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Application of Linear Programming to Optimize Sugarcane Production and Sugarcane Farming Income at HGU Jengkol PT. Perkebunan Nusantara X

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ABSTRACT: Sugar production in Indonesia is currently unable to meet domestic needs, even though the potential demand for domestic sugar is still relatively high. Therefore, targeted efforts are needed to predict the decline in sugar production. One of the efforts in that direction is to optimize sugarcane production of HGU Djengkol PT Perkebunaan Nusantara X. This research aims to maximize income and increase sugarcane production by optimizing the area per crop category/ This research was carried out at HGU Djengkol PT Perkebunan Nusantara X. This research will take place from October 2023 to November 2023. The data collected is in the form of secondary data, namely sugarcane production data and income for the 2022 growing season, climate/weather data, and area per crop category. The data analysis method used is Linear Programming using POM software for Windows. The results showed that optimization of the broad composition per plant category can increase the income of HGU Djengkol by 107%, with actual income of Rp. 26,974,475,108, - after being optimized to Rp. 28,817,240,000,-, to get maximum income, by eliminating the category of ratoon 2 plants with a combination of area per category of plants Pure PC 30%, PC BR, 5%, RT 1 35% and Lahan Bero 30%. can increase HGU Djengkol sugarcane production by 102% with actual sugarcane production of 100,488 tons after being optimized to 102,432 tons.

KEYWORDS: Linear programming, Optimization, Sugarcane production, Revenue, Sugarcane plantation

I. INTRODUCTION

The sugarcane-based sugar industry in general in Indonesia is very dependent on the supply of sugarcane raw materials, most of which still rely on people's sugarcane. In table 1, it can be seen that the development of sugarcane harvest area in Indonesia over the last ten years (2012-2022) has fluctuated relatively but tends to stagnate because it only increases by an average of 0.84% per year. In 2011, the sugarcane harvest area in Indonesia was only 450,298 thousand ha, and had decreased from 2016 to 2021 with the lowest harvest area in 2019 covering an area of 411,435 thousand ha and experiencing an increase in harvest area in 2022 covering an area of 488,982 thousand ha.

Table 1. Data on the Development of Indonesia's Acreage, Sugarcane Production, and Hablur in 2011-2022

Year	Broad (Ha)	Production (Ton)	Productivity (Ton/Ha)	Rendeming (%)	Sugar (Ton)	Sugar productivity (Ton/Ha)
2011	450.298	30.323.228	67,3	7,35	2.228.258	4,95
2012	451.191	31.888.928	70,7	8,13	2.591.687	5,74
2013	469.228	35.526.070	75,7	7,18	2.551.024	5,44
2014	477.123	33.723.378	70,7	7,65	2.579.173	5,41
2015	445.651	30.164.097	67,7	8,28	2.497.997	5,61
2016	440.733	33.310,838	75,6	6,62	2.204.619	5,00
2017	425.617	28.806.385	67,7	7,37	2.121.671	4,98
2018	414.847	27.850.011	67,1	7,80	2.170.948	5,23
2019	411.435	27.728.270	67,4	8,03	2.227,046	5,41
2020	420.505	29,737.781	70,7	7,17	2.130.719	5,07
2021	447.398	32.340.604	72,3	7,27	2.350.834	5,25
2022	488.982	36.436.781	74,5	6,60	2.405.907	4,92

Source: Internal data of Holding Perkebunan, 2022

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Sugar factories in Indonesia are only spread across 12 (twelve) provinces, with the largest producers in East Java Province. The average sugar production in East Java Province during 2018-2022 is 1.05 million tons per year, and contributes 47.34% to Indonesia's sugar production. Based on the estimates of the Directorate General of Plantations for 2022, East Java's crystalline sugar production reached 1.05 million tons, much higher than other sugar-producing provinces. Lampung Province, as the second largest sugar producing province in the same year was only able to produce sugar amounting to 801.82 thousand tons. The other ten sugar-producing provinces are only able to produce sugar of 494.22 thousand tons in 2022 (Ministry of Agriculture, 2022).

PTPN X is one of the plantation companies in East Java Province that also meets the national sugar stock, but PTPN X's harvest area for 12 years has fluctuated so that it affects the amount of sugarcane produced, this can be seen in table 2 The development of the fluctuating harvest area and tends to decrease, the highest harvest area in 2013 was 77,787 thousand ha and continued to decline to 53,762 ha in 2022.

