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New Trends of Sugarcane Cultivation Systems Toward Sugar Production on the Free Market: A Review

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ABSTRACT

Sugar is one of the staple food commodities that has an important role in the Indonesian economy. The high demand for domestic sugar has resulted in the inability of sugar factories to meet the demand for sugar consumption because domestic sugar production is still low. This is due to decreased land area and productivity, low sugar yield rates, and low factory efficiency. This paper describes the improvement of sugarcane cultivation to the process of making sugar to support national consumption. The article uses a systematic review method on the latest sugarcane research and reports the conditions directly on the plantation. The results show that the existing sugarcane supply is still less than the factory's demand, so the factory worked inefficiently. Even though the factory has new machines and technology to produce good quality sugar with a capacity of 4,600 TCD, companies can take a coaching approach to the surrounding community to carry out sugarcane cultivation and provide financial support to the surrounding community. Based on the reality of low production and factory efficiency, the government needs to support the sugarcane cultivation system through farming production systems, improving factory machine capacity and labor for sugarcane estate in the global market era.

INTRODUCTION

Sugarcane is one of the essential industrial crops in Indonesia, with a land area of around 400,000 ha with an average yield of 60-70 tons of cane per ha. Sugar cane is mostly cultivated under rain-fed conditions contributing to more than 60% of sugar production (Putra & Damayanti, 2012). Sugar is a strategic commodity in the Indonesian economy because it is a basic need after rice, corn, and soybeans (Darma, Amandaria, Akzar, M. Arsyad, & Tenriawaru, 2020). Demand for sugar for food production is increasing every year (Laga, Langkong and Muhpidah, 2019). The supply of sugar cane is the most important factor in the success of the sugar industry (Damayanti & Putra, 2011). In fulfilling this supply, many problems are faced by sugar factories so that sugar yields are following the desired standards starting from old factory age, reduced sugar cane land, and lack of varieties. Agricultural inefficiency, poor technology adoption, slow product diversification, market regulation, and lack of adequate industry research and development support are also reasons for low productivity, leading to a flood of cheap imported sugar due to poor quality (Toharisman, 2016).

Continuous intensification in crop production has become increasingly important over the last few years. Efficient production demands increased yields without expanding the agricultural area or increasing the amount of agricultural inputs. In Trimpler, Stockfisch, & Märländer's (2017) research, the factors that support increased productivity in the form of environment, management, and agricultural characteristics are extracted, such as crop rotation, fertilization according to needs and human resource

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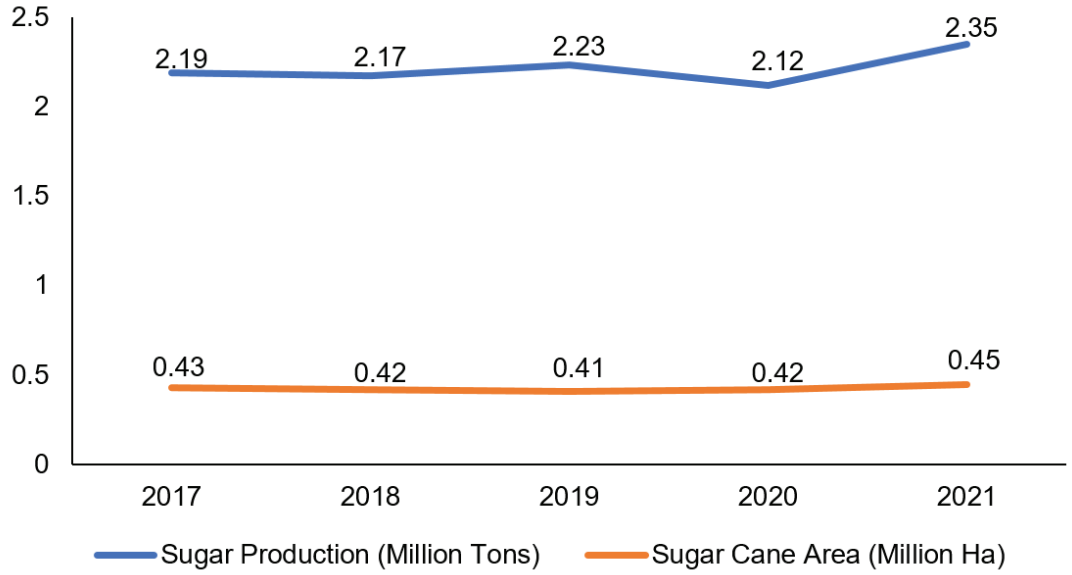
management (Shrivastava, Srivastava, Solomon, Sawnani, & Shukla, 2011). Policy intervention or siding with the system of sugar production in Indonesia is one of the prerequisites for increasing sugar productivity. Reconstruction of the sugarcane farming system can increase the technical and economic efficiency of existing sugar factories in Indonesia. These two aspects need to be addressed because it is impossible to expect an increase in the efficiency of the sugar factory if the quality of the yield of sugar in the farmers' cane is deficient, capital support from the banking sector and other non-bank institutions are weak, causing structural problems in the upstream sugar production sector (Arifin, 2021).



