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The Potentials of *Bongkar Ratoon* and Good Agricultural Practices (GAP) for Sugar Productivity and Self-Sufficiency in Indonesia

Mohammad Abdul Ghani[1)], Dradjad Hari Wibowo[2)], Mahmudi[3*)], Dimas Eko Prasetyo[3)], Iman Yani Harahap[4)], Risvan Kuswurjanto[4)], Titik Widyasari[4)], Danang Permadhi[4)], Pugar Indriawan[5)], Anna Kusumawati[6)] , Reismaya Wanamertan Nugroho[6)]

[1)] PT Perkebunan Nusantara III (Persero). Gedung Agro Plaza Lt. 15, Jl. H. R. Rasuna Said Kav. X2 No.1, Kuningan Timur, Setiabudi, Jakarta Selatan 12950, Indonesia
[2)] Office of the Coordinating Minister of Food (Expert Team); Perbanas Institute
[3)] PT Sinergi Gula Nusantara. Jalan Jembatan Merah Nomor 03-11, Surabaya 60175, Indonesia
[4)] PT Riset Perkebunan Nusantara – Pusat Penelitian Perkebunan Gula Indonesia. Jl. Salak No.1A, Bogor 16128
[5)] LPP Agro Nusantara. Jalan Urip Sumoharjo Nomor 01, Yogyakarta 55222
[6)] Politeknik LPP Yogyakarta. Jalan LPP No. 1 A, Yogyakarta, 55222
[*]) Corresponding author
Email addresses: azam.mahmudi@gmail.com; prodpangan@gmail.com

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Abstract

To attain national sugar self-sufficiency by 2030, the Indonesian government has issued Presidential Regulation No. 40/2023 stipulating acceleration of sugar self-sufficiency and supplies of bioethanol as a biofuel. This paper discusses strategies and practical programs to increase productivity as mandated by the Presidential Regulation, using literature reviews and a gap analysis on secondary data obtained from four demo-plots involving plantation companies and farmers. With a land size ranging from 4.4 to 8.4 hectares, each demo-plot applied *bongkar ratoon* (replacing ratoon with plant cane) and other key components of sugarcane's Good Agricultural Practices (GAP). They include plant variety and maturity recomposition, correct and timely doses of fertilization and water management. The results show that *bongkar ratoon* and GAP raise productivity from around 5 tons of sugar/hectare to 8.73 - 20.14 tons of sugar/hectare. While the results show promising potentials, expanding the demo-plots into large scale plantations is not straightforward, requiring comprehensive strategies, programs and action plans, some of which are outlined in this paper for both Holding Perkebunan Nusantara's smallholder- and own-plantations.

Keywords: Sugar self-sufficiency, sugarcane productivity, sugar productivity, *bongkar ratoon*, good agricultural practices (GAP), Holding Perkebunan Nusantara, smallholders *(tebu rakyat).*

Introduction

Sugarcane is a crop that has been cultivated by more than 90 countries located in tropical and subtropical regions and is globally valuable (Kusumawati et al., 2023) as a raw material for the sugar industry, especially in Indonesia (Chinnadurai, 2017). Sugarcane was chosen because it has high sucrose and low fiber content (Solanki et al., 2017). Therefore, sugarcane is still the main ingredient for producing sugar. The sugar demand in Indonesia always increases, 2-3% per year for consumption sugar and 5-6% per year for industrial sugar. In 2022, the national sugar demand has reached 6.67 million tons, consisting of 3.29 million tons of sugar consumed and 3.38 million tons of industrial sugar. However, national sugar production in 2022 is only around 2.40 million tons from state-owned and private sugar factories. This condition is due to the absence of an increase in yields, both yields and productivity of sugar cane plants (Sulaiman et al., 2019), causing Indonesia to still depend on imports to meet domestic needs. Based on historical data, national sugar productivity once reached > 10 tons/ha, according to the agroclimatic conditions of the plantation at that time. Technological advances, microclimatic conditions, and soil fertility can be adjusted to meet crop production needs. In addition, with the development of plant breeding research, varieties with a yield potential of up to 12 tons of sugar/ha are now available. With this condition, the technological support to achieve national sugar self-sufficiency is sufficiently available. The government has issued Presidential Regulation No. 40 of 2023 to accelerate national sugar self-sufficiency and the provision of bioethanol as biofuel. Strategic programs for sugarcane development are concretely set to include increasing productivity, adding new plantation areas, increasing the efficiency and capacity of sugar factories, improving farmers' welfare, and increasing bioethanol production.

The goals of sugar self-sufficiency are national sugar consumption by 2028, industrial sugar self-sufficiency by 2030, and increased bioethanol production. The PTPN (*Perseroan Terbatas Perkebunan Nusantara*) III (Persero), as the lead player in sugar self-sufficiency, has been assigned by the government (Article 17 of Presidential Regulation No. 40 of 2023) to increase sugarcane productivity to 87 tons/ha through improved agricultural practices, namely seedling, planting, plant maintenance, and the process of slashing and loading and transporting; expanding the sugarcane plantation area to a minimum of 179. 000 ha from plantation land, smallholder sugarcane land, and forest areas allocated through changes in designation, use, or utilization of forests with social forestry and multi-enterprise systems; improve efficiency, utilization, and capacity of sugar factories to achieve a yield of 8.05%, and improve the welfare of sugarcane farmers. To realize the targets set in the Presidential Regulation, PTPN has developed a road map and action plan as a policy guideline for achieving self-sufficiency in sugar consumption and industry and bioethanol production.

This paper will discuss the results of an analysis of the current sugarcane productivity performance based on evaluating the cultivation patterns implemented in several smallholder sugarcane farmer groups. In addition, observations of demo plots of cultivation technology applications are carried out to obtain gap analysis information and become the basis for synthesizing operational strategies to support the achievement of national sugar self-sufficiency targets.

Sugarcane's Good Agricultural Practices (GAP): factors determining productivity

Sugarcane ratooning is a common cultivation practice in sugarcane plantation, where the root, buds and other underground parts of the plant are left intake during harvest and let grow into succeeding plantation. Despite being more cost-efficient than plant cane (PC) grown from seeds or seedlings, as time goes by ratoon cane (RC) become prone to pests and diseases and its productivity drops. With poor cultivation management, the declines in productivity can be significant. Replacing ratoon with plant cane, or *bongkar ratoon*, while very costly, is universally accepted as an effective way to arrest the declines (Kuntohartono and Hendroko, 1995; Gomathi *et al.* 2013).

