Sugarcane value chain in Kenya

Abstract

Kenya envisioned that 2030 it would have improved citizen livelihood through agricultural industrialization. Some challenges exist in achieving this goal, especially the effects of climate change and technology transfer. Sugarcane production, for instance, has been elusive with several factories in Kenya experiencing losses. In this work, we explore the sugarcane value chain in Kenya compared to other sugarcane-growing regions that have recorded profits from the sugarcane industry. The production matrix of sugarcane in Kenya is approximately 8.7 million metric tons per year. Out of which, approximately 690,000 metric tons of sugar is generated. The remaining biomass is majorly wasted. Major sugar factories in the world earn their profits from this remaining biomass. Kenya needs to impress technology transfer and convert this waste into profitable products.

Introduction

Kenya vision 2030 has been pegged on improving livelihood trough cooperation and sustainability of various materials in agriculture other than industrialization (MoALD, 2023). However, this has not been a walk over due to climate change turmoil and other connective challenges in the economy. Sugar cane production create a value chain advantage whose contribution average 1007 US Dollars/ tons (Mati 2019). MoALD 2023 and economic survey 2022 reported that agriculture sector accounted for 22.4% of the overall Gross Domestic Product (GDP). In Kenya, sugarcane value chain is based on the production right from planting, managing, processing and distribution of the final products (sugar, bioethanol, Molasses and fertilizers) (Monroy *et al*. 2013; Oseko 2015; Arachchinge *et al.* 2020). However, Monroy *et al*. 2013 reported that the production of sugarcane is highly dominated by out growers who also tend to own the factories for production scheme. The total production in Kenya depend on the inputs used during the planting process. Inputs such as fertilizers, sugarcane stalks, personnel, equipment, and treatments using pesticides has been of importance in the realization of steady outputs in terms of profit.

The high demand in milling has resulted to a decline in the end product due to premature harvesting of sugarcane and low production coupled by poor management of sugar industry (Kenya: Sugar

Annual, 2023). According to a report by Kenya: Sugar Annual, 2023, the decline is predicted to low metric tons of 650000 metric tons by the year 2023/2024 due to drought witnessed across the country (MoALD 2023). The decline has also created a gap in employment since there has been unemployment in the sugarcane sector as represented in **Figure 1** (Thuku *et al.* 2019; USPB-001, 2019).

The decline has been a serious concern and has been on a rising trend. This could be due to the aforementioned challenges in sugar industry. The total number of people lost and/or losing their jobs in the sector was for both skilled and unskilled. The major challenge arises from the poor governance of the industries producing sugarcane in Kenya (Economic Survey 2022). A good example is the Mumias Sugar company whose closure led to hit both farmers and employees of about 500,000 families losing their job within the western Kenya region (COTU-K press report 2015).

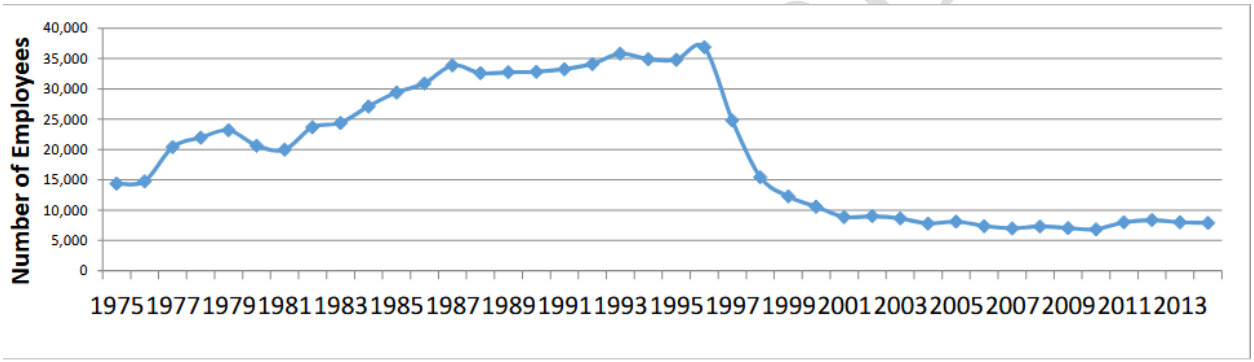

Fig 1: Employment in the sugar industry in Kenya from 1975 to 2014. Source: USPB-1, 2019; Kenya Sugar Board Books. *Accessed on 19/09/2023*

There is also a shift of focus from sugarcane cultivation to other crops in the country apart from increase in the total population. Poor transport within the country has also contributed to delayed delivery of the canes to the factory by the out growers making them shift from the production of canes to other agricultural activities (Mudoga, 2011). Poor and delayed payments has also made the farmers to have mind shift (Kabeyi 2020). Moreover, Mati and Thomas 2019, reported that there was an increase in the area under sugarcane over the years covering approximate 220000 Ha yet production was still low (55 tones/Ha). Contrary to this, a study done by Kamer 2023 reported that in 2021, there was a significant increase in the production of sugar cane approximately to 7.1 million metric tons represented in **Fig 2** (Kamer 2023). Perhaps the negative deviation was due to the aforementioned challenges.

Although Kenya is located within the tropical belt suitable for growing sugarcane, the decline in production has been consistent. Justin Walton 2023 reported that about 80% of the world's sugar is produced from countries located in the tropical and subtropical climate regions. In his report, 20% of the sugar produced come from the sugar beets. Sugar beets are mostly grown in the temperate zones of the Northern Hemisphere (Walton 2023). Some of the top countries growing sugarcane are; Brazil, Thailand, United States of America, China and India (Mati 2019).