Remarks: Source: Indonesian Statistics Center (2021)

Fig. 1. Total area and production of sugar from sugarcane plantations in Indonesia in 2017-2021

Table 1. Indonesian sugar cane area by category of producers (2011 – 2021)

Years	Category of Estate			Total Area (ha)
	Government Estates (ha)	Private Estates (ha)	Small Holders (ha)	
2011	84,601	107,888	242,473	434,962
2012	80,890	114,018	247,750	442,658
2013	89,015	119,646	262,280	470,941
2014	88,056	121,624	262,996	472,676
2015	80,648	136,679	238,492	455,819
2016	76,979	131,189	239,182	447,350
2017	68,549	123,750	227,847	420,146
2018	68,928	110,977	235,758	415,663
2019	56,858	116,965	239,231	413,054
2020	56,684	124,461	237,851	418,996
2021	59,384	136,144	253,480	449,008

Remarks: Source: Indonesian Statistics Center (2021)

The challenges of cheap sugar imports to Indonesia demonstrate the scale of demand for the commodity, which places Indonesia among the world's largest buyers by volume, especially from the country's food and beverage manufacturing sector. The effort to reduce sugar imports yearly is by rehabilitating and building sugar factories (Pudjiastuti & Kembauw, 2017). Indonesian sugar has been included in the sensitive list in the AFTA (ASEAN Free Trade Agreement) since 1996. Sensitive list products will make Indonesia protect commodities with import tariffs that Indonesia can set with a maximum tariff of 40% (Ratya, Nuhfil, & David, 2013). The sugar factory's construction and rehabilitation are to achieve sugar self-sufficiency in the coming years. Apart from that, efforts were also made to expand the area of sugarcane plantations and increase the yield of sugar per hectare. The price of sugar and other agricultural commodity prices strongly influences the willingness of farmers to plant sugarcane. Sugar cane farmers have an important role in sugar production. They face the problem of decreasing sugarcane productivity and reducing arable land (Sulaiman, Sulaeman, Mustikasari, Nursyamsi, & Syakir, 2019). Total area and production of Indonesian sugar as shown in Fig. 1.

Sugarcane is one of the essential industrial crops in Indonesia, with a land area of around 400,000 ha with an average yield of 60-70 tons of cane per ha. Sugar cane is mainly cultivated under rain-fed conditions contributing to more than 60% of sugar production (Putra & Damayanti, 2012). The bright prospects for investment in the national sugar industry can be seen from the increasing interest of the private sector to invest in the sector. Implementing sustainability in industry is a challenge for scientists as well as engineers. This is important because it guarantees the continuity of meeting basic human needs (Zahara, 2018). In addition, the government also plans to revitalize existing sugar units, expand the sugar cane area and establish several new sugar units in collaboration with the private sector to realize the self-sufficiency plan. Indonesia is a developing country whose economic growth is promising and has the potential to become a developed country in the economic field. The sugar industry is interesting to study considering that the commodity of sugar is one of the food needs whose role is in fulfilling the completeness and needs of food (Tayibnapis, Wuryaningsih, & Sundari, 2016). The national sugar industry must be popular in its own country so that domestic sales can increase and be able to compete. Indonesian sugar cane area by category of producers is clearly shown in Table 1.

ASEAN countries contributing around 10% of world sugar production are important global trade players (Rianse, Abdullah, Hartono, Suryantini, & Widayati, 2016). Indonesia's potential in sugarcane production has a high chance. There is still 30 percent to boost national sugarcane production. Production technology development has increased the opportunity to provide good quality sugarcane seeds and encourage farmers to continue producing. Sugarcane is an important commercial crop with a potential industrial and bioenergy perspective (Babu et al., 2021). Eastern Indonesia has the potential to grow sugar cane to enter the free market because there is still a lot of lands that can be used for farming. Especially in Southeast Sulawesi, which has a sugar factory and is one of the largest in Indonesia, namely PT. Prima Alam Gemilang, which is located in Bombana Regency. The factory has a capacity of 4,600 TCD, which means it needs 4,600 tons of sugarcane. The factory was just established in 2019 and had challenges and opportunities in meeting the demand for sugar in Indonesia, including the lack of supply of sugarcane that goes to the factory to be milled. Currently, the factory plantation can only fulfil 2,000 tons of sugar cane, and many areas are still being worked on and need capital big deal to manage it.

Meanwhile, the supply from community plantations could only meet 150 tons of sugarcane. The obstacle faced by the community was also the initial capital in cultivating sugarcane which was not small. The people of Bombana Regency have also been interested in carrying out gold mining activities, the results of which can be obtained immediately compared to those who do farming. In terms of land area, Bombana Regency has potential in sugarcane cultivation, especially if a factory with a large milling machine capacity has been established. Another problem is the availability of the number of workers to manage the plantations. The factory still imports workers from outside the area to manage the land. The lack of workforce is due to the low number of people living in the area and the competition for labor between sugar factories, and this causes more and more labor costs. Not only in the input section, the next problem arises when the cane that

has been cut down must be milled immediately so that the sugar cane yield does not decrease, but what happens is that the supply of sugar cane must be collected first for several days waiting for other cane supplies to accumulate until it reaches the ideal weight for grinding. As a result, the yield of sugarcane is reduced, and the quality of sugar is also reduced. For some of the problems described, the sugar factory needs to synergize with various parties to solve the problem and achieve the supply of Indonesia's sugar needs can be met and even achieve self-sufficiency in sugar.

MATERIALS AND METHODS

This review included scientific articles about new sugarcane cultivation trends, from farms to factory processing to make sugar. This research applied other sugarcane cultivation comparison requirements with what researchers saw directly at research sites, such as 1) articles that have been published after peer review; 2) articles reporting on the latest trends in sugarcane cultivation; 3) research works, international conferences, notes, papers presented at congresses, books, and theses; 4) and written consistently in English. In addition, only articles published in the last decade (2011 to 2022) were retrieved.