According the Indonesian Sugar Plantation Research Center (P3GI), factors that determine sugarcane productivity to reach genetic potential include the TMA (*tebang muat angkut* or harvesting-loading-transporting) management, pest control, seed quality improvement, fertilizer application, and irrigation management, as presented in Figure 1 (Sutrisno, 2014; Young & Nock, 2017; Gomathi et al., 2013).

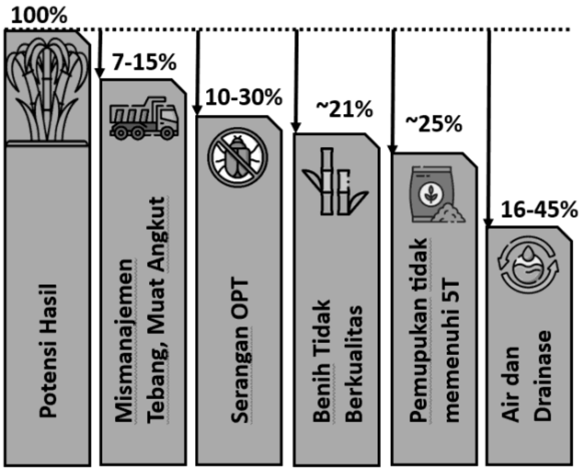

Figure 1. Potential Sugarcane Yield Loss Based on On-Farm Production Factors

Source: Sutrisno, 2014; Young & Nock, 2017; Gomathi et al., 2013

Sugar production optimization is influenced by seed quality. Quality and certified seeds are superior sugarcane varieties aged 6-8 months, with a germination rate of >90%, normal growth, free of pests and diseases, and high production potential (Parnidi, 2021).

Good water management also supports the increase in sugarcane productivity. The water management principle is provided according to plant needs and land management or drainage. For dry lands, a water management system (WMS) is needed. The provision of irrigation can significantly increase sugarcane production by improving soil moisture conditions at optimal levels (Surendran et al., 2016).

In sugarcane cultivation, fertilization is required at a dose according to plant needs based on the results of soil analysis at the local location), to obtain high sugarcane yields and, at the same time, maintain the carrying capacity of the soil (Pawirosemadi, 2011). Sugarcane yield and productivity are closely related to the quality and efficiency of fertilization strategies (Karman, 2018). To achieve efficient fertilization, it applies the 5 (five) right principles, the right type, the correct dose, the right time, the right way/place, and the right quality.

Pest and disease control is needed to avoid weight loss caused by non-optimal sugarcane growth (Kumalasari et al., 2022). Routine pest and disease monitoring efforts are helpful for more effective and efficient control measures. At harvest time, optimal sugar productivity is expected to be obtained, so it is necessary to determine the right cutting time and optimal transportation. Millable sugarcane raw materials must meet the criteria of maturity, cleanliness, and freshness, which suit the standards to optimize the potential yield (Hilmi et al., 2018).

Methods

The authors employ a literature review and a gap analysis of secondary data obtained from four demo-plots involving plantation companies and farmers. Each demo-plot has the following lan size: (a) 8.35 hectares for Plantation 1, (b) 4.40 hectares for Plantation 2, (c) 5.15 hectares for Plantation 3, and (d) 7.83 hectares for Plantation 4. *Bongklar ratoon* and good agricultural practices (GAP were applied on the plots, supervised by qualified teams from the Sinergi Gula Nusantara.

On the demo-plots, superior seeds/breeding varieties were planted, taking into account land typologies. The varieties are known to be resistant to cutting, diseases and fire wounds. These varieties need to be optimized agronomically by limiting the cutting period (a maximum of 3 times), providing sufficient water for de-rooting work (*pedot oyot)* and fertilization. The ideal crop composition consists of 30% early maturity, 40% middle maturity, and 30% late maturity, and only develop 3 varieties per category according to specific eco-location conditions, with optimization through replacing 1-2 varieties with the lowest productivity. Optimal cropping patterns and seed garden gaps were carried out through adjustments to the planting plan to obtain a sufficient harvest period for the planting age.

To identify, evaluate, and interpret the data obtained, the authors undertook a literature review in accordance with Kitchenham (2004). Observations were made to evaluate crop production performance in two cultivation groups: five smallholder sugarcane samples and the four demo-plots.

Data evaluation was carried out through gap analysis by comparing production performance in the two cultivation groups to obtain a synthesis of the main factors that determine the achievement of sugarcane productivity performance, yield, and productivity/sugar (Peltier, 2021). As comparative data for describing the performance of smallholder sugarcane (TR) productivity., secondary data on national sugarcane performance in 2019-2023 was taken (Ditjenbun, 2024). Based on the gap analysis results, further synthesis is carried out toward achieving self-sufficiency in national sugar consumption in 2028, according to Presidential Regulation No. 40 of 2023.

Results and Discussion

1. Smallholder farmers (TR) productivity 2019-2023

Smallholder farmers (TR) is vital to the national sugar supply. TR sugar production contributes 63% to national sugar production. Until now, national sugar production is still insufficient to meet the needs of sugar consumption and total sugar needs (consumption and industry). National sugar production in 2023 reached 2.271 million tons, still below the needs of sugar consumption and industry of 6.613 million tons.

TR productivity performance observation results in 2019-2023 (Table 1) show that TR productivity is 65.25-73.76 tons/ha with sugar productivity of 4.85 - 5.56 tons/ha (2019-2023). This condition is still not optimal because the genetic potential of sugar production based on released varieties can reach 7.7-14.6 tons/ha (Table 2).

Table 1. TR productivity 2019-2023

Description	2019	2020	2021	2022	2023	Average
Land Area (Hectares)	239.681,10	217.084,30	251.137,80	291.253,48	298.297,00	
Sugarcane Productivity (Ton/Hectares)	70,24	71,53	72,07	73,76	65,25	70,57
Yield (%)	7,92	7,10	7,65	6,70	7,44	7,36
Sugar Productivity (Ton/Hectares)	5,56	5,08	5,52	4,94	4,85	5,19

Source: Secondary Data (Production performance report: Directorate General of Estate Crops)

The use of TR varieties in Indonesia is 86% dominated by late-maturity varieties. On the other hand, high sugar yields can be achieved if there is a balance between early, middle, and late-maturity varieties adapted to each variety's characteristics. The following presents potential productivity and yield of superior sugarcane varieties (Table 2).