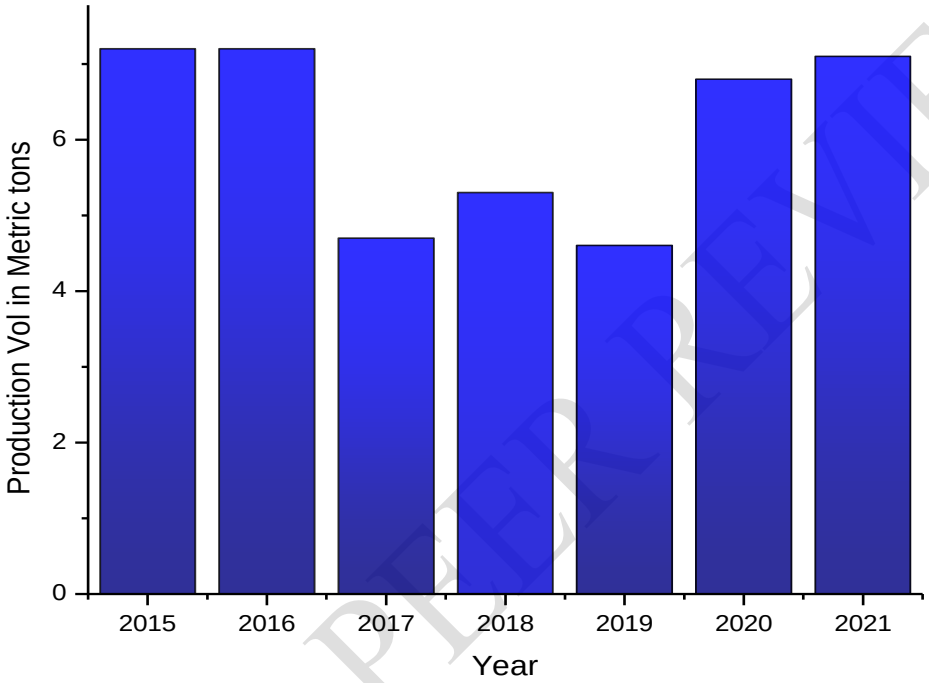

Fig 2: Volume of sugarcane produced in the year 2015 to 2021. Source (Kamer 2023)

Although Kenya has not been listed in the recent reports as the country producing sugar, sugarcane has been grown in some areas mainly for production of consumable sugar (Kenya: Sugar Annual, 2023). In Kenya, Sugarcane is mainly grown in Chemilil, Kibos, Muhoroni, soin, sonysugar, transmara, Mumias, Nzoia, West Kenya and Butali areas elevation ranging from 1300m to 1700m above sea level (Information on Improved sugarcane varieties, 2013). The production of sugarcane however increased slightly as represented in **Table 1** (Economic survey 2023). In Kenya. Apart from a few out growers, many industries are located near the farms growing the canes on a large scale (AFINOL 2018). This is so in order to facilitate swift transportation to the factory.

Meanwhile there is need to discuss sugar processing in Kenya and other top countries producing sugarcane in the world.

Table 1: Production of selected agricultural products (2021-2022). *Source*: (Economic survey 2023)

Crop	Units	2021	2022
Maize	Million bags	36.7	34.3
Wheat	000 Tonnes	349.1	270.7
Rice	000 Tonnes	186.0	192.3
Tea	000 Tonnes	537.8	535.0
Coffee	000 Tonnes	34.5	51.9
Sugarcane	000 Tonnes	7783.3	8707.8
Cut flowers	000 Tonnes	210.1	198.7

1.1 **Sugar cane processing in Kenya**

Sugarcane processing in Kenya involves chain processes that are determined by the quality and quantity of the end product. The chain processes involve two main steps; first, processing of sugarcane into raw sugar and second involves processing the sugar into a refined sugar (Rajindar Singh 2015).

1.2 **Sugar cane Price in Kenya**

Sugarcane price in Kenya is based on the cane weight, Tone Cane/Tone of Sugar ratio, sugar price, net factory sugar price and farmer sharing ratio (MoALD 2023). The formula however, according to MoALD 2023, does not depend on the quality so as not to limit and disadvantage the industry. Currently, the sugarcane rate in Kenyan shillings is between 227.10 and 300 per kilogram in Nairobi and Mombasa (Wamucii 2023). However, the price change depending on the prevailing production factors.

1.3 **Processing of sugarcane into raw sugar**

This involves crushing the sugarcane to extract the juice used in the subsequent steps (Practical action 2009). During this process, the juice is filtered to remove solid particles then boiled (heating up to a temperature of 115℃) to remove excess water molecules (Practical action 2009). The sugarcane bagasse remains after extraction are used as fuel during the boiling and/or used in the production of bioethanol (Practical action 2009; Tse *et al.* 2021; Kumar *et al*. 2014). However, the efficacy of the juice obtained from the canes depends on the employed technology (Practical action 2009). A report from Practical action 2009, indicated that the brix of the juice was influenced by the routine filtration process. Brix indicates the ratio of sugar to water which according to Zoecklein *et al* 2010, may change depending on the physiological conditions of the fruit used (Zoecklein *et al* 2010).

Sugar processing for economies of scale require modern technologies for efficient production (Arachchinge *et al.* 2020). In Kenya, some out growers use local methods to extract juice from sugar cane (Mudoga 2011). This method though local and carried out by small scale farmers, it can be improved for future prospect in sugar industry for sustainability purposes (Mudoga 2011).