Several keywords were selected to search for articles in reputable research databases, namely Scopus and Web of Science. In each database search, keywords were used: "trends in sugarcane cultivation" or "sugarcane in free trade". It was then looked at the reference list of the selected papers in case any were missing and potentially relevant articles during dataset generation. Apart from the year, only research articles and books were chosen as references. Concerning social or psychological motivating factors for farmers and companies towards new trends in sugarcane cultivation, this study also looked directly at the sugarcane plantations by conducting in-depth interviews with each stakeholder who played an essential role in sugarcane development. Thirty-nine articles were selected and analyzed to review the new trend of sugarcane cultivation systems toward sugar production in the free market.

RESULTS AND DISCUSSION

Farming and Sugar Industry

Following the study of Li & Yang (2015) regarding sugarcane farming and the sugar industry, several factors influence the success of the sugar industry, including synchronization from upstream to downstream, providing good quality seeds with land suitability, availability of superior resources and factories that can accommodate sugarcane supply. There is already a large-capacity sugar factory, and it is just a matter of how the sugar factory can increase its supply of sugarcane for the needs of the factory and can also benefit the surrounding community. The success of sugar factories can be seen in many areas of the island of Java, where the characteristics of the population are easy to accept sugar cane and become a source of family income. The relationship between sugar factories and stakeholders has been very well developed. Therefore, experience based on the results of previous research can be used as a learning tool for sugar factories in increasing sugarcane production.

Sugar factories cannot stand alone in meeting the needs of sugar cane factories, and production must also come from smallholder plantations to support the needs of sugar cane, good cooperation between sugar factories and the community can encourage a positive ecosystem in promoting prosperity. The potential and opportunities for realizing the Bombana Regency area as a national sugar barn can be realized with the collaboration of stakeholders from the government, the private sector, and the surrounding community. Especially for people new to sugar cane, it takes a diligent and patient effort to educate the surrounding community about sugar cane cultivation. Therefore, this research examined the optimization of sugar cane production in meeting the sugar cane supply at the sugar factory of PT. Prima Alam Gemilang. The study includes potential problems and strategies sugar factories can use to increase production and quality. The success of the sugar factory, which has been carried out in several areas such as in Java, has a more extended experience than the island of Sulawesi. The studies that have been carried out can be used as a reference in factory development according to the geographical conditions of the factory.

Increasing sugar cane yields is very important in filling the gap between national production and the rising demand for sugar, which aligns with Indonesia's growing population (Riajaya, 2021). This review includes several significant findings. First is cultivating and producing sugar cane into sugar, from preparing the land to turning it into sugar.

Production processes raw materials into an output or product to sell and market. In a sugar factory, the production process is to process sugar cane to produce sugar. The sugar production process is integrated; the level of sugar produced by a sugar factory is determined not only by the factory's circumstances and conditions but also by the cane in the plantation. Production requires cooperation and coordination from various parties to achieve maximum sugar yields. Sugar factory production activities include sugar cane cultivation, nursery, land management, planting, maintenance, logging and transportation, sugar production process, and waste handling. All production activities must follow specific standards for good quality and competitiveness in free trade.

Improving Sugarcane Cultivation

Cultivating sugar cane is an effort to adjust the environment of the plants so that the plants produce according to their potential, one of which is through the availability of quality seeds. In particular, certified seed plants to increase the production of sugarcane cultivation is one of the primary efforts of the Indonesian government (Suwandari et al., 2020). The achievement of sugarcane production is mainly influenced by the availability of high-yielding varieties of sugarcane developed through domestic sugarcane breeding programs (Widyasari, Putra, Ranomahera, & Puspitasari, 2022): sugar cane cultivation, land preparation, management, planting, and maintenance. Sugarcane plantations in Indonesia mostly grow on dry land under various climatic conditions (Riajaya, 2020). Sugar cane cultivation is divided into two planting methods, namely Plant Cane (PC) and Ratoon cane (RC). Plant cane is a sugarcane plant whose seeds come from a nursery where the land must be cultivated first. After the cane plant is cut down, the next plant is called ratoon cane or Keprasan plant. Ratoon Cane (RC) is the cultivation of sugar cane by not planting new sugarcane seeds on the land but using shoots that grow from stumps after the sugar cane is harvested. Ratoon Cane sugarcane cultivation does not require soil processing to reduce operational costs. The Ratoon Cane cultivation method can usually be done up to three times with the indicator that the distance between the plants is not too far and the sugarcane shoots are still good. Plant cane production costs are more expensive than ratoon cane costs because of the processing of plant cane land.

The success of hanging sugar cane depends on the cultivation technique. Good cultivation and post-harvest techniques will obtain high sugarcane productivity and yield. The sugarcane cultivation group includes land clearing and soil processing, planting, plant maintenance (fertilizing, drying, control of OPT/plant-disturbing organisms), and harvesting and transportation of sugarcane to the factory (Magfiroh, Zainuddin, & Wibowo, 2016). Among them, the most important aspect is partnership. The nucleus-plasma partnership model can still be an alternative for the development of plantation production. Still, it is necessary to structure the decision options of 'profit sharing' and 'buy out system' in plantations and factories or a mutually beneficial combination.

New Trends in Nursery

The main objective of the nursery is to meet the needs of high purity and quality seeds. The characteristics of sugarcane that have varieties include increased productivity, high yield potential, resistance to pests and diseases, low flowering rates, and resistance to Kepras. Sugarcane seeds of good quality can be obtained from nurseries with good soil conditions (Powar, Patil, Gurav, Sabale, & Powar, 2021). High soil health will increase the quality of the amount of sugar cane produced, so sugar production will also increase (Rahardjo, Rachmawati, & Soetjipto, 2019). In general, nurseries are carried out in nurseries, with the age of each nursery stage being 6-8 months. The seeds used by the factory are adapted to environmental conditions to achieve optimal production. Providing the right amount of fertilizer and nutrients in nurseries can increase the productivity of the sugarcane itself (Silva et al., 2022).