Table 2. Potential productivity and yield of superior sugarcane varieties

No	Variety	Maturity Type	Sugarcane Productivity (ton/ha)	Yield (%)	Sugar Productivity (ton/ha)
1	PSKA 942	Early – Middle	108	8,25	8,91
2	PS 862	Early	119	9,7	11,54
3	PSKA 095	Early – Middle	120,6	10,33	12,46
4	PSNX 052	Middle - Late	99,35	10,88	10,81
5	NXI 4T	Late	91,1	8,45	7,70
6	PSBM 971	Middle - Late	109	9,35	10,19
7	PSNXI - 943	Middle	116,7	9,36	10,92

Source: Secondary data (Description of varieties Ministry of Agriculture of The Republic of Indonesia)

2. Sugar productivity demo-plots

Demo plots on an area scale of 4.4 to 8.4 ha conducted in the 2023/2024 planting season in one of the Plantation Companies showed that the application of sugarcane cultivation according to Good Agricultural Practices (GAP) and the selection of plant varieties could produce sugarcane productivity of 100.28 - 262.96 tons/ha with yields of 7.66 - 8.71 percent and sugar productivity of 8.73 - 20.14 tons/ha. The demo plot results are presented in Table 3.

Table 3. Demo-plot data

No.	Description	Plantation 1	Plantation 2	Plantation 3	Plantation 4
1	Land Area	8,35	4,40	5,15	7,83
2	Land Typology *)	RHL	RHL	BPL	BPL
3	Variety	PS 881	PS 882	NXI 4T	NXI 4T
4	Planting Period	4B	4A	5A	4A
5	Fertilization **)	NPK : 4 ku/ha ZA : 2 ku/ha SP 36 : 1 ku/ha KCl : 1 ku/ha	NPK : 4 ku/ha ZA : 2 ku/ha SP 36 : 1 ku/ha KCl : 1 ku/ha	ZA : 10 ku/ha SP 36 : 2 ku/ha KCl : 2 ku/ha	ZA : 8 ku/ha SP 36 : 2 ku/ha KCl : 2 ku/ha
	Equal to				
	N	102 kg/ha	102 kg/ha	210 kg/ha	168 kg/ha
	P2O5	36 kg/ha	36 kg/ha	72 kg/ha	72 kg/ha
	K2O	60 kg/ha	60 kg/ha	120 kg/ha	120 kg/ha
6	Herbicide Application	Ametryn : 4 l 2.4 D : 3 l Diuron : 1 l	Ametryn : 4 l 2.4 D : 3 l Diuron : 1 l	Ametryn : 2,5 l 2.4 D : 1,5 l Pada 30 HST	Ametryn : 2,5 l 2.4 D : 1,5 l Pada 30 HST
7	Sugarcane Production (Ton)	837,68	555,30	1.231,51	2.058,98
8	Sugarcane Productivity (Ton/ha)	100,28	126,09	239,13	262,96
9	Yields (%)	8,71	8,67	7,74	7,66

10	Sugar Productivity (Ton/ha)	8,73	10,93	18,51	20,14

Source: Secondary data (P3GI: Pilot Project Optimasi Produktivitas Gula/Sugar Productivity Optimization Pilot Project)

Notes:

*) BPL (Heavy Soil, Irrigated, Good Drainage); RHL (Light Soil, Rainfed, Good Drainage)

**) 2 times application (at planting and 45 HST)

Based on the production data of the demo plots conducted in the four plantations, the application of sugarcane cultivation in a broader area, especially smallholder sugarcane, will require good strategy and management. This is not an easy challenge to implement at the farm level. However, because the average land ownership of individual smallholder sugarcane farmers is also relatively small, below five hectares, the opportunity to implement sugarcane cultivation according to GAP to achieve a minimum sugar productivity of 8 tons/ha can still be achieved.

3. Gap analysis

The gap analysis of the TR and Demo plot data in Table 1 and Table 3 shows that the proper application of GAP to sugarcane cultivation can increase sugarcane productivity from an average of 70.57 tons/ha to 100.28 - 262.96 tons/ha or sugar productivity from an average of 5.19 tons/ha to 8.73-20.14 tons/ha, and sugar yield can also be increased from an average of 7.36% to 7.6-8.7%.

Tabel 4. Productivity gaps between smallholder farmers and the demo-plots

Description	Farmer	Plantation 1	Plantation 2	Plantation 3	Plantation 4
Sugarcane Productivity (Ton/Ha)	70.57	100.28	126.09	239.13	262.96
Yields (%)	7.36	8.71	8.67	7.74	7.66
Sugar Productivity (Ton/Ha)	5.19	8.73	10.93	18.51	20.14
Gap (Farmer Gap)					
Sugar Productivity (Ton/Ha)		29.71	55.52	168.56	192.39
%		29.63	44.03	70.49	73.16
Yields		1.35	1.31	0.38	0.3
%		15.50	15.11	4.91	3.92
Sugar Productivity (Ton/Ha)		3.54	5.74	13.32	14.95
%		40.55	52.52	71.96	74.23
Gap (Plantation 1)					
Sugarcane Productivity (Ton/Ha)			25.81	138.85	162.68
%			20.47	58.06	61.86
Yields			-0.04	-0.97	-1.05
%			-0.46	-12.53	-13.71
Sugar Productivity (Ton/Ha)			25.81	138.85	162.68
%			236.14	750.14	807.75
Gap (Plantation 2)					
Sugarcane Productivity (Ton/Ha)				113.04	136.87
%				47.27	52.05
Yields				-0.93	-1.01
%				-12.02	-13.19
Sugar Productivity (Ton/Ha)				7.58	9.21
%				40.95	45.73
Gap (Plantation 3)					
Sugarcane Productivity (Ton/Ha)					23.83
%					9.06

Description	Farmer	Plantation 1	Plantation 2	Plantation 3	Plantation 4
Yields					-0.08
%					-1.04
Sugar Productivity (Ton/Ha)					23.83
%					0.01

The increase in sugarcane productivity in plantations 1 and 2 can occur due to several factors. The planting period in Pattern A aligns the type of maturity of PS 881 and PS 882 varieties, which have early and early middle maturity types, respectively. In addition, both varieties are suitable for dry land, so the production potential will be optimal when planted on RHL land typology.