1.4 **Local production of sugar cane Juice in Kenya.**

Farmers growing Sugar cane in Kenya not only deliver the harvest to Industries but also extract juice locally to benefit the village surrounding the farms. This could be due to poor roads and decline in the production of sugarcane that affects the quality and quantity require in metric tons (Mudoga 2011). However, locally, the efficacy of extracting the juice was significant containing 65.9% sucrose represented in **table 2** (Mudoga 2011). Meanwhile, the local production and extraction of juice from sugar cane to date is still practiced in various counties in Kenya.

Table 2: Composition of sugarcane juice obtained locally in Kenya. *Source*: Mudoga 2011

Product	Cane Juice
Sucrose	65.9%
Moisture	35.5%
Invert Sugar	0.30%
Mineral Matter (Ash)	0.15%

Organic Non-Sugar	0.13%
Percent solid by refractometer	66.3-66.7%
p H	8.3-8.7%
Sediments	0.05%

Mudoga 2011 reported that, local extraction involves trimming and washing, passing the cane through a sugarcane mill to extract juice, determination of the juice, measurement, evaporation at different rates, purification and evaluation using potential customers represented in **fig 3**.

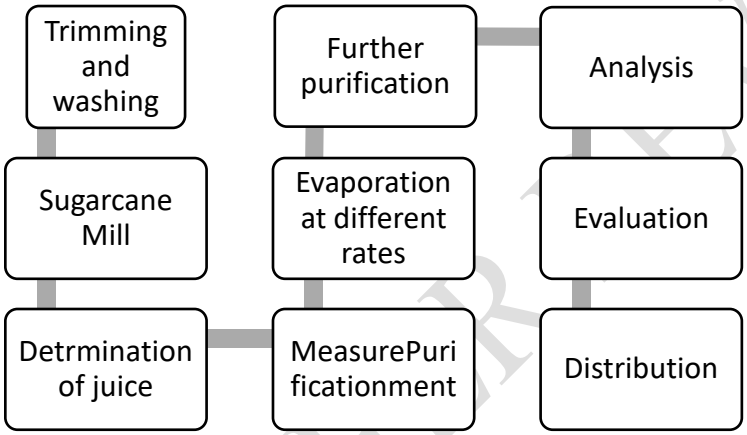

Fig 3: Flow diagram for local juice extraction. *Source*: Mudoga 2011

1.5 **Modern Technology in production of sugar cane Juice in Kenya**.

Development of new techniques has been used in various companies including Mumias sugar company, Kibos sugar company, Muhoroni sugar company, Soin sugar company, Nzoia sugar company, South Nyanza Sugar company, West Kenya sugar company and Chemilil sugar company producing both sugar and bioethanol as the main products (Kabeyi 2020; AFRINOL 2018). The technology typical of proper installed machine and equipment majorly use prototype of local juice extraction methods. Just like in use of local methods in sugar production, modern technology employ various steps to realize the products (Kabeyi 2020). Sugar processing follows the following steps:

i) Cane harvesting

This method involves harvesting mature canes using hand-cutting. The canes are cut and loaded in trucks or trailers to the milling site (Kabeyi 2020). This process is commonly used in the country up

to date possibly due to lack of technology as compared to that in Florida-USA where harvesting is done using mechanical methods like a single-row and combined-style harvester (The sugar Association 2019; Kabeyi 2020).

ii) Crushing and milling to extract juice

The canes are cleaned and crushed by the rollers and crushers to obtain the juice. The conveyors push the canes from one mill to another for further extraction of the juice (Mudoga 2011). Once all the juice is removed from the cane, the remaining stalk without the sucrose is called the bagasse. The bagasse is used as a fuel during the boiling to remove water molecule from the extracted juice (Kabeyi 2020). A report on sugar extraction by Kabeyi 2020, revealed that, for efficiency purposes, lime is added to the juice to neutralize the organic acids and also to control the high temperature raised to approximate 95℃. This whole process leads to formation of a precipitate in the clarifiers separated from the juice after addition of phosphates (Kabeyi 2020). The mud is also separated from the juice using the centrifugal method. The juice is then taken into the evaporators for two processes: to condensate the juice and to crystallize the sugar (Kabeyi 2020).

iii) Evaporation, Crystallization and purification

After juice extraction, the juice is condensate and then crystallized to sugar (The sugar Association 2019). Accord to Kabeyi 2020, The clarified juice is the preheated in the heat exchanger then passed through the evaporation stations heated by steam to remove water molecules (Mudoga 2011; Kabeyi 2020). A number of evaporators are applied typically for obtaining more quality and purified juice without water vapor. This produces a syrup containing 65% solid and 35% water (Kabeyi 2020). The syrup is mixed with lime phosphoric and other polymers flocculants which are aerated and filtered in the clarifier according to Kabeyi 2020.

iv) Crystallization of sugar.

This process occurs in the vacuum pans where sugar crystals are produced from the syrup which is boiled until it reaches super saturation stage to obtain sugar crystals (Kabeyi 2020). According to Kabeyi 2020, the massecuite formed are transferred to high speed centrifuge where the molasses is

separated out whilst sugar remaining in the buckets. After crystallization process, the sugar is then refined by washing it.

1.6 **Byproducts in Sugar Production**

Sugar cane bagasse, molasses and filter cake are the main byproducts obtained during sugarcane milling (Mati 2019). The products have various advantage in building the economy of the country. For example, sugar cane bagasse and molasses are used in the manufacture of fertilizers and in the ethanol production (Monroy *et al*. 2013; Oseko 2015; Arachchinge *et al.* 2020). This is as a result of utilizing economies of scale.