Table 2. Data on PTPN X Sugarcane Harvest and Production Area for 2010-2022

No	Tahun	Luas Panen (Ha)			Tebu (Ton)		
		Tebu Sendiri	Tebu Rakyat	Jumlah	Tebu Sendiri	Tebu Rakyat	Jumlah
1	2010	5.040	69.630	74.670	433.738	5.847.762	6.281.500
2	2011	4.427	66.232	70.659	293.144	5.323.479	5.616.623
3	2012	5.167	66.958	72.125	402.219	5.670.046	6.072.265
4	2013	2.973	74.814	77.787	238.393	6.499.159	6.737.552
5	2014	2.266	70.168	72.434	168.545	5.942.412	6.110.957
6	2015	2.438	67.863	70.301	187.449	5.000.906	5.188.355
7	2016	3.170	67.441	70.611	281.951	5.662.945	5.944.896
8	2017	3.383	54.177	57.560	233.327	4.100.082	4.333.409
9	2018	3.418	51.291	54.710	243.452	3.648.123	3.891.575
10	2019	3.143	47.660	50.803	252.306	3.555.761	3.808.067
11	2020	3.318	43.462	46.780	245.750	3.111.609	3.357.359
12	2021	3.753	40.148	43.901	283.325	3.266.893	3.550.218
13	2022	4.604	49.158	53.762	389.808	4.173.615	4.563.423

Source: Internal data of PTPN X, 2022

In table 2. the area of sugarcane harvest itself owned by PTPN X shows the highest area of sugarcane itself in 2012 covering an area of 5,167 ha, while the lowest area in 2014 covering an area of 2,266 ha, but in 2015 there began to be a trend of increasing the area of sugarcane itself to 4,604 in 2022, the increase in area was dominated by leased land owned by farmers, business cooperation land (KSU) with other agencies (PTPN XII, KLHK, and the Prosecutor's Office) and agroforestry cooperation land with Perum Perhutani through the P81 program, while for HGU land, the increase was due to the purchase of HGU land, namely HGU Ngusri in 2019 covering an area of 298 ha and HGU Sempu in 2020 covering an area of 258 ha (table 3).

Table 3. PTPN X's Own Sugarcane Area per Category in 2015-2022

Kategori	Luas Tebu Sendiri (ha)							
	2015	2016	2017	2018	2019	2020	2021	2022
Sewa	494	920	1.358	1.274	712	560	536	767
HGU	1.944	2.250	2.025	2.145	2.207	2.237	2.303	2.454
Kerjasama Usaha (KSU)	-	-	-	-	-	215	492	778
Agroforestry	-	-	-	-	224	306	422	605
Jumlah	2.438	3.170	3.383	3.418	3.143	3.318	3.753	4.604

Source: Internal data of PTPN X, 2022

PTPN X has 4 HGU lands, namely HGU Djengkol, HGU Sumberlumbu, HGU Ngusri and HGU Sempu, in table 4 the total area of PTPN X's Baku HGU covers an area of 4,465 Ha, with productive land covering an area of 3,875 Ha or about 87% of the total area. Meanwhile, of the productive land area used for milled sugarcane covering an area of 2,538 Ha or 57% of the total HGU area of PTPN X.

Table 4. Area of PTPN X HGU Statement in 2022

No	Uraian	Luas HGU PTPN X (ha)				
		HGU Djengkol	HGU Sempu	HGU Sbr.Lumbu	HGU Ngusri	Jumlah
A	Tanaman					
	- PC	703	53	560	48	1.364
	- RC 1	509	151	300	102	1.062
	- RC 2	6		36		42
	- RC 3					-
Jumlah A		1.218	203	897	150	2.468
B	Pembibitan					
	- KBP					-
	- KBN	8		9		17
	- KBI	38		40		78
	- KBD	191		199		390
Jumlah B		237	-	248	-	485
C	Lahan bero	580		342		922
D	Emplasement/Pondok/ Lapangan Olah raga				3	3
E	Kantor, Perumahan/ Pabrik/ Kolam limbah dll	8	1	6		14
F	Jaringan jalan kebun	119	6	69	10	204
G	Areal Cadangan (Ex Fuso, Rawa, hutan lindung dll)	65	48	54	129	296
H	Daerah Aliran Sungai (DAS)			6	6	13
I	Lahan Puslit Gula	60				60
Total		2.287	258	1.622	298	4.465

Source: Internal data of PTPN X, 2022

HGU Djengkol is one of PTPN X's HGUs which is currently still actively producing with a total raw area of 2,287 Ha, with a productive land area of 2,035 ha or about 89% of the total raw area, in 2022 the area used for milled sugarcane is only 1,218 Ha or 53% of the total raw area, while the remaining area is used for sugarcane seedlings covering an area of ± 237 Ha and Lahan Bero covering an area of 580 Ha, respectively 11% and 26% of the total raw area of HGU Djengkol (Table 4)

Land area that is difficult to increase and land productivity that tends to stagnate requires PTPN X management to optimize land use as optimally as possible, so good area planning per crop category is needed, this will provide guidance for PTPN X management to be able to optimize the amount of income and increase milled sugarcane production.