With the application of fertilizers according to standard sugarcane cultivation standards, irrigation according to crop needs, klentek according to the stages of sugarcane cultivation and proper harvesting, sugarcane productivity can reach at least 100 tons/ha. Meanwhile, the increase in yield in plantations 1 and 2 is also due to several factors. The yield in the range of 8.67-8.71% can be achieved because the planting period follows the type of maturity of the variety so that the optimal yield potential can be achieved. In addition, the implementation of good harvesting and transportation also greatly influenced the yield and sugar production target.

In contrast to farms 1 and 2, sugarcane cultivation in farms 3 and 4 differed slightly in terms of the sugarcane varieties used and the fertilizer applications made. Although the planting period of Pola A does not align with the maturity type of the NXI 4T variety, which is a slow-maturity variety, the use of fertilizer at a dose of about twice as much as plantations 1 and 2 can increase sugarcane productivity to > 200 tons/ha. In addition, planting in the BPL land typology supports plant growth with guaranteed water availability during the growth period. However, in terms of yield achievement, plantations 3 and 4 have lower yields than plantations

1 and 2 because the planting period of Pattern A for late-maturity varieties causes sugarcane to be harvested when its maturity is not optimal. However, because the sugarcane productivity is twice the productivity of plantations 1 and 2, the sugar productivity in farms 3 and 4 is higher than in plantations 1 and 2.

Based on the above analysis, the achievement of optimal sugarcane productivity can be obtained through the use of quality seeds (Pratiwi, 1990), irrigation according to plant needs (Marin et al., 2020), fertilization in sufficient quantities (de Oliviera et al., 2017), pest and disease control, and slash and carry management (Bantacut et al., 2012). In addition, in non-ideal conditions, such as the availability of seeds that do not match the planting period, additional production inputs can help increase production. However, in the end, it must still be calculated whether the cost of providing additional production inputs is smaller than the profit obtained. Based on the gap analysis, the sugar productivity target of 8 tons/ha at the farm level can be achieved.

4. *Bongkar ratoon*

a. Varieties recomposition

Increasing sugarcane productivity is closely related to the suitability of varieties (genotypes), environmental typology and macroclimate, and sugarcane cultivation management following the GAP (Sulaiman et al., 2019; Srivastava, 2012; Thorburn et al., 2017). For this reason, various kinds of research have been carried out on sugarcane varieties with variations in maturity, fertilizer applications and the use of technologies such as maturity booster substances and irrigation techniques for monitoring water requirements in sugarcane plants (Zeng et al., 2020).

Soil conditions in sugarcane plantations in Indonesia have diverse physical and chemical properties. In addition, sugarcane plants are still influenced by climatic factors such as rainfall, air temperature and length of sunlight. Several technical and non-technical constraints affect the productivity of sugarcane, including substandard sugarcane cultivation, planting outside the optimal period, sugarcane planting currently shifting to dry land, seed quality problems, and the potential productivity of varieties not optimal, and the slash-and-carry system is less optimal.

The ratoon cane (RC) composition in Indonesia is still relatively high compared with plant cane (PC) crops. According to the Directorate General of Plantation's Cost of Production survey data for 2019-2022, the proportion of PC and RC areas on paddy fields and moorlands is almost the same, namely around 10% PC and 90% RC.

In addition, the moor area dominates compared to paddy fields with a proportion of 20%:80%. Since paddy fields are prioritized for rice, the development of sugarcane has shifted to dry land/moorland. On moorland, especially in areas with a firm dry season (Java Island and South Sulawesi), productivity is far below the potential productivity of rice fields (irrigated) (Halimah, 2008). On moorland, there is no adequate water availability for irrigation. Meanwhile, efforts to conserve rainwater in the dry season are still not widely carried out due to limitations.

Table 5. PC dan RC composition 2019 - 2022

Year	Sample Area (hectares)							
	Ricefield				Moor/Dry Land			
	PC	RC	% PC	% RC	PC	RC	% PC	% RC
2019	3.229,07	28.446,66	10,19	89,81	8.330,62	99.987,96	7,69	92,31
2020	1.888,00	12.954,00	12,72	87,28	6,382,00	65.048,00	8,93	91,07
2021	2.752,30	23.046,50	10,67	89,33	7.739,30	86.597,30	8,20	91,80
2022	2.640,40	23.728,30	10,01	89,99	11.347,00	98.566,10	10,32	89,68

Source: Directorate General of Estate Crops Data 2019 – 2022

The productivity of pruning plants is often lower than that of the first crop. According to Gomathi et al. (2013), the number of stems per ha in RC 1 and RC 2 decreased by 16.5% and 15.7% compared to the first crop, and there was a decrease in the number of sprouts in RC 1 and RC 2 by 17.0% and 18.1% compared to the PC crop. The number of sprouts and stems per ha is the basis of production estimation.

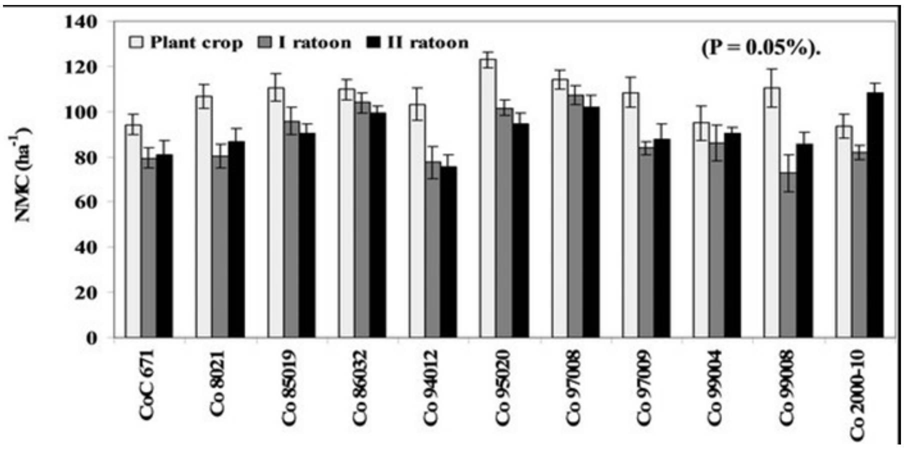

Figure 2. Decrease in number of stems per hectare (PC, RC1 and RC2) for various sugarcane varieties (Gomathi et al., 2013)

Leaf development in sugarcane is essential for photosynthesis, leaf canopy closure and light interception. Among several plant's physiological attributes, leaf area is closely related to yield and dry matter. Leaf Area Index (LAI) in RC 1 and RC 2 plants in the stem elongation phase decreased by 13.0% and 26.6% compared to their PC counterparts. Biomass production in the early phase of plant growth was still relatively comparable, but in the later phase, there was a reduction in biomass production. In the phase of sugarcane stem elongation, there was a reduction in dry matter production in RC 1 and RC 2 plants by 23.4% and 32.5% from their PC plants, while in the maturity phase the reduction in dry matter was 25.1% and 31.0%.