1.7 **Sugar distribution**

Sugar distribution in Kenya is facilitated by segmented sector which attempt to stabilize prices by balancing with the imports (MoALD, 2023). The sugar companies create sustainable distribution to various destinations within the country. The bridging in sugar industry is created in such a way that it cannot affect the cash flow by limiting the retail price (Alex *et al*. 2023). The proper channel has been through satisfaction by Kenya Bureau of Standards (KEBs) which control the entry of sugar from the companies into the market. The control is based on liaison with the Kenya Sugar Manufacturer Association (KESMA) which was formed for the interest of the millers (MoALD, 2023; Sugar subsector strategic plan 2021).

There has been a rise in the total production cost from 2018 due to climate change and cost of production averaging 1007 US Dollars/ton (Mati and Thomas 2019). The cost of sugar processing in Kenya (USD 832 per tonnes) is higher than other countries producing the same quality and quantity of sugar (MoALD, 2023; Alex *et al*. 2023). The turmoil in sugar industry in terms of production has been due to a number challenges such as technological economics, agronomics, mismanagement and policy limitations (Mati and Thomas 2019), According to Mati 2019, Kenya has been one of the sugar importer since 1980s due to the aforementioned challenges that led to decline in productivity unlike other top sugar cane producing countries: USA, Brazil, Thailand, China and India (Mati 2019). According to the report, before then, Kenya was exporting sugar.

1.8 **Export and Importation of Sugar in Kenya**

Sugar import has been rising due to the decline in the production of sugarcane in Kenya (MoALD, 2023; Sugar subsector strategic plan 2021). Mati 2019 reported that since 1980s Kenya has been frontier in importing raw sugar in order to curb the crisis witnessed in in decline in sugar production. Kenyan government imported approximately 72.6Million in Raw sugar, placing it as the 33rd largest of raw sugar in the world (Economic complexity in Kenya report, 2021). However, in 2021, Kenya exported raw sugar averaging 66.6Million in raw sugar to Rwanda, Malawi, Tanzania, Niger and democratic Republic of Congo (Economic complexity in Kenya report, 2021). The import in this case was higher than the respective export made in 2021. According to Economic complexity in Kenya report, 2021, raw sugar, import in the same year was the most imported product from Zambia (6.51M), Zimbabwe (4.7M), Eswatini (34.1M), Mauritius (18.5M) and Egypt (3.29M) (Economic complexity in Kenya report, 2021). Moreover, Kenya imported approximately 16,615 metric tons of white/brown sugar amounting to 8000 metric tons (Statista 2023)

1.9 **Government involvement in sugar industry**

Although there has been minimal result at both ends of the sugar industry, the government is frontier in sourcing out various robust modern technologies in favor of sugar industry in Kenya (MoALD, 2023; Alex *et al*. 2023; Onyango 2018). The incentives and moral support have been given to the farmers to enhance effective production of sugar cane in the country. This was done by lowering the total cost of production to mitigate the effect (Onyango 2018). Such favors are implemented to stimulate growth of the industries dealing both in sugar and ethanol production. Examples include subsidizing the cost of fertilizer, renovation of the machines, free education on agricultural planning and other benefits such as good Sacco for farmers, writing off of loan portfolio, payment of loans owed by the companies to the farmers and revival of the industries like Mumias sugar company.

However, encroachments of the rapid growing population have reduced the total land used for sugar cane cultivation (Kabeyi 2020). This is due to shift in farming. In addition, delayed payment and poor pays has been a challenge in the sector. This reduces the morale of farmers hence leading to change of plan in farming causing a decline in the production of the sugar canes (Kabeyi 2020).

2.0 **Sugarcane production in East Africa**

2.1 **Sugarcane value chain in Uganda, Tanzania**

Sugarcane production in Uganda takes same trend just like in Kenya. However, there was an increase in the quantity produced in 2021 averaging 5.37 million Tonnes (Knoema 2022). According to Knoema 2022, the change has been increasing with minor negative deviations as represented in **table 3**. The sugarcane production is also pegged on improving the social-economic aspects of youths within the country to foster and sustain quality livelihood of the population (Mwanika *et al*. 2021).

Table 3: Marginal quantities of *Saccharum Officinarum* produced from 2010 to 2021. Source: https://www.knoema.com

Year	Quantity (Tonnes)	Deviation, %
2010	3320000	_
2011	3650000	9.94
2012	3750000	2.74
2013	4600000	22.67
2014	4650000	1.09
2015	5225000	12.37
2016	5200000	-0.48
2017	5327000	2.44
2018	5503000	3.30
2019	5500000	-0.05
2020	5360000	-2.55
2021	5369184	0.17

In Kenya the socio-economic activities are not necessarily linked on sugar production alone. Otherwise climate change as a factor of concern has led to diversity in economic and agricultural activities in order to curb and mitigate the effect (UN-Habitat, 2022). This is as a result of change in weather patterns witnessed in northern and eastern part of Kenya (MoEF 2023). However, in both countries there was COVID-19 economic disruptions alongside corruption and economic inequality (Economic growth and trade, 2022). The report (Economic growth and trade 2022) indicated that

Kenya had built a dynamic and diverse economy by ascertaining an economic growth of 5.9% between 2010 and 2018 contributing 95 billion Kenyan shillings to the GDP. Part of Uganda has faced the same climate change effect although the contribution of the sugarcane to the GDP was approximately 15% (Martiniello et al. 2021).