The target of optimizing milled sugarcane production and income of HGU Djengkol is to optimize the productive land area of HGU Djengkol which can be utilized for milled sugarcane at the lowest possible cost.

II. GRAND THEORY

Technical Aspects of Sugarcane Cultivation

Technical aspects of sugarcane cultivation are important in the development of sugarcane farming. Some technical aspects that need to be considered include the use of superior seeds, fertilization, institutional aspects, good management, good nursery, good management and maintenance, proper harvest preparation, and post-harvest (Susilowati & Tinaprilla, 2020; Lubis et al., 2022). The decline in sugarcane yield and productivity is likely closely related to soil degradation as a result of long-term cultivation of monoculture sugarcane (Kusumawati et al., 2022). In an effort to increase sugarcane productivity, the application of sugarcane cultivation technology such as the bud chips method in sugarcane plant nurseries can be an effective solution (Hadiyanti et al., 2023). In addition, the use of certain sugarcane seeds can also affect the need for seedlings for sugarcane cultivation, assuming that the correct planting method will result in optimal growth of sugarcane seedlings (Budi et al., 2022; Lailiyah et al., 2022). The use of hand tractor-based agricultural machinery tools is also one of the technical aspects that need to be considered in sugarcane cultivation maintenance activities (Purwantoro et al., 2019). A comparative study of sugarcane cultivation business between certain varieties can also provide information on the income level of sugarcane cultivation business and the efficiency of sugarcane cultivation business (Ikka et al., 2021). In the context of sugarcane development, the role of stakeholders in empowering sugarcane farmers is also an important thing to pay attention to (Adnyana &; Mohktar, 2019). In the context of sugarcane cultivation, the technical efficiency of sugarcane farming is also the focus of research, where factors affecting the technical inefficiencies of sugarcane farming need to be analyzed (Astuti et al., 2021). In addition, controlling the main pests and diseases of sugarcane is also a crucial technical aspect in sugarcane cultivation (Muliasari &; Trilaksono, 2021). In this case, the use of technology such as machinery and equipment that meets the needs and conditions of sugarcane cultivation in Indonesia also needs to be considered (Iqbal et al., 2014).

Tiering of Nursery Gardens

The cultivation of sugarcane seedlings is a crucial aspect of sugarcane farming. Several studies have focused on optimizing the growth and productivity of sugarcane seedlings. Hadiyanti et al. (2023) discussed the use of bud chips in sugarcane seedling cultivation, emphasizing its potential to enhance sugarcane productivity. Additionally, the study by Nasamsir & Huffia (2020) explored the use of cow manure as a means to enhance the productivity of sugarcane seedlings, indicating the importance of nutrient management in seedling cultivation. Moreover, the study by Muliandari et al. (2021) emphasized the impact of fertilization, water distribution, and plant management on sugarcane growth and yield, underscoring the multifactorial nature of sugarcane productivity. In addition to seedling cultivation, the growth of sugarcane plants has also been a subject of research. Soleh et al. (2020) investigated the impact of waterlogging on sugarcane growth, highlighting the detrimental effects of excessive rainfall on plant growth and yield. Furthermore, Astuti (2019) conducted a life cycle assessment of sugarcane cultivation, emphasizing the environmental implications of sugarcane farming and the need for sustainable practices in the industry. These studies collectively underscore the multifaceted nature of sugarcane cultivation, encompassing aspects such as seedling cultivation, disease management, nutrient optimization, and environmental sustainability. By integrating these findings, sugarcane farmers and researchers can gain comprehensive insights into optimizing sugarcane farming practices to enhance productivity and sustainability.

Production Theory

The theory of production in economics involves the combination of available inputs, such as capital and labor, in the production process to generate output. This theory aims to understand the efficient use of resources to maximize output (Nainggolan & Soleman, 2022). It is essential to comprehend the concept of business prospects in the future, which includes understanding the theory of production and the theory of the firm (Murniati, 2021). Additionally, the neoclassical economic theory states that the production function is expressed as a function of capital, labor, and technology, highlighting the key factors influencing production (Hasibuan, 2022). Moreover, the theory of production efficiency encompasses technical, allocative, and economic efficiency, which are crucial in optimizing production processes (Situmorang & Girsang, 2021). The concept of circular economy, as an antithesis to production economics, emphasizes sustainable and regenerative practices, deviating from linear consumption patterns (Emalia et al., 2023). Furthermore, the economic theory of total factor productivity plays a significant role in understanding the differences in capital per worker across countries, attributing it to variations in total factor productivities (Prescott, 1998). Additionally, the elasticity of substitution in CES production functions contributes to economic growth, providing insights into the variations in the substitutability of inputs in the production process (Klump & Preissler, 2000).