In the new nursery method that has been carried out, there is an interaction effect between sugarcane varieties and multilevel nurseries on the proportion of plant viability and height. Using a single bud (bud-chip) technique based on SOP can produce a viability proportion of up to 90% (Budi, Redjeki, & Prihatiningrum, 2016). However, until now, it is still widely used by sugar cane farmers in Indonesia as a planting material. Setts are taken from the rod with 2-3 buds. Another way is to use a set of top cuts. Ironically the sugarcane seedlings are planted with most of the farmers' sugarcane. The source of the parent stock nursery is unclear; even from the cutting of the plants, the number

of shoots used as a source of seeds cannot be counted. So that in the end, it significantly reduces the productivity of sugarcane per hectare.

Land Preparation and Processing

Sugarcane requires intensive labor, especially in sugarcane plantation areas (Fig. 2a) with hilly topography and almost cannot introduce plantation technology or mechanization. That way, labor in the field as a substitute for plantation and harvesting machines becomes crucial. Due to the delay in the planting process due to a lack of workforce, the maintenance, harvesting, and transportation of sugar cane from the plantation to the factory significantly affect the yield of sugarcane as discussed with field officers (Fig. 2b).

Before processing the land, the first thing that must be done is land preparation. Land must be prepared in advance so land management can be carried out correctly. Land preparation activities prepare soil conditions so that the physical and chemical properties are suitable for plant growth and can be sustainable (Singh, Singh, Singh, & Gupta, 2016). Environmental sustainability has attracted attention due to global environmental concerns, and one of its main focuses is agricultural production. Sugarcane is a globally important crop, and one of the issues that must be addressed for sustainable production is how soil quality is considered in sugarcane cultivation (Martini et al., 2020). At the sugar factory, land preparation is done manually, namely, by collecting the remains of broken cane and then burning it. Besides being helpful in clearing land, burning will also release K elements in the soil for sugar cane growth.

Land preparation is an effort to prepare land for sugar cane growth by creating soil conditions for planting. Evaluating soil properties confirmed higher levels of soil organic matter and micro and macro nutrients that interact with soil pH and texture in soils with newly cultivated sugarcane production capable of influencing microbial ecology (Bigott, Hoy, & Fultz, 2019). Land suitability evaluation is a prerequisite for assessing the limitations of sustainable land use planning (Jamil, Ahmed, & Sajjad, 2018). Land cultivation can reduce pest and disease populations in sugarcane. Silicon is one of the elements for increasing resistance to various pressures (Rahardjo, Achadian, Taufiqurrahman, & Hidayat, 2020). The objectives of tillage are as follows: a) Creating the soil structure needed for plant growth, creating water infiltration, improving aeration, and facilitating root development, b) Reducing run-off and reducing erosion, c) Inhibiting or killing weeds, d) Increasing soil fertility by killing insects, pest larvae or eggs, by changing the environmental conditions below the soil surface. Land preparation consists of three stages, namely: a) Plow One. This activity is carried out to turn over the soil and clear the land from the remaining roots of the previous sugarcane harvested in a particular direction in plowing, which often uses an outward circular pattern. b) Plow Two. In cultivating the land, it did not apply harrowing but did two plowings. The goal is that the land is cleaner and the remaining vegetation doesn't grow anymore. This activity uses the same implementation as plow one, with crossed directions but plow two depends on the condition of the land. Plow two is only carried out if the soil on the ground is hard and clay, c) Irrigation. It aims to make a place to grow sugar cane. Technically making water on new land and replanting is not much different, only different in the treatment and depth of water.

Replanting is a sugarcane plant that is grown from the demolition of a pre-existing cane. Sugarcane land cut down is done with soil preparation and processing, then it can be cultivated using sugar cane seeds. Sugarcane management activities consist of efficiency activities at the crop level (on-farm) to sugar factory efficiency (off-farm). Increasing production, sugar cane productivity, and yield through intensification activities. This activity is crucial in sugar production because it dramatically influences the growth and yield of sugar cane. In addition, replanting exercises can improve the quality of the planting medium by tilling the soil so that the soil's physical and chemical conditions improve (Melinia, 2022). During the implementation of sugarcane planting, several things need to be considered, including: buying varieties (genotypes), cane to be planted, using seeds, using seeds, covering, and compacting (Pratiwi, 2020).

Sugarcane Planting

Before planting activities occur, paying attention to important things such as land conditions, sugar cane seeds, pest and disease factors, and fertilizers is necessary. For sugar cane seeds, what needs to be considered is the condition of the seeds, namely, the cane eyeballs are in good condition. The seeds are then cut every 3 to 4 eyes or about

30 cm. Sugarcane seeds that have been cut into pieces are placed in the grooves of the plant or kairan. When planted, the eye position of the cane segment must face sideways. This is intended to optimize the sugarcane that will grow. Optimal row space arrangement is essential for rapid biomass growth (Som-ard, Atzberger, Izquierdo-Verdiguier, Vuolo, & Immitzer, 2021). Planting technology includes harvesting and sorting sugarcane seeds, preparing seeds, and placing planting material into well-prepared nurseries (Nalawade, Mehta, & Sharma, 2018). The sugarcane placement method itself is in the form of double overlapping. After planting, the seedlings are covered with soil and ready to be rinsed. At the sugar factory, planting is done manually. They are generally using human power. The advantages of planting manually are the accuracy and neatness of the plants, and the operating costs are not expensive. The equipment used, for example, is a machete to cut sugarcane.