According to Kuntohartono and Hendroko (1995), the drastic decline in productivity of cut plants in Indonesia is caused by several factors, among others: (a) the delay in branding activities, (b) the presence of vessel disease or Ratoon Stunting Desease (RSD), (c) continuous planting of sugarcane without any land rotation, (d) soil compaction, (e) the use of sugarcane varieties that are not resistant to branding, and (f) lack of fulfillment of nitrogen element requirements.

To overcome the constraints of decreasing sugarcane productivity, several opportunities exist to increase productivity, namely by carrying out bongkar ratoon activities. *Bongkar ratoon* is an activity of rejuvenating sugarcane plants by dismantling plants and replanting using new seeds. Ratoon dismantling activities can increase sugarcane productivity because, generally, the potential production of sugarcane (ratoon) is less than the production of the first plant (plant cane) can reach around 80%-90%. To achieve optimal yields in ratoon crops, the varieties planted must be resistant to cut, resistant to vessel disease (RSD), resistant to fire wounds, and have enough water for pedot oyot work and fertilization. The optimal production potential of cut plants in Java Island is only around 2-3 times, after which the productivity decreases.

Using superior seeds (breeding varieties) suitable for the land typology and cultivation under the rules will certainly provide optimal productivity. Using impure sugarcane seeds will cause growth patterns that require different cultivation. If it has different maturity characteristics, it results in different yield potential, so the potential yield of each variety is not optimal.

Implementing long-term sugarcane cultivation until the third ratoon requires using quality seeds (free from RSD). Vessel disease /RSD is one of the diseases that cause a decrease in sugarcane productivity. This disease has been widely spread in several countries. In South Africa, the losses caused reached 19% to 41%, while on irrigated land, there was a yield loss of 21% to 32% depending on the variety, number of stems and stem length reduced, both on moorland and irrigated land (Bailey and Bechet, 1997). Seeds free from RSD can be obtained from seeds originated from tissue culture or seeds treated with hot water treatment (HWT). Hot water treatment of seeds can reduce vessel disease from 15% to 1% in Colombia (Mirzawan, 1995).

b. Maturity arrangement

Using breeding varieties is one of the most effective ways to increase productivity. The use of superior varieties has contributed economically to the sugar industry. The success of increasing sugarcane productivity requires the availability of seeds, superior varieties and good slash and load management. The determination of superior varieties to be developed is carried out after the selection process and adaptation tests, followed by the dissemination stage to users through sugarcane stalls and demo plots.

The productivity of a sugarcane variety is largely determined by the genetic potential of the variety and its growing environment. Using superior varieties, followed by applying sugarcane cultivation according to GAP, will produce optimal productivity. The growing environment/land typology and the application of sugarcane cultivation are very diverse at this time, which will determine the superior varieties that are suitable for each location/region. The superiority of a sugarcane variety is strongly influenced by the local ecolocation and cultivation system.

Variety composition and dynamism also need to be considered for productivity improvement. The maturity categories during the milling season are: early, middle and late, and at least three varieties can be developed from each category so that only 9 varieties are developed for each ecolocation. It is expected to dynamically replace one or two varieties from the composition of the least productive varieties, so the number of varieties developed does not swell. The new varieties selected or replaced should come from the results of variety orientation conducted on the ecolocation with local cultivation techniques. The ideal proportion of area for each variety maturity category is 30% (early), 40% (middle), and 30% (late).

Another strategy to increase sugarcane productivity is optimizing planting period and variety suitability. The optimal planting pattern (May - July) must be implemented, so the following year's milling season can be harvested at a sufficient age according to the maturity category. The planting period for early maturity varieties is April - May, early - middle maturity in May - June, middle maturity in June - July and late middle maturity in July - August.

Table 6. Maturity pattern of milled sugarcane plantation (KTG)

Maturity Type	Planting Time			
	May	June	July	August
Early				
Early – Middle				
Middle				
Middle – Late				

Source: Pawirosemadi, 2011

Seedlot girdling corresponds to the planned planting period of the first crop, so in this way, the plants are old enough to be harvested according to their maturity type. For example, early maturity varieties can be cut down at the beginning of milling (May) with a plant age of 12 months or more.

Research conducted by P3GI Pasuruan showed an increase in sugarcane productivity and potential sugar productivity by 27.84% and 50.18%, respectively. Recommendations for replacement varieties consider the type of land typology and maturity of sugarcane varieties.

c. Fertilization

Fertilization inefficiency has an impact on productivity reduction of ±25%. Several things that must be met in fertilization are the dose and type of fertilizer based on the soil and/or leaf analysis results. Good fertilization is done with 5T (right type, dose, time, place and quality), using inorganic fertilizers verified by the Ministry of Agriculture. In addition, additional organic matter needs to be done to increase the efficiency of inorganic fertilizer absorption, soil water holding capacity, and soil structure improvement by returning all plant residues (sugarcane crop residues) and soil organic returns (Pawirosemadi, 2011).

Table 7. Impact of maturity arrangement on sugarcane- and sugar-productivities

Plantation *)	Typhology **)	Past Variable	Substitutes Variable	Sugarcane productivity		% Change	Potential sugar productivity		% Change
				Past Variable	Substitutes Variable		Past Variable	Substitutes Variable	
1	RPL	HW	PS 862	65,01	86,62	33,24	6,69	8,09	20,93
		PS 851	PS 862	66,72	86,62	29,83	7,17	8,09	12,83
	RPJ	HW	PS 862	66,85	82,01	22,67	6,77	8,76	29,48
		HW	BL	71,17	84,76	19,08	6,53	7,66	17,30
2	BPL	BL	PS 862	69,96	78,35	11,99	4,71	7,47	58,58
		BL	VMC 76-16	78,74	95,36	21,10	5,30	9,52	79,57
	RPL	BL	VMC 76-16	74,50	86,88	16,62	5,01	8,67	73,05
3	BPJ	BL	PS 881	60,7	73,54	21,15	4,77	5,82	22,01
	RPL	BL	PS 881	44,67	51,82	16,02	3,04	5,59	83,88
4	BPJ	BL	PS 862	75,50	106,76	41,40	6,56	10,36	57,92
		PSBM 88-45	PS 862	71,57	106,76	49,17	5,25	10,36	97,33
		HW Merah	PS 862	68,81	106,76	55,15	5,64	10,36	83,69
	RPL	BL	PS 862	71,97	90,64	25,95	5,57	8,79	57,67
		HW Merah	PS 862	72,43	90,64	25,14	7,01	8,79	25,36
		PS 864	PS 862	71,39	90,64	26,96	6,57	8,79	33,89
	BPL	BL	PS 862	67,29	87,47	29,99	5,68	8,48	49,40
Average				68,58	87,85	27,84	5,77	8,48	50,18