Income Theory

The concept of income in economics and accounting encompasses various theories and factors that influence financial behavior and economic outcomes. Financial literacy, lifestyle, and income have been found to influence financial behavior through product pricing (Maharani et al., 2022). Additionally, deindustrialization is viewed as a decline in the real value added by the manufacturing sector or a decrease in its contribution to national income (Sari & Wulansari, 2022). Financial inclusion plays a role in addressing income inequality, as it is related to the development of the financial sector and income distribution (Febriaty et al., 2022). Furthermore, theories on income distribution aim to address national income disparities among different societal classes, particularly the widening gap between the rich and the poor (Syahrin et al., 2022). The negative correlation between education growth and income disparity is supported by three theoretical frameworks (Lutfiani & Yuniasih, 2021). Moreover, the Kuznets curve theory suggests that in the short term, increasing national income leads to income inequality, but in the long term, it results in reduced income inequality (Fajar & Hariyanto, 2021). Empirical evidence has shown that financial development and ICT may reduce income inequality, although the results are diverse (Shaharuddin et al., 2018). National income, which can be measured by Gross Domestic Product (GDP), Gross National Product (GNP), and National Income (NI), serves as an indicator of a country's economic status and the value of production and expenditure within its economy (Pratiwi et al., 2023). Furthermore, the allocation of public funds and government spending has a significant impact on poverty alleviation, with income distribution inequality and government spending negatively affecting poverty (Muliati et al., 2019). Additionally, fiscal illusion research has been conducted to understand the impact of income increases on national income, particularly in Sumatra (Mellizka et al., 2022). The relevance of economic welfare through income allocation and distribution in Indonesia from an Islamic economic perspective has been explored (Putra et al., 2022). Moreover, human capital changes have been identified as a fundamental factor in reducing income inequality (Nadya & Syafri, 2019). The use of the Lorenz curve to visually represent income distribution and the impact of structural changes on income inequality in Jawa Barat have been studied (Winarti & Permadi, 2019; Putri & Monika, 2022). Furthermore, the economic benefits of natural tourism activities in fulfilling household expenditure and national park conservation have been analyzed (Istiqomah et al., 2019). The effectiveness of Good Dairy Farming Practice (GDFP) on dairy farmer income and welfare has been explored, indicating that higher GDFP values lead to increased farmer income (Mardhatilla & Amini, 2022). Additionally, the economic impact of ecotourism development in Kepulauan Seribu has been studied, showing indications of increased income and related activities (Aryunda, 2011). The impact of economic policies in the agro-industry sector on poverty and household income distribution in Indonesia has been analyzed using the Social Economic Balance System (SNSE) model (Susilowati et al., 2016). Furthermore, the empowerment of the Kaliwungu Kidul village community in processing local banana-based products to increase income has been explored (Annisa & Ekowati, 2021). Lastly, the relationship between the level of participation of members of the Muara Tigo Manunggal Livestock School and income has been investigated, highlighting the potential for increasing income and national revenue through livestock export-import activities (Rofi & Saleh, 2020).

Linear Programming

Linear programming is a powerful mathematical method widely used in various fields such as computer science, mathematics, and engineering. It involves optimizing a linear objective function subject to linear equality and inequality constraints. The application of linear programming extends to diverse areas, including computer network design, structural engineering, and sensitivity analysis. For instance, proposed a method for the optimal placement of piezoelectric active bars in vibration control by topological optimization, demonstrating the application of linear programming in structural engineering (Zhao et al., 2008). Additionally, linear programming algorithms have been utilized for sparse filter design in computer networks, highlighting its relevance in computer science and algorithm development (Baran et al., 2010). Moreover, sensitivity analysis in linear programming has been a subject of research interest, with studies focusing on new geometric approaches and tolerance-based methods to study the behavior of optimal solutions under changes in program data (Kaci & Radjef, 2022; Filippi, 2005). Furthermore, the application of linear programming extends to fields such as biotechnology, where it has been used in the development of reliable simulators for dynamic flux balance analysis, integrating genome-scale metabolic network analysis with dynamic simulation of the extracellular environment (Höffner et al., 2012). In the realm of mathematics, linear programming has been employed in solving fractional programming problems, with algorithms proposed for efficient solutions to specific forms of fractional programming problems (Qiu et al., 2021). Additionally, the application of linear programming in semi-infinite programming has been explored, with sensitivity analysis conducted via partitions, extending the concept of optimal partition from ordinary to semi-infinite linear programming (Goberna et al., 2010).

III. RESEARCH METHODOLOGY

Types of Research

The type of research carried out is descriptive research in the form of case study research. This research focuses intensively on one particular object that studies it as a case.