Several new methods can accelerate sugarcane growth, such as using bacteria on a heterogeneous group of microorganisms in the rhizosphere. These microorganisms live in association with sugarcane roots, can stimulate plant growth, and can reduce disease incidence. Among many PGPRs, the most studied genera include Azospirillum, Bacillus, and Pseudomonas (dos Santos, Diaz, Lobo, & Rigobelo, 2020). Sugarcane growth can be optimized by a suitable combination of PGPRs, environmental conditions, and plant genotypes (Mehnaz, 2011). In this regard, additional efforts should be put into developing sound inoculants and production systems that reduce the amount of chemical fertilizers and insecticides used to increase soil fertility and crop productivity.

(a) (b)

Fig. 2. (a) Sugarcane plantations on hilly land, (b) researchers discussed with sugar cane field officers.

Fig. 3. Mechanical sugarcane harvester.

Plant Maintenance

Maintenance activities for sugarcane plants at the sugar factory include the following actions: a) Embroidery, which aims to fill in empty places in the rows of sugarcane plants to meet the target number of shoots per meter. Stitching activities are carried out when the plants are one month old or after the first fertilization and before the second fertilization so that the difference in the age of the plants is not too significant. Plant seeds for replanting must be of the same type, healthy, and free from pests and diseases. Embroidery is done manually using shoes. Land on sugarcane plants that do not grow is as deep as 15-20 cm. Then a new cane mule is placed, covered with earth, and watered. b) Land subsidence is the process of stockpiling soil in sugarcane plants. The aim is to strengthen the sugarcane plants and provide a growing medium for the sugarcane shoots. Getting off the ground is generally done twice. The first is done when the sugarcane is three months old. The tool used to get off the ground is a hoe. In Ratoon Cane, what is done is to cover the cane kitchen with soil to help the internal drainage process. c) The watering process, the sugarcane plant's water requirement is carried out in the watering process. Watering can accelerate the vegetative growth phase of sugarcane. Watering is done in the dry season after the sugar cane is planted during the vegetative period. d) Fertilization, fertilization process is carried out to maintain the soil's high productivity by maintaining or improving the physical and chemical conditions of the soil. Fertilization is done to increase the availability of nutrients in the soil for plants. e) Control of pests and diseases. As a cultivated plant, sugar cane has many pests and diseases. If these pests and diseases are not controlled, it can reduce the productivity of the sugar cane. Maintenance of litter on the ground surface can also delay sugarcane growth during winter in colder areas, affecting crop yields (Otto et al., 2016). Pest and disease control generally consists of mechanical, biological, and chemical methods. Maintenance analysis can be more controlled by increasing the number of employees at each service post, but it will likely incur significant additional operational costs (Rodrigues, Morabito, Chiyoshi, Iannoni, & Saydam, 2018).

Maintenance of sugarcane pests becomes one of the obstacles. The dominant pests that attack sugarcane include shoot borers and swine lice. Observing pest attacks is carried out once a week to determine the population and level of pest attack so that further efforts can be determined from pest attacks in the field. Pest control is carried out in various ways, namely chemically and mechanically (Leonaldo, 2019). Chemical control is carried out using systemic insecticides with active carbofuran ingredients. Giving carbofuran is carried out simultaneously with fertilization activities, with the first dose of 30 kg/ha and the second application of 45 kg/ha. Giving carbofuran prevents attacks by stem borers, shoot borers, and grubs. Mechanical control is carried out manually with human power. This activity is known as klentek or removing dry sugarcane leaf fronds. Klentek is done to overcome pest infestation. The tool used is a machete, and its working capacity is around 25 people/ha.

Sugarcane Harvesting and Transporting

The rearing and harvesting phase is vital in job creation as it is labor-intensive. It was found that the wages and working conditions of sugarcane farming were lower than that of rice farming. This may lead to a future lack of labor for sugarcane farming (Prasara-A & Gheewala, 2016). Harvesting and transporting sugarcane is the final determinant of the success of sugarcane cultivation because the smoothness of harvesting and transportation of sugarcane plays a significant role in the complete delivery of sugarcane from the area to the factory. This is related to not only the ability to meet raw material needs but also the ability to meet needs—raw materials and the ability to maintain the quality of sugarcane. Cultural operations for sugarcane production are challenging, especially harvesting. Modern sugarcane machines and labor-saving devices reduce sugarcane production costs and help timely completion of procedures, reduce human boredom, and enable efficient utilization of resources with better quality output (Singh, Singh, Sharma, Singh, & Srivastava, 2011) . This helps in increasing overall production and productivity. There is an urgent need to introduce modern sugarcane machinery, which is now available domestically, such as sugarcane cutter cultivators, intercultural and weeding machines, sprayers, and chopper harvesters are increasingly being accepted. Although the initial cost is very high, the benefits of its use are much more. Agricultural traffic control is an alternative management in this field, with the aim of maintaining the physical quality of the soil, so as to

increase the growth of sugar cane roots, productivity and quality of technology (Souza, Souza, Silva, Barbosa, & Araújo, 2014) in which mechanical sugarcane harvester is necessary (Fig. 3).

Harvesting sugarcane using machines is more efficient so as to generate profits for the company. The harvester route planning problem is a common real-life problem in the sugarcane energy sector. Computational tests were performed using data from a sugarcane energy company, which confirmed the model's efficiency in providing a solution that minimizes harvester maneuvering time. According to the solution obtained, time reduction was observed compared to the traditional harvesting process for the same area when machine harvesting routes were not planned. In addition to shortening harvest time, it should be stressed that optimizing harvester routes reduces fuel consumption, harvester wear and tear, and labor costs, thereby increasing company profits. In addition, there is an essential environmental contribution because by optimizing routes, CO_2 emissions, and other pollutant gases are reduced (Santoro, Soler, & Cherri, 2017).

