014; Marin & Jones, 2014; Marin et al. 2017; Vianna et al., 2020). Figure 1 highlights the indicators used to simulate the development of a plant in Marin (2014).

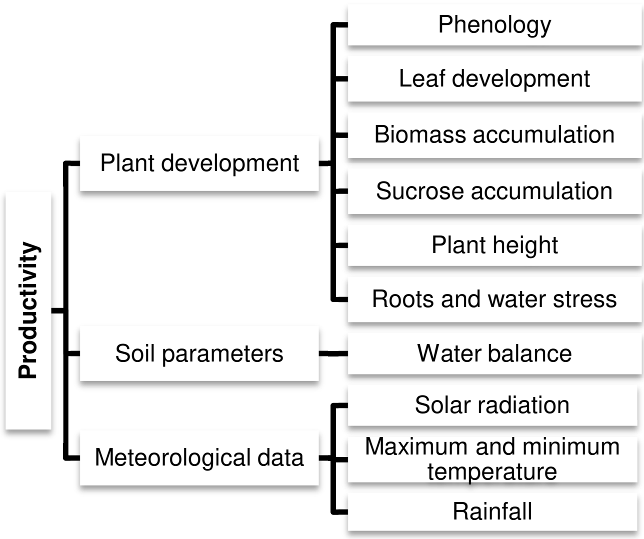

Figure 1. Indicators of the SAMUCA agrometeorological model
Source: Marin (2014).

The model proposed by Marin (2014) differs from other models in its use of data on climate, soil and agricultural management, providing elements that allow the prediction of sugarcane productivity with greater accuracy and reliability. This model focuses on biophysical processes, using algorithms that calculate the sugarcane yield through a series of data that influence the crop: phenology, plant development, photosynthesis, biomass and sucrose accumulation, plant extension, water stress and soil water.

Moreover, this model considers information related to the soil and climate of the region where the biological asset is planted so that it can adequately estimate the growth and production of sugarcane. In addition, it uses a deterministic approach for sugarcane, analysing variables to define future productivity (Marin, 2014). Thus, it is suggested that by measuring the effects of weather conditions and their impacts on sugarcane productivity, it is possible to provide more reliable information to determine fair value with greater accuracy. That said, the second research hypothesis was established:

H2: The fair value of sugarcane using yield based on the SAMUCA agrometeorological model is significantly close to the fair value using actual yield.

3 Methodology

This research is classified as quantitative because it estimated numerical parameters, tested hypotheses using statistical analyses to draw conclusions (Ghauri et al., 2020). It fits into a descriptive research category, as it describes the behavior of phenomena in order to extract information and details about a problem or issue (Collis & Hussey, 2005). For this study, information was used from 12 farms of a plant in the interior of São Paulo from 2002 to 2007. The sample was selected based on convenience since the plant was selected for ease of access by the researcher (Fávero & Belfiore, 2017). Table 1 shows a summary of the data on the plant sample and its treatment.

Table 1
Data on the plant in the interior of São Paulo

Total number of farms	**645**
(-) Farms with incomplete plots (do not have information from 2002 to 2007)	(629)
(-) Farm with plots with significantly different areas	(3)
(-) Farm with missing crop yield information	(1)
(=) Final sample	**12**

The sample was divided into plots (indicative of specific area), and information on area, cutting stage, harvest year and month, tons of sugarcane per hectare, and total recoverable sugar was documented. Information on actual crop yield data determined based on historical data and simulation are detailed below:

i) **Cash flow with actual sugarcane yield:** actual crop yield, that is, the actual data of the harvested yield evaluated by the agricultural sector.

ii) **Cash flow with sugarcane yield determined by historical data:** the calculation was estimated according to the previous harvests, averaging these values to define the total recoverable sugar (TRS), ton of sugarcane per hectare (TSH), and ton of total sugarcane (TS) of the farms according to their plot. Table 2 represents the crop years used for the yield calculations, considering the availability of the data to estimate sugarcane yield.