Location and Time

The research was conducted in sugarcane plantation HGU Djengkol PT. Perkebunan Nusantara X (PTPN X), in Plosokidul Village, Plosoklaten District, Kediri Regency, East Java and the research was carried out on October 15-November 15, 2023 which included planning, research, implementation, data analysis, and report preparation.

Population and Sample

This research is a case study of the application of linear programming to increase income and optimization of sugarcane production at HGU Djengkol PT. Perkebunan Nusantara X (PTPN X). The data used are acreage data, sugarcane production data and income data per crop category at HGU Djengkol MT. 2021/2022, and other data supporting this study.

Data Collection

Data collection is obtained from secondary data obtained from internal data of HGU Djengkol PT Perkebunan Nusantara X, literature studies, both from related agencies, as well as from books, journals, and previous research, which have been tested for truth. Literature studies are carried out by reviewing several sources that have been proven to be true, such as through books that reveal linear programming theories, journals that discuss production and revenue optimization using linear programming and data from the Central Statistics Agency.

Data Analysis Methods

The analysis method used is linear programming to determine the optimal area per plant category in HGU Djengkol PTPN X and data processing using POM software for Windows 3 so that it will be obtained to maximize revenue and optimize sugarcane production at HGU Djengkol. To achieve optimal results from the management of existing resources, proper planning is needed that can realize the maximum potential that exists with the expected optimal work results.

IV. RESULTS AND DISCUSSION

HGU Djengkol Revenue Analysis in 2022

Sugarcane farming income is revenue from all sugarcane farming activities which is reduced by the total costs incurred during sugarcane production activities. Sugarcane farming produces output in the form of sugarcane stalks that are milled to sugar mills. Revenue from sugarcane farming can be obtained from the amount of sugar and drops per ton produced multiplied by the price of sugar and the price of drops per ton. In this study, the calculation of sugarcane farming income uses a profit-sharing system based on the yield produced. Where sugarcane income is the entire total revenue of HGU Djengkol minus operational costs. The productivity, revenue, cost and average profit of sugarcane farming per hectare based on crop categories in HGU Djengkol are presented in table 5. below.

Table 5. Average Productivity, Revenue, Cost, and Income per hectare in HGU Djengkol in 2022

Uraian	Satuan	PC Murni	PC BR	RT 1	RT 2	Total
Luas	ha	510	193	509	6	1.218
Produktivitas Tebu	ton/ha	93	83	72	64	82
Produktivitas Gula	ton/ha	6,85	6,08	5,36	4,17	6,09
Produktivitas tetes	ton/ha	4,18	3,69	3,24	2,89	3,71
Harga Gula	Rp/ton	11.500.000	11.500.000	11.500.000	11.500.000	11.500.000
Harga tetes	Rp/ton	2.200.000	2.200.000	2.200.000	2.200.000	2.200.000
Penerimaan Gula	Rp/ha	78.757.207	69.944.161	61.627.690	47.952.587	85.326.795.808
Penerimaan Tetes	Rp/ha	9.206.202	8.119.539	7.134.571	6.352.663	9.932.519.300
Penerimaan Total	Rp/ha	87.963.409	78.063.700	68.762.261	54.305.250	95.259.315.108
Biaya	Rp/ha					
a. benih		9.100.000	9.100.000	910.000	910.000	6.864.931.788
b. pupuk		9.419.000	9.419.000	9.419.000	9.419.000	11.473.331.075
c. Herbisida		1.057.719	1.057.719	1.057.719	1.057.719	1.288.412.812
d. biaya garap kebun		17.296.000	17.296.000	9.431.000	9.431.000	17.015.973.762
e. panen		13.018.872	11.598.259	10.089.293	8.983.563	14.068.362.111
f. bunga bank		3.687.268	3.687.272	2.081.775	2.081.776	3.664.264.456
f. Biaya Proses		15.018.850	13.380.000	11.639.224	10.363.631	16.229.563.996
Total Biaya	Rp/ha	68.597.709	65.538.250	44.628.011	42.246.690	70.604.840.000
Pendapatan	Rp/ha	19.365.700	12.525.450	24.134.250	12.058.560	24.654.475.108

Source: Processed Internal Data of HGU Djengkol, 2022

In table 5. above, it shows that the average productivity of sugarcane per crop category in HGU Djengkol, namely PC Murni, PC Bongkar Ratoon, Ratoon 1, and Ratoon 2 are 93 tons / ha, 83 tons / ha, 72 tons / ha and 64 tons / ha, respectively. Meanwhile, sugarcane farming income per ha for each crop category at HGU Djengkol, namely PC Murni, PC Bongkar Ratoon, Ratoon 1, and Ratoon 2 respectively amounted to Rp. 19,365,700/ Ha, Rp. 12,525,450/ Ha, Rp. 24,134,250/ Ha and Rp. 12,058,560/ Ha, respectively.