New Trends in Sugar Production Process

Sugar production is a complex process and can be understood as a function of several variables (Nazir, Jariko, & Junejo, 2013). The sugar production process in the sugar factory is a production process flow. This process shows that the process of processing sugar cane into sugar is interconnected, which means that if there is a bottleneck at one production stage, it will affect the following production process. Sugar processing in a sugar factory includes seven steps: weighing, milling, refining, evaporation, crystallization, spinning, and finishing.

The sugar industry is the most significant contributor to the socio-economic development of the main sugarcane-producing regions (Li & Yang, 2015). The success of factories in producing sugar is also influenced by existing technology, not only modern production machines but also cultivation knowledge from human resources—a powerful sugarcane management system involving Information and Communication Technology (Solomon, 2016). Process of harvesting of sugarcane becomes easier with the help of machines. Still there are some processes in agriculture that require special care while atomizing (Jadhav, Kanthale, Barve, & Shinde, 2023). Knowing the amount of cane cut is very important concerning felling and transport planning because knowing the amount of cane cut can be planned for the amount of transportation, the amount of cutting power, and planning costs. It is necessary to estimate the amount of sugarcane to be cut down. The principle of felling sugar cane is the same as the principle of harvesting fruit: choosing ripe cane to cut down first and assuming that mature sugar cane will get a high yield. A preliminary analysis periodically needs to be carried out to determine the maturity of sugar cane. The principle of the preliminary implementation is to take sugarcane samples randomly and systematically to be milled in a small laboratory-scale mill.

Preliminary analysis activities are not only to determine the maturity of the sugar cane but also to determine the durability of the sugar cane to be cut and how much the yield of sugar cane in the garden increases or decreases. Before logging, a survey of loggers was also carried out at the location of the loggers' power source, which is usually relatively constant every year. The sugar mills contract some of the loggers. It is necessary to develop technology to replace falling power which can be carried out more efficiently and effectively (Eggleston, Cole, & Andrzejewski, 2013). Mechanical sugarcane harvesting has reduced production costs and will reduce the number of laborers (Ma, Karkee, Scharf, & Zhang, 2014).

CONCLUSION

To further increase sugar production and yield value, the company should improve the quality of sugarcane supply to farmers. Companies can seek to evaluate sugarcane based on quality, not just quantity, and by integrating coaching, adding cultivation extension workers for smallholder sugarcane farmers, facilitating farmers to get sugarcane production facilities more efficiently, and facilitating the provision of bank credit. Improving the sugarcane agriculture technology system is critical based on the reality of low production. It is essential to research collaboration with academics to look at the technical aspects of sugarcane cultivation activities to get a more precise composition of cultivation activities in increasing sugar production to fulfill global market demand.

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REFERENCES

Arifin, B. (2021). *Pertanian Bantalan Resesi: Resiliensi Sektor selama Pandemi Covid-19*. INDEF. https://books.google.co.id/books/about/Pertanian_Bantalan_Resesi_Resiliensi_Sek.html?id=9wNBEAAAQBAJ&redir_esc=y

Babu, K. H., Devarumath, R. M., Thorat, A. S., Nalavade, V. M., Saindane, M., Appunu, C., & Suprasanna, P. (2021). Sugarcane transgenics: developments and opportunities. In *Genetically modified crops* (pp. 241–265). Springer. https://doi.org/10.1007/978-981-15-5897-9_12

Bigott, A. F., Hoy, J. W., & Fultz, L. M. (2019). Soil properties, microbial communities, and sugarcane yield in paired fields with short- or long-term sugarcane cultivation histories. *Applied Soil Ecology*, *142*, 166–176. https://doi.org/10.1016/j.apsoil.2019.04.027

Budi, S., Redjeki, E. S., & Prihatiningrum, A. E. (2016). Effect variety and stratified plantlet nursery to the growth sugarcane (Saccharum officinarum L.) propagated in single bud. *Research Journal of Seed Science*, *9*(2), 42–47. https://doi.org/10.3923/rjss.2016.42.47

Damayanti, T. A., & Putra, L. K. (2011). First occurrence of Sugarcane streak mosaic virus infecting sugarcane in Indonesia. *Journal of General Plant Pathology*, *77*(1), 72–74. https://doi.org/10.1007/s10327-010-0285-7

Darma, R., Amandaria, R., Akzar, R., M. Arsyad, & Tenriawaru, A. N. (2020). Energy and Land Conservation: Brown Sugar Processing with Appropriate Technology. *Int. J. Adv Sc. and Tech*, *29*(8), 1701–1717.

dos Santos, R. M., Diaz, P. A. E., Lobo, L. L. B., & Rigobelo, E. C. (2020). Use of plant growth-promoting rhizobacteria in maize and sugarcane: Characteristics and applications. *Frontiers in Sustainable Food Systems*, *4*, 136. https://doi.org/10.3389/fsufs.2020.00136

Eggleston, G., Cole, M., & Andrzejewski, B. (2013). New commercially viable processing technologies for the production of sugar feedstocks from sweet sorghum (Sorghum bicolor L. Moench) for manufacture of biofuels and bioproducts. *Sugar Tech*, *15*(3), 232–249. https://doi.org/10.1007/s12355-013-0229-6

Indonesian Statistics Center. (2021). *Indonesia sugar cane statistics 2021*. https://www.bps.go.id/publication/2022/11/30/6392bf8e4265949485d85e72/statistik-tebu-indonesia-2021.html

Jadhav, M., Kanthale, V., Barve, S., & Shinde, V. (2023). Design and fabrication of semiautomatic sugarcane bud cutting machine. Materials Today: Proceedings, 72, 1302–1306. https://www.sciencedirect.com/science/article/abs/pii/S2214785322061193