Uganda sugarcane farming is also practiced by out growers where the sustainability is controlled by farmers and Uganda Manufactures Association (UMA) while in Kenya the production and millers are controlled by Kenya Sugar Manufacturer Association (KESMA) (Martiniello *et al*. 2021; MoALD 2023; The EastAfrican by Anami 2021). However, there are various associations in Uganda which has been on course to involve sugarcane out growers in order to bring them on board for international sugarcane production world chain (Martiniello et al. 2021). There has been growth of political fragmentations within the country embedded on sugarcane production value chain. This was as a result of massive increase in the production of sugarcane from 1476215Tonnes in 2000 to 4892047 Tonnes in 2019 (FAOSTAT, 2021; FAOSTAT, 2022; Martiniello *et al*. 2021). Moreover, according to the report, there was a significant increase in the total hectare from 20000ha to 70000ha during the production. This is pegged on contract schemes which is susceptible to global development agencies stating as a way of "grabbing land" which promote inclusive development via integration of smallholders (Martiniello 2020). Therefore, Uganda as compared to Kenya has done much well as first in East Africa in terms of sugar production by producing approximately 514000 metric tons and Kenya being the second producing approximately 441 000 metric tons in 2019 (Statista 2023; Anami, 2021). Tanzania and Zambia was taking the 3rd position producing 436 000 metric tons (Statista 2023). In the newsletter, the EastAfrican by Anami on January 14 2021, Kenya imported 90,000 Tonnes of sugar from Uganda after exhausting its import quota in 2020. Moreover, the report indicated that Uganda had 11 sugar mills producing 510 000 Tonnes versus the consumption of 360, 000 Tonnes giving the country upper hand to export the rest of the sugar. In Kenya a total of 690, 000 metric Tonnes of sugar was produced and still was low for the total consumption (Kenya: Sugar Annual 2022). In addition, the report also confirmed a prediction of decline in the production in the preceding year 2022/2023 from 69000 metric tons to 660000 metric Tons (Kenya: Sugar Annual 2022).

2.2 **Top countries in Sugarcane production**

Top producing countries such as Brazil, United States of America, India, India, Thailand and China has adequately employed modern technologies unlike in developing countries such as Kenya where the technology applied in sugar industry is not much developed (Walton 2023). The sustainability typical of sugarcane production parameters are highly evaluated to stimulate the production schemes. This is facilitated by continuous evaluation of the current methods applied in sugar cane production and the political stability that might affect the sector (Walton 2023). Walton through Investopedia 2023, reported that of more than 110 countries producing sugar, their contribution is affected by local politics and set economic policy. A good example is the estimated decline of sugar beet production by 23% in the year 2023 (Walton 2023).

In Kenya local politic has led to a deprived sugarcane production schemes due to increased political instability and other factors such as mismanagement of the sugar industries and the witnessed corruption such as that witnessed in Mumias Sugar company.

a). **Brazil**

Brazil, one of the largest sugarcane producer in the world has not only been producing sugar for human consumption but also for bioethanol production (Rossi *et al*. 2021; Antunes *et al*. 2019; Zhang and Govindaraju 2018)). Brazil produced approximately 621million metric tons of sugarcane crop (Sugar Annual report 2023). In 2021 Brazil produced 29.98 billion liters of ethanol where by in 2022 the quantity was predicted to rise by about 9% (Ethanol producer magazine 2022). However, Walton 2023 reported that the country resolved a decision of shifting a fraction of sugarcane crop from ethanol to sugar production. Sugarcane production in Brazil since 1990s has tripled due to a high demand of sugar and bioethanol as a fuel represented in **table 4** (Rossi *et al*. 2021; Walton 2023). On the other hand, Kenya main aim of sugarcane production is for the production of sugar for human consumption otherwise by serendipity, bioethanol is produced as a result of large quantities of

byproducts (Mati *et al*. 2019). Unlike in Kenya with a total of 11 sugarcane millers apart from private millers, Brazil sugar sector have approximately 432 mills and distilleries which crush about 625 million tons of sugarcane /crop producing about 27 billion liters of ethanol and 38.7 million tons of sugar (Rossi *et al*. 2021; Economic complexity in Kenya report, 2021). The millers have very little interference from political waves since they are fully supported by the government (Mati 2019).

Table 4: Sugar and ethanol production in Brazil

Harvest year	Sugar (000 tons)	Change (%)	Ethanol (thousand M^3)	Change (%)
1980/81	8.25	_	3.70	-
1985/86	8.03	-3	11.83	219
2000/01	16.19	102	10.59	-10
2010/11	38.00	135	27.38	158
2012/13	38.24	1	23.23	-15
2016/17	38.73	1	27.25	17

Source: *Antunes et al. 2019; UNICA 2017).*

The attribute to its climatic conditions has contributed to sugarcane production and in the growth of sugar and bioethanol industries due to its location in the tropical and sub-tropical parts of the world. (Antunes *et al*. 2019). Antunes (2019) affirmed that Brazil has large size of land set aside for sugarcane production and the presence of extensive river basins. The sugar sector in Brazil has contributed approximately 8% to its Gross Domestic Product (GDP) (Brinkman *et al*. 2018; Defante *et al*. 2020; Economic Research Service 2022). However, even though Agricultural crop production has accounted 15% to the GDP, the quantity produced is much lower as compared to that in Brazil (Josephat Kombo and Alice Ndiema 2022).

Furthermore, the large production of bioethanol from sugarcane has highly replaced the use of fossil fuels in the country reducing the carbon emission which contribute to the greenhouse effect and global warming (UNEP 2019). The government set policies are geared towards mitigating the detrimental impact caused by carbon emission originating from fossil fuel in the country (Antunes et 2019; Rossi *et al*. 2021).

Pro-Alcool *program* initiative in Brazil was a government agenda to support the bioethanol production in Brazil where technology and good political governance was launched to replace gasoline vehicles with ethanol designed vehicles (Antunes et al 2021; Barros *et al* 2014). In Kenya,

there is less bioethanol produced from the sugarcane since the sole aim of the sugarcane production is for sugar. Ferraz *et al*. 2021, reported that sugar production has led to a positive rise in the average number of people employed in Brazil; unskilled employee was declining while the skilled employees were increasing as represented in **figure 4**.