Lahan Bero Revenue in 2022

HGU Djengkol Lahan Bero is land that is left unplanted with sugarcane or collaborated with outside parties to plant other commodity crops, the use of Lahan Bero is usually effectively carried out from October to February. The use of Lahan Bero in order to provide additional income at HGU Djengkol by conducting business cooperation with external parties with the KSU (Business Cooperation) scheme where in accordance with the regulations of the directors of PTPN X, Lahan Bero can be collaborated with external parties with a minimum compensation value (NKM) of Rp. 4,000,000 per ha. In carrying out this business cooperation, HGU Djengkol does not incur costs, so that the minimum compensation value becomes income from HGU Djengkol.

HGU's Total Revenue in 2022 before optimization

The use of HGU Djengkol land area of 1,798 ha is used for the category of pure PC plants, PC Bongkar Ratoon, Ratoon 1, Ratoon 2 and Lahan Bero with an area of 510 ha, 193 ha, 509 ha, 6 ha and 580 ha, respectively, with a percentage of 28.4%, 10.7%, 28.3%, 0.3% and 32.3%, according to table 5 resulting in total revenue of Rp 26,974,475,108,- and milled sugarcane of 100,488 tons.

Table 6. Area, Composition per Category, and Total Revenue of HGU Djengkol in 2022

Kategori	Luas (ha)	Komposisi perkategori (%)	Pendapatan per ha (Rp/ha)	Total pendapatan (Rp)
PC Murni	510	28,4	19.365.700	9.878.695.395
PC BR	193	10,7	12.525.450	2.414.293.013
RT 1	509	28,3	24.134.250	12.288.122.422
RT 2	6	0,3	12.058.560	73.364.279
Bero	580	32,3	4.000.000	2.320.000.000
Jumlah	1.798	100		26.974.475.108

Source: Processed Internal Data of HGU Djengkol, 2022

Maximization of HGU Djengkol Revenue with Linear Programming

HGU Djengkol's income is obtained from the use of HGU land with various categories of plants, namely PC Murni, PC Bongkar Ratoon, Ratoon 1, Ratoon 2 and Lahan Bero. Each category of plants is limited by:

1. the amount of costs budgeted by the company in 1 fiscal year (RKAP), where to organize milled sugarcane and Lahan Bero in 1 year the required capital budget is Rp. 70,604,840,000,-
2. the need for seeds for planting pure PC and PC unloading ratoon as much as 13 tons per ha while the need for seeds for embroidery of ratoon plants is 1.3 tons or 10% of the needs of PC plant seeds, while the availability of seeds (KBD) at HGU Djengkol is 11,088 tons,
3. maximum land area that can be used for milled sugarcane (PC &; Ratoon) and Lahan Bero covering an area of 1,798 ha
4. Planting time for Pure PC for 90 days, namely with planting months in April-June and PC Unloading Ratoon for 30 days in July, the ability to plant Pure PC and Unload Ratoon covering an area of 1 ha takes 0.167 days or 6 ha per day. While the pras time needed is around 105 days, namely in the middle of May to August with the ability to prac 1 ha, it takes 0.1 day or 10 ha per day.

The following is the constraint table data in HGU Djengkol:

Table 7. Constraint Data in HGU Djengkol

Uraian	x_1	x_2	x_3	x_4	x_5	Tersedia
Lahan (ha)	1	1	1	1	1	1.798
Bibit (ton)	13	13	1,3	1,3	0	11.088
Tanam PC Murni (hari)	0,167	0	0	0	0	90
Tanam PC Murni (hari)	0	0,167	0	0	0	30
kepras (hari)	0	0	0,1	0,1	0	105
Biaya (Rp)	68.597.710	65.538.250	44.628.010	42.246.690	0	70.604.840.000
Keuntungan (Rp)	19.365.700	12.525.450	24.134.250	12.058.560	4.000.000	

Source: Processed Internal Data of HGU Djengkol, 2022

Solving the problems faced by HGU Djengkol using linear Programming, the method used is a simplex method consisting of variable definitions, goal functions, and limitations or constraint functions owned by HGU Djengkol. After the purpose function and constraint function are determined, the analysis continues using the POM For Windows 3 application, the purpose of using this application is to avoid calculation errors if the calculation is done manually. The calculation results use the POM For Wondows 3 application as listed in table 8.