Jamil, M., Ahmed, R., & Sajjad, H. (2018). Land suitability assessment for sugarcane cultivation in Bijnor district, India using geographic information system and fuzzy analytical hierarchy process. *GeoJournal*, *83*(3), 595–611. https://doi.org/10.1007/s10708-017-9788-5

Laga, A., Langkong, J. and Muhpidah, M. (2019) 'Pengaruh penggunaan jenis gula terhadap mutu kurma tomat', Canrea Journal: Food Technology, Nutritions, and Culinary Journal, pp. 62–68. https://doi.org/10.20956/canrea.v2i1.212

Leonaldo, D. A. (2019). *Pemeliharaan Tanaman Tebu Dengan Sistem Klentek di PT. Perkebunan Nusantara xi PG Semboro Jember*. https://sipora.polije.ac.id/8365/

Li, Y.-R., & Yang, L.-T. (2015). Sugarcane agriculture and sugar industry in China. *Sugar Tech*, *17*(1), 1–8. https://doi.org/10.1007/s12355-014-0342-1

Ma, S., Karkee, M., Scharf, P. A., & Zhang, Q. (2014). Sugarcane harvester technology: a critical overview. *Applied Engineering in Agriculture*, *30*(5), 727–739. https://doi.org/10.13031/aea.30.10696

Magfiroh, I., Zainuddin, A., & Wibowo, R. (2016). *Dinamika dan Risiko Kinerja Tebu Sebagai Bahan Baku Industri Gula di Indonesia*. https://repository.unej.ac.id/handle/123456789/79245

Martini, A. F., Valani, G. P., Boschi, R. S., Bovi, R. C., da Silva, L. F. S., & Cooper, M. (2020). Is soil quality a concern in sugarcane cultivation? A bibliometric review. *Soil and Tillage Research*, *204*, 104751. https://doi.org/10.1016/j.still.2020.104751

Mehnaz, S. (2011). Plant growth-promoting bacteria associated with sugarcane. In *Bacteria in agrobiology: crop ecosystems* (pp. 165–187). Springer. https://doi.org/10.1007/978-3-642-18357-7_7

Melinia, F. A. (2022). *Penanaman Tebu (Saccharum officinarum L.) di Areal Replanting Divisi II PT Gula Putih Mataram Sugar Group Companies Lampung*. https://ereport.ipb.ac.id/id/eprint/10287/

Nalawade, S. M., Mehta, A. K., & Sharma, A. K. (2018). Sugarcane planting techniques: a review. *Contemporary Research in India: National Seminar Recent Trends in Plant Sciences and Agricultural Research (PSAR-2018)*,98–104. https://www.researchgate.net/profile/Sachin-Nalawade-2/publication/322976767_SUGARCANE_PLANTING_TECHNIQUES_A_REVIEW/links/5a7a7e96a6fdccebdd81a251/SUGARCANE-PLANTING-TECHNIQUES-A-REVIEW.pdf

Nazir, A., Jariko, G. A., & Junejo, M. A. (2013). *Factors affecting sugarcane production in Pakistan*. https://www.researchgate.net/publication/283072524_Factors_Affecting_Sugarcane_Production_in_Pakistan

Otto, R., Castro, S. A. Q., Mariano, E., Castro, S. G. Q., Franco, H. C. J., & Trivelin, P. C. O. (2016). Nitrogen use efficiency for sugarcane-biofuel production: what is next? *Bioenergy Research*, *9*(4), 1272–1289. https://doi.org/10.1007/s12155-016-9763-x

Powar, R. V, Patil, S. B., Gurav, M. D., Sabale, P. R., & Powar, T. R. (2021). Techno-Economic Assessment of Sugarcane Nursery for Successful Commercialization. *Agri-Entrepreneurship: Challenges and Opportunities*, 322343.https://www.researchgate.net/publication/356106402_TechnoEconomic_Assessment_of_Sugarcane_Nursery_for_Successful_Commercialization

Prasara-A, J., & Gheewala, S. H. (2016). Sustainability of sugarcane cultivation: case study of selected sites in north-eastern Thailand. *Journal of Cleaner Production*, *134*, 613–622. https://doi.org/10.1016/j.jclepro.2015.09.029

Pratiwi, I. Y. (2020). *Pengelolaan Tanaman Tebu (Saccharum officinarum L.) Lahan Kering di PT Gula Putih Mataram, Lampung Tengah, Dengan Aspek Khusus Manajemen Penanaman*. https://repository.ipb.ac.id/handle/123456789/46660

Pudjiastuti, A. Q., & Kembauw, E. (2017). Sugar Price Policy and Indonesia's Trade Balance. *J. Advanced Res. L. & Econ.*, *8*, 2540. https://doi.org/10.14505//jarle.v8.8(30).26

Putra, L. K., & Damayanti, T. A. (2012). Major diseases affecting sugarcane production in Indonesia. *Functional Plant Science and Biotechnology*, *6*(2), 124–129. http://www.globalsciencebooks.info/Online/GSBOnline/images/2012/FPSB_6(SI2)/FPSB_6(SI2)124129o.pdf

Rahardjo, B. T., Achadian, E. M., Taufiqurrahman, A. F., & Hidayat, M. R. (2020). Silica Fertilizer (Si) Enhances Sugarcane Resistance to The Sugarcane Top Borer Scirpophaga excerptalis Walker. *AGRIVITA, Journal of Agricultural Science*, *43*(1), 37–42. https://doi.org/10.17503/agrivita.v1i1.2654

Rahardjo, B. T., Rachmawati, R., & Soetjipto, D. (2019). Sugarcane leaf litter as soil amendment to stimulate collembolan diversity. *AGRIVITA, Journal of Agricultural Science*, *41*(2), 295–301. https://doi.org/10.17503/agrivita.v41i2.2245