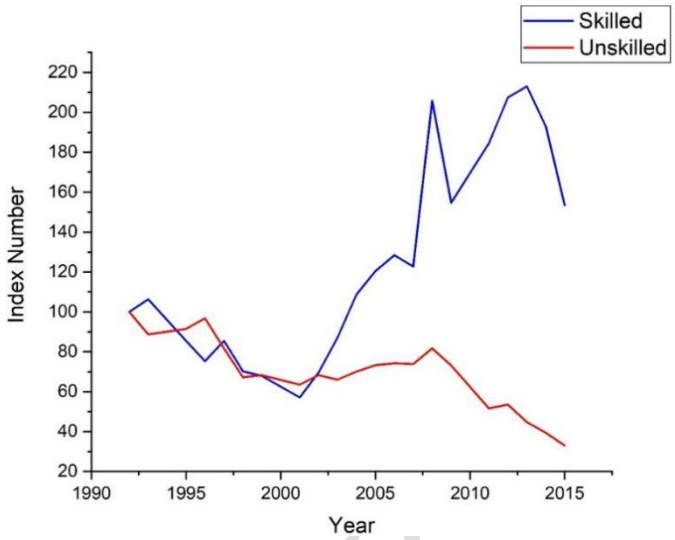

Figure 4: Number of people employed (Skilled and unskilled) in Brazil from 1992 to 2015. Source: (IBGE data 2019: Ferraz et al. 2021).

The average schooling of people as a requirement in sugarcane sector was still low. **Figure 5** represents a total number and the evolution of the average years of studies of employed individuals in Agriculture and sugarcane production vis a vis other agricultural activities in Brazil between 1992 to 2015.

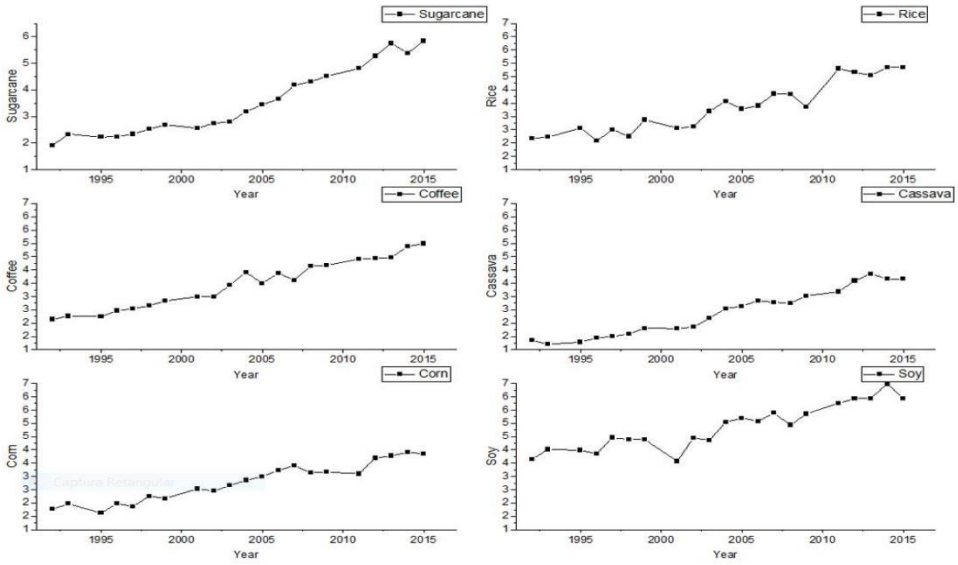

Fig 5: Average years of studies of employees in Agriculture and sugarcane production and others Agricultural activities in Brazil from 1992 to 2015. Source: (IBGE data 2019: Ferraz et al. 2021).

b). **United States of America (USA)**

United States of America produced over 34.6 million tons of sugar cane in 2022 rating it among the top 5 countries in the world with a massive sugarcane production (Statista 2023). According to the report (Statista 2023), 180 million tons of sugar are produced globally. However, Brazil dominated the world market in sugarcane production (Statista 2023). In the United State of America, total area of sugarcane production is 928.65k acres producing 8.42 million metric tonnes of sugar. The consumption of sugar in US is approximately 11.5 million metric tons whilst India being the leading sugar consuming country in the world amounting to 29.5 million metric tons (Statista 2023). As compared to Kenya, production of sugarcane, export of sugar, import and consumption are very low as compared to U.S.A Sugar industry.

U.S.A has invested in both sugar beets and sugarcane production for sugar in the country. Sugarcane has been the most viable perennial plant for the production of sugar in the country. For this reason, Acreage for sugar production rose from 704 000 acres in 1980s to 903 400 acres in filial year 2020/21 leading to a growth of sugarcane from 2.91 million metric tonnes to 4.251 million STRV in the same period (Economic Research Service 2021).

I. Sugarcane production in United State of America

Unlike in Kenya, Value added products in U.S.A such as sucrose are used as a sweetening agent for foods and in the manufacture of other food staffs such as soft drinks, candies, preservatives and cakes (AgMRC 2022; Sugar and sweeteners outlook, 2022). According to the report (AgMRC 2022) other value-added products are Blackstrap molasses, Bagasse, Ethanol and electricity. Moreover, currently sugarcane in the U.S is mechanically harvested. The byproducts such as molasses are often used for the production of paper, plastics, mulching building boards or for animal bedding (AgMRC 2022). However, corn-derived sweeteners are also used in the same way as sugar (Sugar and sweeteners outlook, 2022).