Table 8. Results of Linear Analysis of Programming Using POM For Windows 3

Linear Programming Results

Maksimasi Pendapatan HGU Djengkol Solution

	X1	X2	X3	X4	X5		RHS	Dual
Maximize	19,365,700	12,525,450	24,134,250	12,058,560	4,000,000			
Lahan	1	1	1	1	1	<=	1,798	4,000,000
Ketersediaan bibit	13	13	1.3	1.3	0	<=	11,088	0
Lahan bero	1	0	0	0	-1	<=	0	0
Kapasitas tanam PC Murni	.167	0	0	0	0	<=	90	36,193,590
Kapasitas Tanam PC BR	0	.167	0	0	0	<=	30	0
Kapasitas kepras RT 1	0	0	.1	.1	0	<=	105	0
Luas Maksimal RT 1	1	1	-1	0	0	>=	0	-8,524,295
Biaya	68,597,710	65,538,250	44,628,010	42,246,690	0	<=	70,604,840,000	.333
Solution->	538.922	87.005	625.927	0	546.146		28,817,240,000	

Source: POM for Windows 3

Table 8. Is the output of data processing using POM for Windows 3. The solution was obtained that to get maximum profit, the area per crop category in 1 growing season was Pure PC covering an area of 538,922 ha, PC Bongkar Ratoon covering an area of 87,005 ha, Ratoon 1 covering an area of 625,927 ha and Lahan Bero covering an area of 546,146 ha, as for Ratoon 2 it was recommended not to be implemented, this was in line with the HGU Djengkol program for so far which only planted sugarcane with a frequency of ratoon only 1 time ratoon, so that the composition of the area per plant category is Pure PC 30%, PC Unloading ratoon 5%, Ratoon 1 35% and Lahan Bero 30%.

Primal Analysis and Reduced Cost Analysis

In the primal analysis, the concept of optimal product combination will be explained in generating maximum profit contribution for business units. In this study, the primary analysis shows information about the combination of land levels that are used optimally so that farmers get maximum profits and then can then compare the results of crop category production optimization with existing production planning. Reduced cost analysis is an analysis that explains the magnitude of activities that are not included in ideal / optimal planning. If it continues to be implemented, it will have an impact on the value of the goal function by the value of reduced costs. Reduced cost shows that if the decision variable, namely the area of production land for each category of crops in units of ha, is forced to be implemented, then the goal function will decrease by reduced cost. There is an increase in gross profit due to changes in the combination of crop category production from actual conditions to optimal conditions. The combination of plant categories and their optimal land area based on optimization results per plant category can be seen in table 9.

Table 9. Optimal Combination of Crop and Land Categories

Variabel	Kategori Tanaman	Luas Aktual (ha)	Luas Optimal (ha)	Reduced cost
X1	PC Murni	510	539	0
X2	PC BR	193	87	0
X3	RT 1	509	626	0
X4	RT 2	6	0	2.931.898
X5	Bero	580	546	0
	Total Lahan	1.798	1.798	

Source: Processed output linier programming (POM for windows 3), 2023

Based on table 9. of 5 categories of crops carried out at HGU Djengkol, the results of optimization analysis show that land use should only be carried out with 4 categories of crops so that farming businesses produce at optimal conditions. HGU Djengkol is not recommended to produce ratoon 2 sugarcane plants, meaning ratoon 2 plants are not recommended to be produced in the future. This is evidenced by the results of the analysis that there is a reduced cost value in the ratoon 2 plant category of 2,931,898 which means that if the ratoon 2 plant is carried out on only 1 ha of land, it will experience a loss of Rp 2,931,898. The optimal land area in this study has a value of 1,798 ha and the actual land condition of 1,798 ha. This shows that the land in the farm has been used optimally, which can be seen from the value of the land obtained is almost the same or with a very small difference in land value.

Table 10. Comparison of Actual and Optimal Revenue of HGU Djengkol

Kategori	Pendapatan Sebelum Optimalisasi			Pendapatan Sesudah Optimalisasi			% Kenaikan
	Luas (ha)	Pendapatan per ha (Rp/ha)	Total pendapatan (Rp)	Luas (ha)	Pendapatan per ha (Rp/ha)	Total pendapatan (Rp)	
PC Murni	510,11	19.365.700	9.878.695.395	539	19.365.700	10.436.604.926	106
PC BR	192,75	12.525.450	2.414.293.013	87	12.525.450	1.089.774.272	45
RT 1	509,16	24.134.250	12.288.122.422	626	24.134.250	15.106.276.402	123
RT 2	6,08	12.058.560	73.364.279	-	12.058.560	-	-
Bero	580,00	4.000.000	2.320.000.000	546	4.000.000	2.184.584.400	94
Jumlah	1.798		26.974.475.108	1.798		28.817.240.000	107

Source: Processed output linier programming (POM for windows 3), 2023

Based on the results of the optimal analysis of the amount of income per crop category, under optimal conditions there are categories of plants that have increased and those that have decreased the amount of income. After land use optimization, the Pure PC and Ratoon 1 categories experienced an increase in revenue by 106% and 123%, respectively, while the PC Unloading Ratoon and Lahan Bero categories experienced a decrease in revenue by 45% and 94% respectively and in total there was an increase of around 107%. Some efforts that can be made to increase income include increasing the amount of production and production quality (yield).