Table 2
Methodology for calculating the historical data scenario

Yields	Calculation Methodology
2004/2005	Average of the 2 previous harvests
2005/2006	Average of the 3 previous harvests
2006/2007	Average of the 4 previous harvests
2007/2008	Average of the 5 previous harvests

iii) **Cash flow with sugarcane yield determined by simulation:** the productivity data were estimated using the SAMUCA agrometeorological model by Marin (2014).

Thus, according to data availability, the measurement dates of biological assets were determined as 03/31/2004, 03/31/2005, 03/31/2006, and 03/31/2007, which were the harvest completion dates each year. The sources of information were the same for the cash flows, so it was calculated 12 cash flows for 12 farms, totalizing 144 observations. The *inputs* were extracted considering the Brazilian market of São Paulo.

The cost was extracted by Agrianual (2005, 2006, 2007, 2008), which is the Brazilian Agriculture Yearbook, where the cost of sugarcane production in the state of São Paulo and information on other crops were obtained. For the calculation of the WACC, data from 2010 were used from private balance sheets to determine the cost of debt and the percentage of the capital of third parties and owned companies without short liabilities, assuming that the plant has a good financial standing and does not depend excessively on the capital of third parties. The risk and the price were obtained from Lima, Neto, Silva and Gastios (2020) considering information available from 11/2010 to 10/2019. Finally, the price was obtained from the CONSECANA (Council of Sugarcane, Sugar and Ethanol Producers of the State of São Paulo) with reference to the month and year of harvest (Elaborated by UDOP[iii] 2021).

3.1 Construction of cash flow

Table 3 shows the step-by-step process for preparing the cash flow, according to the guidelines of the Ibape[iv] (2019) booklet. Thus, the normality of the information was tested using the Shapiro-Francia test, according to the sample size. However, because most of the pairs of the compared groups did not have a normal distribution, the nonparametric Wilcoxon test was used (Fávero & Belfiore, 2017). This test is used to test differences between combined pairs of data, considering the ranks of the sample data (Triola, 2008). Thus, the TRS, TSH, TS, revenue, cost, and fair value were compared based on the productivity estimate calculations to identify whether there was a significant difference in the calculations when the source of information for the sugarcane yield estimate was varied.

Table 3
Step-by-step calculation of the biological assets

Calculation step	Equation
Revenue	$[(TSH \times Area \times TRS) * (Price)]$
Cost	$\left(\frac{Total\ Cost}{Mean\ productivity}\right) \times Tons\ of\ sugarcane$
Depreciation of the carrier plant	$\frac{Formation\ cost}{Useful\ life}$
Contributory Asset Charge (CAC)	$\left\{\left(Depreciation \times Depreciation\ factor\right) \times Annual\ return\ rate\right\} + \left\{\left(Depreciation \times Depreciation\ factor\right) \times (1 - \%(IR\ and\ CSLL)\right\}$
Tax benefit	$\left[Sugarcane\ field\ distribution/(1 + Discount\ rate)^{6/12}\right] \times Income\ tax\ rate\ and\ Social\ Contribution\ on\ Net\ Income$

Calculation step	Equation
Tax benefit calculation factor	$\left[\frac{1}{(1 - tax\ benefit)}\right] - 1$
Tax Amortization Benefit (TAB)	$Current\ value\ of\ Registration\ Data\ Sheet * Tax\ benefit\ calculation\ factor$
Value of biological assets	$Revenue - Cost - Income\ tax\ and\ Social\ Contribution\ on\ Net\ Income - CAC + TAB$

Source: Adapted from Ibape (2019).

4 Presentation and discussion of results

According to the yield estimates for the historical and simulated data, it is possible to compare their results with the actual scenario. The descriptive statistics of the measurements of the 12 farms are shown below in Table 4.

Table 4
Descriptive statistics

		Actual		Historical Data		Simulated	
Data	**Obs.**	**Avg.**	**SD**	**Avg.**	**SD**	**Avg.**	**SD**
TRS	176	147.38	12.77	146.49	6.91	125.04	9.86
TSH	176	78.92	15.55	90.29	14.15	79.96	17.33
TS	176	817.74	537.53	928.51	598.73	846.95	610.75
Revenue	176	31,944.5	21,810.5	36,484.6	25,025.8	28,987.42	24,055.57
Cost	176	17,862.74	11,948.8	20,303.2	13,436.2	18,579.2	14,002.24
Fair value	176	10,445.51	9,380.31	12,258.9	10,961.8	7,265.2	9,429.9

Note: TRS is total recoverable sugar, TSH is tons of sugarcane per hectare, TS is tons of sugarcane, and fair value corresponds to the measurement of the biological assets.