Source: Secondary Data (P3GI Variety structuring study, Pasuruan, 2012), processed

Notes:

*) 1= Situbondo; 2= Banyuwangi; 3= Jember; 4= Lumajang

**) RPL= Light soil, watered, well drained; RPJ= Light soil, watered, well drained; BPL= Heavy soil, watered, well drained; BPJ= Heavy soil, watered, well drained

d. Water management

Water is one of the important components to support plant growth and production. Sugarcane plants need water during germination to stem growth at 1-9 months. In the germination phase, aged 1-3 months, sugarcane needs water to germinate and grow tillers. At the age of 3-9 months, sugarcane needs water to grow shoots and stems. At the age of 9-12 months, sugarcane requires less water because it has entered the generative phase, where there is a sugar production process in the sugarcane stem.

The effect of water availability on sugarcane production ranges from 16-45%, which means that if the sugarcane plant is not sufficiently irrigated, production can decrease by 16-45%. Case studies on the potential productivity of sugarcane on non-irrigated and irrigated land comparison are presented in Table 8.

Table 8. Sugarcane productivity between irrigated and non-irrigated plantations

Area	Irrigated (Ha)	Non-Irrigated (Ton/Ha)	Irrigated (Ton/Ha)	% Difference
1	1.178,6	56,0	70,3	25.54
2	364.3	53.6	65.7	22.57
3	77,8	70,6	90,1	27,60
4	3.665	84,6	104,7	23.76
5	2.577,3	74,5	96,0	28.85
6	464.9	18.0	30.5	69.44
Total	7.498,7	59.2	91.2	54.05

Source: PT Riset Perkebunan Nusantara Internal Technical Report

Table 8 shows that sugarcane plants that were irrigated produced higher yields than those that were not irrigated. Irrigated sugarcane production was 22.57-69.44% greater than non-irrigated. Meanwhile, for smallholder sugarcane cultivation at the time of PC planting with irrigation, while for RC, it is not irrigated. Potential productivity on irrigated land is 100-120 tons/ha, while RC production without irrigation ranges from 70-85 tons/ha.

Irrigation during PC is very important because it is the beginning of sugarcane cultivation, so the number of shoots and their growth is closely monitored with the expectation that later, during RC, the number of sugarcane stalks will be maintained.

Irrigation systems used in sugarcane cultivation include furrow irrigation, sprinkler irrigation for travellers, and sprinkler irrigation for big guns. The irrigation system cannot run well if the water source is insufficient. Sugarcane cultivation land is currently dominant on rainfed land, which relies only on rainwater to meet sugarcane plants' water needs.

This water limitation needs to be overcome to increase the productivity of sugarcane plants. One way can be done is with a Water Management System (WMS) where water management is carried out efficiently according to the amount of water sources and crop needs, which requires planning, development and management of water resources for both quantity and quality in all water uses.

For smallholder sugarcane areas on marginal land, water is the most crucial problem. It is necessary to have water supply facilities from both irrigation and deep well pumps. These facilities can be run through government assistance programs through related agencies.

5. TR productivity improvement strategy

a. Strategy for crop and maturity recomposition (PC/RC) (2024-2028)

Table 9 presents planning for application of GAP on TR within the Holding Perkebunan Nusantara.

Table 9. TR crop and maturity composition

Composition	Area (Ha)	Percentage	Maturity Type	Area (Ha)	Percentage (%)
PC	6,600	5	Early	9,420	7
R1	5,400	4	Middle	28,072	22
R2	5,800	5	Late	88,207	70
R3 Above	107,899	86			
Total	**125,699**	**100**		**125,699**	**100**

Source: Secondary data (Plantation Holding), processed

The total TR area in 2024 in the scope of the plantation holding is 125,699 ha. Of the total area, the composition of plants is still dominated by ratoon plants 3 and above as much as 86%. Meanwhile, the varieties are dominated by slow maturity at 70%. To change this composition, seed planning is needed for ratoon unloading so that the composition of plants and varieties is close to ideal. Seed requirements for the bongkar ratoon program are presented in Table 10.

Table 10. Seed requirements for the TR *bongkar ratoon* program

Stage	2025		2026		2027		2028	
	pattern A	pattern B	pattern A	pattern B	pattern A	pattern B	pattern A	pattern B
Sugarcane Milling Plantation	700	300	2,800	1,200	9,420	21,980	6,280	25,120
Flat Seed Plantation				1,346	3,140	897	3,589	
Parent Seed Plantation			192	449	128	513		
Old Seed Plantation		400	64.08	18.31	73.24			
Seed Plantation		9	3	10				
Main Seed Plantation	58	28	1					

Source: Primary Data, processed

Bongkar ratoon in 2025 is planned to be 1000 ha, then in 2026, it will increase to 4000 ha and will increase 31,000 ha or 25% of the TR area in 2027. Seed requirements require planning and tiering. The upper tier of the main staple seed garden (Kebun Benih Pokok Utama/KBPU) is fulfilled from the tissue culture laboratory. In 2025, seed needs for unloading ratoon are met from existing seeds that have been planted. For 2026 and beyond, this can be achieved from tissue culture seeds, if the process in the laboratory begins at the end of 2024. The bongkar ratoon program will change the composition of plants and varieties.