Dual Analysis

Table 11. Dual Analysis of Resource Usage

Jenis Kendala	Slack/surplus	Dual
Lahan	0	4.000.000
Bibit	2.137,24	0
Lahan Bero	7,224	0
Jumlah Hari tanam PC Murni	0	36.193.590
Jumlah hari tanam PC BR	15,47	0
Jumlah hari Kepras	42,407	0
Biaya	0	0,333

Source: Processed output linier programming (POM for windows 3), 2023

Based on the results of the dual analysis, what is included in the limiting constraints is land resources, Pure PC planting capacity and cost availability. The three types of resources have a slack / surplus value equal to zero and a dual > value of 0, where if there is an increase in resource availability by one unit on land in ha units it will increase profits by Rp 4,000,000 and if there is an increase in the number of Pure PC planting days by one unit on the number of planting days in units of days it will increase profits by Rp 36,193,590, and if there is an increase in cost availability by one unit (Rp) it will increase profits by Rp 0.333. this implies that the most important resource additions increased are Pure PC planting days, land area availability and cost availability.

HGU Sugarcane Production After Optimization

Based on the results of the dual analysis, what is included in the limiting constraints is land resources, Pure PC planting capacity and cost availability. The three types of resources have a slack / surplus value equal to zero and a dual > value of 0, where if there is an increase in resource availability by one unit on land in ha units it will increase profits by Rp 4,000,000 and if there is an increase in the number of Pure PC planting days by one unit on the number of planting days in units of days it will increase profits by Rp 36,193,590, and if there is an increase in cost availability by one unit (Rp) it will increase profits by Rp 0.333. this implies that the most important resource additions increased are Pure PC planting days, land area availability and cost availability.

Table 12. Actual Production and Optimal Sugarcane Production

Kategori	Produksi tebu Aktual			Produksi Tebu Optimal			% Kenaikan
	Luas (ha)	Produktivitas (ton/ha)	Total Produksi (ton)	Luas (ha)	Produktivitas (ton/ha)	Total Produksi (ton)	
PC Murni	510	93	47.436	539	93	50.115	106
PC BR	193	83	15.968	87	83	7.208	45
RT 1	509	72	36.693	626	72	45.108	123
RT 2	6	64	390	-	64	-	-
Jumlah	1.218	82	100.488	1.252	82	102.432	102

Source: Processed output linier programming (POM for windows 3), 2023

Based on the results of optimal analysis of the land used per crop category, under optimal conditions there are categories of plants whose production has increased and which has decreased the amount of production. After land use optimization, the Pure PC and Ratoon 1 categories experienced an increase in production by 106% and 123%, respectively, while the PC Unloading Ratoon and Lahan Bero categories experienced a decrease in production by 45% and 94%, respectively.

Based on the results of the analysis in Table 12. it shows that agricultural businesses have not produced optimally. It can be seen from the difference between actual production and optimal production. In actual conditions, the categories of crops produced for sugarcane plants are 4 categories of crops with actual sugarcane production during one growing season of 100,488 tons,-, while in optimal conditions it is recommended that only 3 categories of crops are produced for optimal production of 102,432 tons. The results of the analysis also show that under optimal conditions, sugarcane production obtained by farmers can still increase by 102 percent or 1,943 tons, besides that there is an increase in the amount of land area used for milled sugarcane production with an actual area of 1,218 ha increasing after optimization of 1,252 ha or an increase of 34 ha. The findings in this study are alternative policies that can be taken by PTPN X Management, especially HGU Djengkol to adjust production policies. The goal is to plan to increase the amount of sugarcane production at HGU Djengkol.

V. CONCLUSION

Based on the results of the analysis and discussion, the following research results were obtained:

1. Optimization of the broad composition per plant category can increase HGU Djengkol's income by 107%, with actual income of Rp. 26,974,475,108, - after optimization increased to Rp. 28,817,240,000.
2. To get maximum income, by eliminating ratoon plant category 2 with broad combinations per plant category as follows; Pure PC 30%, PC BR, 5%, RT 1 35% and land bero 30%. With an area of 538,922 ha, 87,005 ha, 625,927 ha, and 546,146 ha respectively.
3. Optimization of the area composition per crop category can also increase HGU Djengkol sugarcane production by 102% with actual sugarcane production of 100,488 tons after optimization to 102,432 tons and milled sugarcane production area increased by 34 ha from the actual area of 1,218 ha increased to 1,252 ha.

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