II. Sugar processing in U.S.A

Sugar processing in United States of America is achieved through two steps: 1. Sugar mill crushing and 2. Sugar refinery extraction. This involves processing raw sugar at the harvesting field due to transportation cost (AgMRC 2022). The sugar is then shipped to the refineries to refine the raw sugar. According to the report by economic research service 2022, U.S relies on refined sugar imports from Mexico and Central America son as to meet the high demand of the market. In U.S, the number of sugarcane millers declined remaining with approximately 16 mills: 11 mills in Louisiana, 4 in Florida and 1 in Texas (AgMRC 2022). AgMRC 2022 report indicated that as the mills were declining, the efficacy of the mills increased significantly.

III. U.S government Policies

American Sugar Alliance, 2021 reported that the government resolved to support the farmers and millers by introducing a policy: No-cost sugar policy which was to ascertain and promote the domestic production displaced by subsidized foreign-produced sugar. According to the report, the farm bill is reauthorized for every five years which authorized the U.S Department of Agriculture to offer loans on the stored sugar. In this case the farmers use the loans to pay their bills and other charges are sorted by the government by storing the sugar for the customers. Furthermore, in the bill, the USDA is mandated to monitor the amount of sugar produced domestically and the one to be exported to the foreign countries. Approximately Thousands of metric tons of sugar are exported to about 40 countries (Outlook of the U.S and World Sugar Markets, 2011). U.S has been one of the country that import sugar for its sustainability.

c). India

India is another top five sugarcane producer in the world producing over 35 million metric tons by financial year 2022/2023 (Statista 2023). Out of 35 million tons approximately 29 million metric tons are consumed domestically (Statista 2023). Statista 2023 report indicated that India sugar export rose to approximately 7 million metric tons as the government was immensely working on the export control to prevent domestic shortages in the country. Area planted for sugarcane production also increased to 5.6 million hectares in order to increase the total metric tons produced in the country. Despite the high rate of consumption in the country, the government has also enhanced and incorporated ethanol production for economies of scale (Statista 2023; Arun and Premkumar, 2022). Sugarcane production has been given an upper hand after cotton as the subsidiary agricultural activity in the country (Arun and Premkumar 2022). India is one of the largest sugar consumer country in the world, consuming approximately 2.6 crore tons. Brazil dominating the market with a total of about 45% of the global exports, India has shown the same rising trend in its sugar exports (Arun and Premkumar 2022). As such, robust mechanisms have been developed in the country making the sugar industry most viable for economies of scale and for the county's future prospects. The trend in sugar production marginal increased from the 2000-01 to 2017-18 as represented in **table 5.** As compared to export rate (19.29%), importation of sugar in the country was higher averaging 37.34% in 2016-17.

Table 5. Area, production and productivity of sugarcane in India.

S. No	Year	Area (in '000 Hectare)	Production (in '000 tons)	Yield (kg/Hectare)
1	2000-01	4315.5	295955.3	68580
2	2001-02	4411.5	297205.4	67371
3	2002-03	4519.8	287369.4	63580
4	2003-04	3938.1	233858.9	59384
5	2004-05	3661.3	237082.7	64754
6	2005-06	4201.4	281165.9	66922
7	2006-07	5151	355520	69022
8	2007-08	5055	348188	68879
9	2008-09	4415	285029	64553
10	2009-10	4175	292302	70020
11	2010-11	4884.8	342381.6	70091
12	2011-12	5037.7	361036.5	71668
13	2012-13	4999	341200	68254
14	2013-14	4993	352142	70522
15	2014-15	5067	362333	71511
16	2015-16	4927	348448	70720
17	2016-17	4436	306069	69001
18	2017-18	4737	379905	80198
	CGR	0.52	1.40	0.87

Source: (Ministry of Agriculture and farmers' welfare. Government of India; Arun and Premkumar 2022).

Major sugarcane producing states in India.

Major sugarcane producing states in India is Uttar Pradesh and Maharashtra; with a significant increase in both area of production and the yield of sugarcane in metric tons are represented in **table 6**. The data was compiled from DES, Government of India (Upreti and Singh 2017).

Table 6. Area, production and yield of sugarcane in Uttar Pradesh and Maharashtra, India

	Uttar Pradesh			Maharashtra		
	Area (lakh ha)	Production (million tonnes)	Yield (tonnes/ ha)	Area (lakh ha)	Production (million tonnes)	Yield (tonnes/ ha)
2000-01	19.38	106.07	54.72	5.95	49.59	83.35
2004-05	19.55	118.71	60.73	3.24	20.47	63.19
2009-10	19.77	117.14	59.25	7.56	64.16	84.87
2014-15	21.41	133.06	62.15	10.3	84.70	82.23
CAGR (2000-2015) %	0.59**	1.1**	0.51	6.01*	7.09**	1.03

Source: compiled from DES, Government of India (Upreti and Singh 2017)

Although some states in India have made a great achievement in sugar industry, Brazil has been dominating the sugar market in the world due to large population in India that has high demand for sugar consumption rate. In India, central government regulates the sugar industry while the state government controls the supply and distribution of the sugarcane (FAO 2023).

d). Thailand

Sugarcane production is one of the most valued and viable agricultural activity that has contributed to economic sustainability of the country (SEI 2021). Sugarcane crop being a vital economic crop in Thailand, a lot of inputs both from the farmers and the government has been used to sustain the production of the crop (Statista 2023). Thailand produced 66.8 million metric tons in 2021 and after evaluation there was a projection of producing approximately 85.5 million metric tons by 2022 (Statista 2023). Main product obtained from sugarcane in Thailand is sugar and ethanol. However, according to report (Thailand: Sugar Annual 2023), decrease in sugarcane acreage in Thailand led to reduced sugar production. The same report indicated that there was a significant increase in exports of sugar in the MY2022/23 due to large exportable supplies and more shipping containers for refined sugar (Thailand: Sugar Annual 2023). Other products such as molasses from sugar production is used in the production of ethanol as a fuel in the country. However, in MY2023/23, there was a reduced molasses production that had a detrimental impact on the subsequent ethanol produced in the country (Thailand: Sugar Annual 2023). As compared to Kenya, the efficacy of sugar production in Thailand is much higher due to advanced technology applied in sugarcane production.