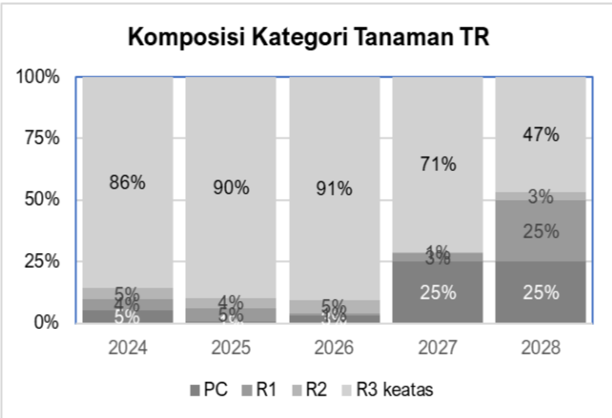

Figure 3: Plant composition after unloading the ratoon

Source: Primary data, processed

Figure 3 shows the projected crop composition with the unloading of the ratoon. In 2024, PC plants are only 5%, then will gradually increase to 25% in the 2027 and 2028 planting seasons. With the increasing composition of PC plants, it can increase sugarcane productivity. In addition, cultivation techniques are needed according to GAP to support productivity targets of up to 95 tons/ha.

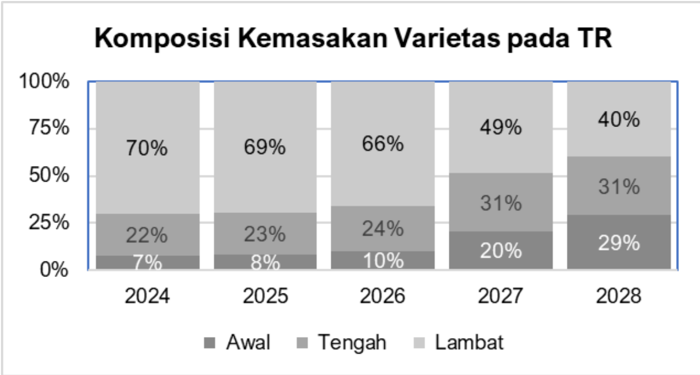

Figure 4. Variety maturity composition after *bongkar ratoon*

Source: Primary data, processed

In addition to arranging plant composition, bongkar ratoon activities can also be used to arrange a variety of compositions. Based on 2024 preliminary data, early maturity varieties composition is 7%. Therefore, in the bongkar program's seed planning, priority is given to providing early-middle-maturity varieties. Based on the projections in Figure 4, the change in variety composition will be gradual so that in 2027, it will reach 20% of early-maturity varieties, and in 2028, it will reach 30%.

In 2003, the government implemented the TR unloading program. The background of the program was low sugarcane productivity, low sugar prices, declining financial strength of planters and declining land area. The program was carried out in 2003-2005, empowering farmers and cooperatives. The benefits of the program to maintain the area of sugarcane even increased, increased sugarcane productivity, and improved variety composition Bongkar Ratoon Program in East Java Province provides an improved condition of the condition of agriculture in East Java with an analysis of the increase in sugarcane productivity (46.3%), increase in yield (10.12%) and increase in hablur (35.98%) presented in Figure 5.

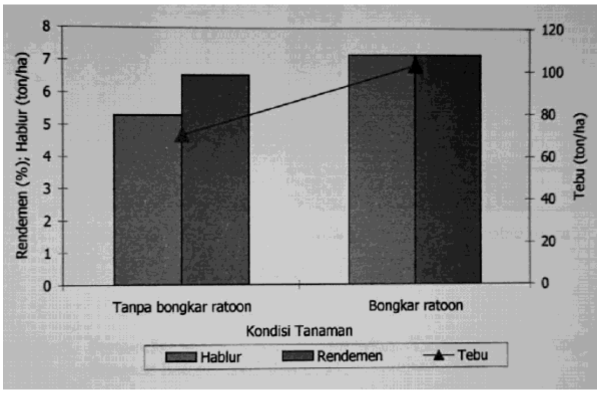

Figure 5. *Bongkar ratoon* program in East Java, Indonesia, 2003

Source: Movement to Increase Yield in East Java, 2006

The bongkar ratoon program is carried out with the main objective to encourage increased production, sugarcane productivity and efforts to increase land area. In addition, this activity also facilitates the improvement of the ability, independence and professionalism of sugarcane farmers through intensive supervision of how to cultivate sugarcane effectively and efficiently. The planting of superior varieties is followed by irrigation and rationalization of fertilization. In this way, it is expected that sugarcane plants have high productivity. In the end, high productivity is expected to influence the increase in the productivity of hablur, the yield produced, and the income of farmers.

Production facilities provided in the unloading ratoon activities are in the form of sugarcane seeds, organic fertilizers, compound fertilizers, medicines and wage assistance (HOK). The fulfilment of this input assistance also needs to be supported by supervision that can be carried out by Partner Sugar Factories and related Research Institutions with the aim of ensuring TR farmers with various constraints on land typology, irrigation, or climate change can get the best solution or treatment effectively and efficiently. In addition, this escort can be a pilot or demo plot for other partner TR farmers to participate in following/emulating technical sugarcane cultivation activities that are effective and efficient in production and income obtained.

b. Projected actual performance and TR production targets (2024-2028)

The impact of the plant composition arrangement and variety maturity in TR in 2024-2028 significantly increases sugarcane and sugar productivity. Figure 6 shows the projection of the actual value and target of sugarcane and sugar productivity in TR in 2024-2028. The actual value projection shows the productivity performance of sugarcane and sugar category TR without the support of promotional policies such as variety arrangement, ratoon removal, ratoon care, technical supervision of sugarcane cultivation with GAP and irrigation infrastructure assistance. Conversely, the projected target value shows the performance of production and productivity of sugarcane/sugar in the TR category with the support of promotional policies.

The actual productivity of sugar cane and sugar in TR is projected to experience stagnant performance, with average growth increasing by 0.62% and 0.41% per year, respectively. This is due to various main factors such as TR cultivation techniques that still do not meet GAP, namely the inefficiency of inputs of production facilities, squeezing more than 5 times and fanaticism of TR farmers with certain varieties. Therefore, if all relevant stakeholders encourage promotional policies through bongkar ratoon activities, variety arrangement and monitoring of sugarcane cultivation in accordance with GAP, they can gradually increase the yield and productivity of sugarcane and sugar in TR.