According to the data presented, it was possible to demonstrate that in comparison to those measured using historical data, the mean TSH and TS of the sample measured using simulated data were closer to the actual value of the harvested sugarcane. The mean TRS measured using historical data was closer to the actual value in comparison to that measured using simulated data. Both measures are important in measuring fair value because while the TS directly impacts the cost, the TRS and the TS affect the revenue. It is important to note that sugarcane can be priced according to the value of the TRS in kilograms, information that is disclosed by the sugarcane mills (Moura et al., 2024), a factor that signals the quality of the sugarcane (CNA, 2007).

The simulated TRS was on average R$ 22.34 below the actual value, which indicates that the revenue may have been underestimated, as seen from the average revenue (R$ 28,987.42 via the simulated data versus R$ 31,944.50 via the actual data). On the other hand, the estimated costs were closer to the costs estimated through actual productivity, highlighting the possible impacts of TSH and TS when compared with those obtained using historical data. Despite this result, the historical data still showed a more approximate mean with respect to the fair value of the biological asset. Additionally, the standard deviations of TS, revenue, cost, and fair value calculated with historical data were higher than those calculated with other productivity measures. This results was likely due to the difference in the areas of the plots (ranging from 1.91 ha to 32.34 ha), showing the diversity of the sample.

The Shapiro-Francia test was performed to test whether the data had a normal distribution. The results of the tests are shown in Table 5.

Table 5
Normality test

Harvest year	Data	Estimate with actual yield	Estimate with yield based on historical data	Estimate with yield based on simulated productivity
		p value	p value	p value
2004/2005	TRS	0.030	0.057	0.001
	TSH	0.244	0.092	0.014
	TS	0.000	0.000	0.000
	Revenue	0.000	0.000	0.000
	Cost	0.000	0.000	0.000
	Fair value	0.000	0.000	0.001

Harvest year	**Data**	**Estimate with actual yield**	**Estimate with yield based on historical data**	**Estimate with yield based on simulated productivity**
		p value	p value	p value
2005/2006	TRS	0.668	0.104	0.013
	TSH	0.154	0.173	0.051
	TS	0.000	0.000	0.000
	Revenue	0.000	0.000	0.000
	Cost	0.000	0.000	0.000
	Fair value	0.000	0.000	0.000
2006/2007	TRS	0.627	0.099	0.014
	TSH	0.598	0.255	0.003
	TS	0.000	0.000	0.000
	Revenue	0.000	0.000	0.000
	Cost	0.000	0.000	0.000
	Fair value	0.000	0.000	0.000
2007/2008	TRS	0.582	0.239	0.042
	TSH	0.279	0.388	0.678
	TS	0.001	0.000	0.000
	Revenue	0.000	0.000	0.000
	Cost	0.000	0.000	0.000
	Fair value	0.005	0.000	0.000

Note: AH_0 of the Shapiro-Francia test indicates that the data follow a normal distribution. A p value below or equal to 0.05 rejects the H0, while a p value greater than 0.05 accepts the H0.

According to the information presented, 76.39% of the data did not have a normal distribution. Thus, the Wilcoxon test was used to compare the samples, and this test does not require the assumption of normality (Fávero & Belfiore, 2017). This test considers whether the sample has paired data or paired samples, as it is applied to the same sample with different treatments. Notably, the data calculated using historical data estimates were compared using the Wilcoxon test with the actual data of the harvested yields, as shown in Table 6.