Ratya, A., Nuhfil, H., & David, K. (2013). Changes effect of sugar import tariff in Indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, *15*(3), 31–38. https://doi.org/10.18551/rjoas.2013-03.06

Riajaya, P. D. (2020). Rainy season period and climate classification in sugarcane plantation regions in Indonesia. *IOP Conference Series: Earth and Environmental Science*, *418*(1), 12058. IOP Publishing. https://doi.org/10.1088/1755-1315/418/1/012058

Riajaya, P. D. (2021). Yields of Promising Sugarcane Clones under Three Different Planting Arrangements. *AGRIVITA, Journal of Agricultural Science*, *44*(1). https://doi.org/10.17503/agrivita.v44i1.2797

Rianse, I. S., Abdullah, W. G., Hartono, S., Suryantini, A., & Widayati, W. (2016). Financial, Economic And Environmental Feasibility Analysis Of Palm Sugar Domestic Industry In Kolaka Indonesia. *International Journal of Economics and Management Systems*, *1*.

Rodrigues, L. F., Morabito, R., Chiyoshi, F. Y., Iannoni, A. P., & Saydam, C. (2018). Analyzing an emergency maintenance system in the agriculture stage of a Brazilian sugarcane mill using an approximate hypercube method. *Computers and Electronics in Agriculture*, *151*, 441–452. https://doi.org/10.1016/j.compag.2018.06.023

Santoro, E., Soler, E. M., & Cherri, A. C. (2017). Route optimization in mechanized sugarcane harvesting. *Computers and Electronics in Agriculture*, *141*, 140–146. https://doi.org/10.1016/j.compag.2017.07.013

Shrivastava, A. K., Srivastava, A. K., Solomon, S., Sawnani, A., & Shukla, S. P. (2011). Sugarcane

cultivation and sugar industry in India: historical perspectives. *Sugar Tech*, *13*(4), 266–274. https://doi.org/10.1007/s12355-011-0105-1

Silva, R. dos S., Jalal, A., Nascimento, R. E. N. do, Elias, N. C., Kawakami, K. C., Abreu-Junior, C. H., … Zhao, F. (2022). Composted Sewage Sludge Application in a Sugarcane Seedling Nursery: Crop Nutritional Status, Productivity, and Technological Quality Implications. *Sustainability*, *14*(8), 4682. https://doi.org/10.3390/su14084682

Singh, J., Singh, A. K., Sharma, M. P., Singh, P. R., & Srivastava, A. C. (2011). Mechanization of sugarcane cultivation in India. *Sugar Tech*, *13*(4), 310–314. https://doi.org/10.1007/s12355-011-0101-5

Singh, S., Singh, P. R., Singh, A. K., & Gupta, R. (2016). Present status and future need of mechanizing sugarcane cultivation in India. *Agricultural Mechanization in Asia, Africa and Latin America*, *47*(1), 75–81.

Solomon, S. (2016). Sugarcane production and development of sugar industry in India. *Sugar Tech*, *18*(6), 588–602. https://doi.org/10.1007/s12355-016-0494-2

Som-ard, J., Atzberger, C., Izquierdo-Verdiguier, E., Vuolo, F., & Immitzer, M. (2021). Remote sensing applications in sugarcane cultivation: A review. *Remote Sensing*, *13*(20), 4040. https://doi.org/10.3390/rs13204040

Souza, G. S. de, Souza, Z. M. de, Silva, R. B. da, Barbosa, R. S., & Araújo, F. S. (2014). Effects of traffic control on the soil physical quality and the cultivation of sugarcane. *Revista Brasileira de Ciência Do Solo*, *38*, 135–146. https://doi.org/10.1590/S0100-06832014000100013

Sulaiman, A. A., Sulaeman, Y., Mustikasari, N., Nursyamsi, D., & Syakir, A. M. (2019). Increasing sugar production in Indonesia through land suitability analysis and sugar mill restructuring. *Land*, *8*(4), 61. https://doi.org/10.3390/land8040061

Suwandari, A., Hariyati, Y., Agustina, T., Kusmiati, A., Hapsari, T. D., Khasan, A. F., & Rondhi, M. (2020). The impacts of certified seed plant adoption on the productivity and efficiency of smallholder sugarcane farmers in Indonesia. *Sugar Tech*, *22*(4), 574–582. https://doi.org/10.1007/s12355-020-00821-2

Tayibnapis, A. Z., Wuryaningsih, L. E., & Sundari, M. S. (2016). Efforts to Achieve Beyond Sugar in Indonesia. *IJMBS International Journal of Management and Business Studies*, *6*(4), 14–22. http://repository.ubaya.ac.id/36412/

Toharisman, A. (2016). An overview of sugar sector in Indonesia. *Sugar Tech*, *18*(6), 636–641. https://doi.org/10.1007/s12355-016-0490-6

Trimpler, K., Stockfisch, N., & Märländer, B. (2017). Efficiency in sugar beet cultivation related to field history. *European Journal of Agronomy*, *91*, 1–9. https://doi.org/10.1016/j.eja.2017.08.007

Widyasari, W. B., Putra, L. K., Ranomahera, M. R. R., & Puspitasari, A. R. (2022). Historical notes, germplasm development, and molecular approaches to support sugarcane breeding program in Indonesia. *Sugar Tech*, *24*(1), 30–47. https://doi.org/10.1007/s12355-021-01069-0

Zahara, Z. F. (2018). *Economic Assessment of the Sugarcane-based Bio-refinery in Indonesia*. Green Asia Education Center. https://doi.org/10.5109/1936219.