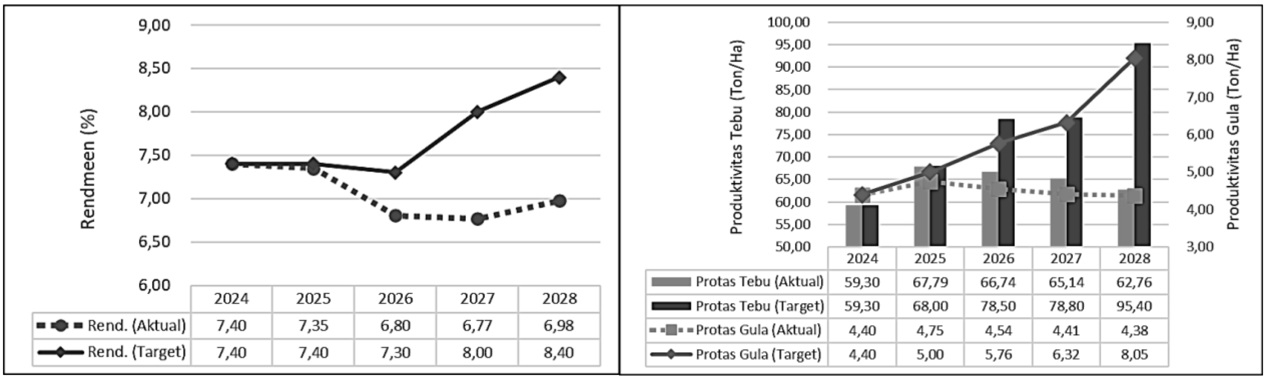

Figure 6. Projected sugarcane's actual and target productivities for TR 2024-2028

Source: Primary data, processed

The potential increase in yield (target) is 9.5% (from the actual value), with a yield value of 8.4% in 2028. Likewise, the productivity of sugarcane and sugar (target) until 2028 can respectively increase by 48.8% (95.40 tons/ha) and 45.5% (8.05 tons/ha) from the actual value. The following in more detail is presented in the graph of the projection of actual and target performance of sugarcane/sugarcane production and productivity in the TR for 2024-2028 in Figure 6.

Based on the projection of actual performance and target yields and productivity of sugarcane and sugar in the TR, the potential revenue obtained can be known. The assumptions built from 2024-2028 are: (1) TR cost of production (BPP) averaged Rp.614,948-Rp.730,610 per ton; (2) Average sugar price of Rp.14,500-Rp.16,320 per Kg; (3) Average drip price of Rp.2,244-Rp.2,429; (4) 3% drip yield; (5) Farmers' sugar profit sharing in the range of 70-80 percent. The result is known that the average total cost in 2024-2028 averaged Rp.42.560 million per hectare. So the potential income of actual and target TR farmers from 2024-2028 respectively amounted to IDR 10.704 million per hectare and IDR 26.360 per hectare, an increase of 146% from the actual value. The following below presents the projection of actual performance and target potential income of TR farming (2024-2028).

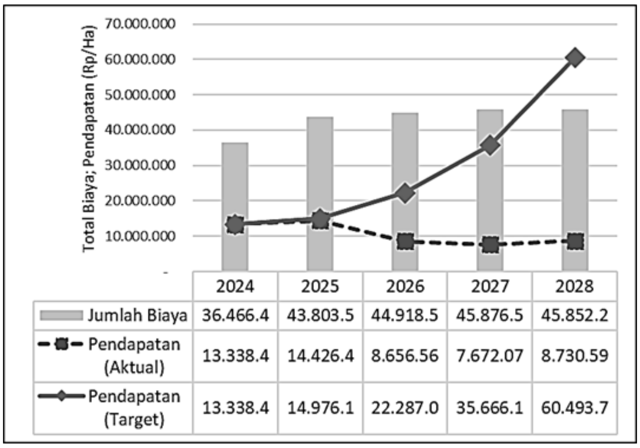

Figure 7. Projected actual and target of TR's farm income 2024-2028

Source: Primary data, processed

The target of achieving sugar productivity of 8 tons/ha in 2028 requires cooperation between stakeholders. One of the efforts by conducting a bongkar ratoon program requires planning related to seeds, production facilities and beneficiaries. For this reason, support from the government is needed so that the program can run well.

Conclusion

Indonesia has a great potential to achieve sugar self-sufficiency, one of which is by optimizing sugarcane cultivation as the main raw material for the sugar and bioethanol industries. National sugar production, which reached 2.40 million tons in 2022, is still far from the demand of 6.67 million tons, making Indonesia dependent on imports. To achieve sugar self-sufficiency in 2028 and industrial sugar self-sufficiency in 2030, the government, through Presidential Regulation No. 40 of 2023, has set several important strategies that include increasing sugarcane productivity, increasing plantation area, and increasing the capacity of sugar factories. Sugarcane land management is divided between people's sugarcane, private plantations, and the state, with a large potential located on people's sugarcane land (63%). The observation of TR productivity performance in 2019-2023 shows that TR productivity is in the range of 65.25-73.76 tons/ha with sugar productivity of 4.85 - 5.56 tons/ha. This condition is still not optimal because the genetic potential for sugar production based on released varieties can reach 7.7-14.6 tons/ha. Trials have been conducted on demonstration plots on an area scale of 4.4 to 8.4 ha showing that the application of sugarcane cultivation according to Good Agricultural Practices (GAP) and the selection of plant varieties can produce sugarcane productivity of 100.28 - 262.96 tons/ha with yields of 7.66 - 8.71 percent and sugar productivity of 8.73 - 20.14 tons/ha. The sugarcane planting system in Indonesia is dominated by the ratoon system (90%). This is also the reason for the low productivity of sugarcane in Indonesia. The productivity of ratoon cane (RC) is lower than that of the first crop (Plant cane) with a decrease in the number of canes by 16.5% and a decrease in the number of tillers by 17% at ratoon year 1 compared to plant cane. Ratoon unloading activities are necessary because they can increase sugarcane productivity by 80%-90%. The potential increase in yield (target) is 9.5% (from the actual value), with a yield value of 8.4% in 2028. Likewise, the productivity of sugarcane and sugar (target) until 2028 can respectively increase by 48.8% (95.40 tons/ha) and 45.5% (8.05 tons/ha) from the actual value, if the crop rejuvenation program (bongkar ratoon), variety arrangement, fertilization, and water management are the key steps in increasing sugarcane productivity. Cooperation between various stakeholders is needed to achieve these targets, including the provision of quality seeds and efficient water resource management. In addition, the fulfilment of fertilizer availability and price certainty is quite crucial for the welfare of farmers. So, the guarantee of fertilizer availability and funding facilities can help reduce the problems that occur among farmers, especially partner farmers. Through these steps, it is expected that the national sugar demand can be met sustainably and the productivity target of 8 tons/ha in 2028 can be achieved.

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