Table 6

Comparison of calculations with historical and actual data

		Yield forecast			**Accounting calculations**		
Harvest	Description	Total recoverable sugar	Tons of sugarcane per hectare	Tons of sugarcane	Revenue	Cost	Fair value
		(n=44)	(n=44)	(n=44)	(n=44)	(n=44)	(n=44)
2004/2005	Statistics	2.182	-3.729	-3.408	-2.042	-3.326	-1.015
	p value	0.0291	0.0002	0.0007	0.0411	0.0009	0.31
	Conclusion	μ μ different	μ μ different	μ μ different	μ μ different	μ μ different	$\mu_{1/2}$ equal
2005/2006	Statistics	-1.039	-3.443	-3.198	-2.661	-3.174	-2.813
	p value	0.2990	0.0006	0.0014	0.0078	0.0015	0.0049
	Conclusion	$\mu_{1/2}$ equal	μ μ different	μ μ different	μ μ different	μ μ different	μ μ different
2006/2007	Statistics	2.801	-5.777	-5.777	-5.765	-5.777	-5.765
	p value	0.0051	0.000	0.000	0.000	0.000	0.000
	Conclusion	μ μ different	μ μ different	μ μ different	μ μ different	μ μ different	μ μ different
2007/2008	Statistics	-0.082	-2.486	-2.159	-1.377	-2.276	-1.26
	p value	0.9349	0.0129	0.0309	0.1685	0.0229	0.2075
	Conclusion	$\mu_{1/2}$ equal	μ μ different	μ μ different	$\mu_{1/2}$ equal	μ μ different	$\mu_{1/2}$ equal

Note: The H0 of the Wilcoxon test is as follows: there are no differences between the two samples.

The results show that the historical data were significant in relation to the TRS in the two harvests, noting that there were no differences between the samples based on historical data and actual data in these harvests. However, when evaluating the TSH and TS, the samples were different in all crop years, this finding corroborates the research of Cavalheiro, Gimenes and Binotto (2019), which criticizes the indifference towards seasonality and plant-specific factors in historical data. These sugarcane yield estimates affect the calculation of revenue, cost, and fair value, as shown in Table 3. That is, when identifying differences between the actual and estimated productivity based on historical data in crop years, there may be a difference in the calculated book values.

For example, revenue showed significantly different results in the three crop years. On the other hand, the cost values were significantly different when calculated with historical and actual data in all harvests. Despite these indicators and the limitation in identifying weather, soil, and biological conditions of the model, which are important for determining fair value (Morozova et al., 2019; Herbohn & Herbohn, 2006), the fair value was significant in half of the crop years, indicating that in 50% of the period, the calculations can be considered from similar samples (sample of historical data and actual data).

Thus, it is not possible to accept or reject **H1** because the evidence from the study was not homogeneous. These results indicate the need for further studies to elucidate the behaviour of the fair value estimated by historical data in relation to the fair value estimated by actual data. By using this method, professionals can simplify the evaluation process of biologically inactive markets, which is complex (Herbohn & Herbohn, 2006). However, there is still the possibility of achieving greater predictability in half of the harvests, thus providing a more reliable representation and utility of information. Additionally, agronomic models that detect a greater number of variables can more effectively capture the biological transformation of sugarcane (Ferraro et al., 2009).

After analysing the scenario where the accounting values were determined by the historical data, the results of the Wilcoxon tests were used to analyse the yield forecast and the accounting calculations, constructed based on the actual data and data simulated by the SAMUCA agrometeorological model. Thus, the crop yield forecast and accounting calculations are shown in Table 7.

Table 7
Comparison of calculations with simulated and actual data

		Yield forecast			Accounting calculations		
Harvest	Description	Total recoverable sugar	Tons of sugarcane per hectare	Tons of sugarcane	Revenue	Cost	Fair value
		(n=44)	(n=44)	(n=44)	(n=44)	(n=44)	(n=44)
2004/2005	Statistics	5.683	2.147	1.961	4.365	1.937	5.613
	p value	0.000	0.0318	0.0499	0.000	0.0527	0.000
	Conclusion	μ μ different	μ μ different	μ μ different	μ μ different	$\mu_{1/2}$ equal	μ μ different
2005/2006	Statistics	5.088	-0.443	-0.058	2.941	-0.058	4.050
	p value	0.000	0.6574	0.9535	0.0033	0.9535	0.000
	Conclusion	μ μ different	$\mu_{1/2}$ equal	$\mu_{1/2}$ equal	μ μ different	$\mu_{1/2}$ equal	μ μ different
2006/2007	Statistics	5.753	-1.155	-1.400	2.754	-1.4	3.956
	p value	0.000	0.2479	0.1614	0.0059	0.1614	0.000
	Conclusion	μ μ different	$\mu_{1/2}$ equal	$\mu_{1/2}$ equal	μ μ different	$\mu_{1/2}$ equal	μ μ different
2007/2008	Statistics	5.403	-1.214	-1.109	2,591	-1.109	5,228
	p value	0.000	0.2249	0.2676	0.0096	0.2676	0.000
	Conclusion	μ μ different	$\mu_{1/2}$ equal	$\mu_{1/2}$ equal	μ μ different	$\mu_{1/2}$ equal	μ μ different

Note: The H0 of the Wilcoxon test is as follows: there are no differences between the two samples.

The results show that the TRS estimated with simulated data differs from the actual value for all harvests. This result can be explained because the agrometeorological model cannot easily define the sucrose content (POL), which affects the estimate of TRS (Marin and Jones 2014). Although Vianna, Nassif, Carvalho and Marin (2020) found that SAMUCA improved in identifying sugarcane POL, this was not reinforced by the current study.

Nevertheless, when evaluating the TSH and TS, the SAMUCA model showed good results since there was only a difference between the samples of one crop year for TSH and TS, providing evidence that Marin's model (2014) can contribute to accounting estimates.

The revenue result showed difference in all crop years, possibly due to the low capacity to capture TRS. This indicates that the meteorological model still needs to evolve and for the purpose of predicting TRS, increasing the number of variables to analyze yield forecast or reviewing the impacts of those already considered by Marin (2014).

In contrast, the cost showed good results when calculated with the agrometeorological model assumptions since it showed no differences among the crop years and was similar to the actual data, suggesting that it can be an alternative to reduce uncertainty and increase the reliability of this indicator, which is a challenge highlighted by authors Silva et al. (2022) and Eilifsen et al. (2020) in constructing the fair value of biological assets without an active market.

Finally, the fair value showed differences in all crop years when compared to actual data, despite the positive outcome identified by TS and TSH. The results allow **H2** to be rejected, indicating that the fair value of sugarcane using yield based on the SAMUCA agrometeorological model does not significantly approach the fair value using actual yield, since the comparison of samples indicates that the fair value based on *inputs* of the SAMUCA agrometeorological model was different from that based on actual productivity. However, the model can be considered positive in the estimates of TS, TSH and cost, and can contribute to a more accurate representation and usefulness of the information in this stage of fair value formation (Machado et al., 2014). Thus, it is necessary to expand the investigation of the indicators provided by the agrometeorological model and their impact on fair value.

To compare the data provided by the SAMUCA agrometeorological model and historical data with the actual data, Table 8 was constructed, consolidating the information derived from the performed tests and their conclusions.

Table 8
Results of comparative tests with actual data

Information	Historical Data	Simulated Data	Option
TRS	Differences in two harvests.	Differences in all harvests.	Historical data
TSH	Differences in all harvests.	Differences in a crop.	Simulated data
TS	Differences in all harvests.	Differences in a crop.	Simulated data
Revenue	Differences in three harvests.	Differences in all harvests.	Historical data
Cost	Differences in all harvests.	There is no difference.	Simulated data
Fair value	Differences in two harvests.	Differences in all harvests.	Historical data

Note: Fewer differences are reflected with better data.

With the data presented, it was difficult to assimilate the climatic and biological effects highlighted by Morozova et al. (2019) and Herbohn and Herbohn (2006) to estimate the yield forecast of biological assets, with both the SAMUCA model and historical data. While the TRS showed greater significance with historical data than with simulated data, the TSH and TS were not significantly determined by this method, indicating a preference for using the model in Marin (2014) to determine these indicators.

These factors may contribute to the calculation of accounting values because in the case of the SAMUCA model, the limitation of the differences between TSH and TS samples generated a cost similar to that of the actual data. In the case of historical data, the significant TRS results may have contributed to the revenue and fair value results being significant. Therefore, it is possible to integrate the TSH and TS estimates from the agrometeorological model and TRS estimates with historical data, ensuring the fair value estimate is more similar to the actual data.

In addition, there is evidence that a change in the source of information (historical or simulated data) of productivity can have different effects on the estimate of fair value when evaluating the accounting calculations that consider the actual data (analysed in the laboratory). This context, combined with the low level of disclosure of fair value assumptions by the sugarcane mills, can compromise comparability among the values disclosed by companies, potentially creating uncertainty for analysts and reducing the reliability of accounting information (Moura et al., 2024). Thus, the intrinsic subjectivity of the techniques for assessing the fair value of sugarcane is a concern to some authors (e.g., Bohusova & Svoboda, 2017; Morozova et al., 2019; Rech & Pereira, 2012; Silva Filho et al., 2013; Martins et al., 2014; Silva et al., 2022), revealing the need to increase the number of studies on the estimation of fair value.

5 Conclusion

When evaluating the steps of the fair value calculation, the importance of the assumptions and how they can play an important role in determining the fair value of the sample was shown. It is important to note that yield, in particular, is rarely addressed by studies (e.g., Silva & Nardi 2019; and Cavalheiro, Gimenes, Binotto & Fietz, 2019) in the context of biological assets. Thus, this study aims to identify the impact of yield forecast on determining the fair value of sugarcane that is in production using real data from a plant located in the interior of São Paulo. The hypothese constructed in this study about agrometeorological model was rejected and the hypothese about historical data was neither accepted nor rejected, so it was not possible to confirm whether the yield models provide an increase in the quality of fair value. However, the use of historical data does not differ significantly from real productivity at fair value in half of the harvests, demonstrating better performance to this technique, despite being more simplistic. In contrast, the ability of the SAMUCA agrometeorological model to estimate tons of sugarcane and cost did not generate better results when presenting differences found in all harvests in relation to the fair value.

These mixed results reinforce the concern of previous studies with the intrinsic subjectivity of measuring the fair value of biological assets without an active market (e.g., Bohusova & Svoboda, 2017; Morozova et al., 2019; Martins et al., 2014; Silva et al., 2022) and highlight that differences can be found between accounting information calculated with different information sources, which may affect the comparability of the disclosed value among companies in the sugar and alcohol sector (Moura et al., 2024). This indicates a lack of consensus on the best way to value these assets and the need to expand the literature in this area.

The study contributes to increase the discussion between complementary knowledge, such as accounting and agronomy, which due to IAS 41 had to come closer together. Furthermore, it provides results that indicate to the regulatory body the necessity to verify that there are several assumptions to be defined, which due to uncertainty can impact the company's results, and current research is beginning to provide the basis for deeper debates in this regard. Moreover, it may impact accounting practices as discussions have been initiated and insights presented that contribute to sugarcane mills and their professionals making more informed decisions when evaluating their biological assets, also highlighting criticisms of potential models used.

The limitation of the study is linked to the sample size and study period, which were restricted to twelve plant farms in four crop years. In addition, the cost and the discount rate were defined based on external sources of information since internal information on the plant was not available. However, this approach is consistent with the premise of IFRS 13 that prioritizes external information sources at the expense of those internal to companies. Thus, the replication of the study for other sugarcane mills or even new crops in samples that consider longer periods is recommended to evaluate whether the results are consistent with the evidence found.

As future studies, it is emphasized the possibility of conducting a quantitative and qualitative study in the plants to understand how decision-making premises impact the measurement of biological assets. The application of the agrometeorological model SAMUCA can also be extended to crops such as soybeans and corn, which allows for the application of the current study in other crops. Furthermore, future research could evaluate other models provided by agronomy and assess their differences and impacts on the economic representation of biological assets.

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[ii] Confederation of Agriculture and Livestock of Brazil.
[iii]Brazilian National Bioenergy Union.
[iv]Brazilian Institute of Engineering Assessments and Expertise in São Paulo.