Sugar consumption by 2020 reached 38.7 Kg per capita which was low as compared to the maxima value of approximately 39.3 Kg in 2011 rating it as the 23rd country out of 265 countries in terms of sugar consumption per capita. (Faostat 2023; Sugar consumption per capita in Thailand 2023). The change in weather patterns caused by climate change such as drought has caused a slight decline in the total production of sugarcane in Thailand (SEI 2023). However, in Thailand most farmers burn the cane before harvesting for ease of harvesting and clearing of the weed (SEI 2021). SEI 2021 report revealed that sugarcane burning in Thailand and Mekong region highly contributed to high air pollution caused by carbon emission. The emission cause greenhouse effect and global warming that in turn cause adverse change in weather patterns that led to climate change (Thailand Economic Monitor 2023). For this reason, quotas are introduced in the country: that the cane brought to the sugar mill should be at least 70% fresh cane and only 30% burnt (SEI 2021).

Unlike in Thailand, Kenya has been frontier in fighting climate change nightmare caused by carbon emission. In this case, no sugarcane burning is allowed in the country before harvesting for ease of harvesting or for any other reason of clearing the weed. As such, low quality sugar is attached to such reasons due to destruction of the sucrose in the juice extracted from the canes. Thailand low sugarcane production has been attributed to the reduced sugarcane acreage (Thailand Sugar Annual 2023). According to Thailand Sugar Annual report, there was need to increase of fertilizers due to reduced price of fertilizers for farmers. However, due to low sugarcane price in the country, small scale farmers have shifted farming activities of sugarcane production to planting cassava due to attractive high selling price realized in cassava market (Thailand Sugar Annual 2023). According to the report, Sugarcane production industry in 2018 recorded the highest produce of sugarcane amounting to 135 million metric tons. However, since then, there has been low produce due to decline in sugarcane acreage in Thailand as represented in **Figure 6** (Thailand sugar annual 2023).

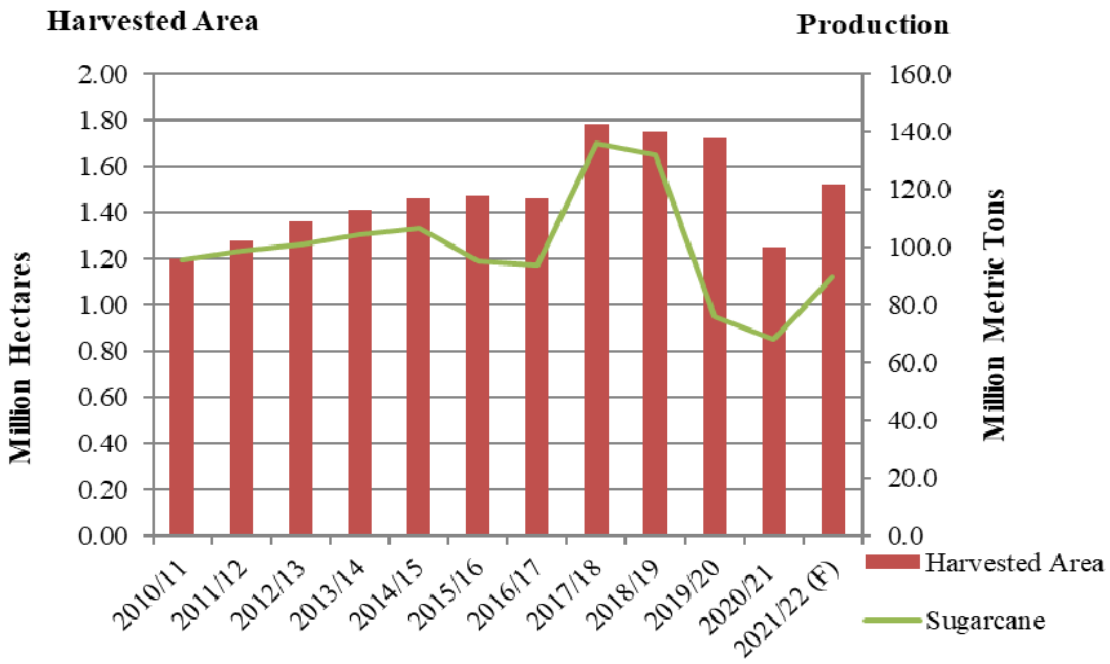

Figure 6. Thailand's sugarcane area and production from 2010/11 to 2021/22

Source: Thailand Sugar Annual 2023. Accessed on 23/09/2023.

Sugar refinery in Thailand goes through similar processes as stated in other Sugar Annual reports. However, apart from sugar production, Thailand produce ethanol (approximately 66 million metric tons) from molasses accounting 60% of the total ethanol produced in the country (Thailand: Sugar Annual 2023). According to the report (Sugar Annual 2023), post forecasts MY2023/24 sugar production (**figure 7**) to increase approximately to 11.2 million metric tons which will also result to a steady increase in the total molasses produced to 3.4 million metric tons.

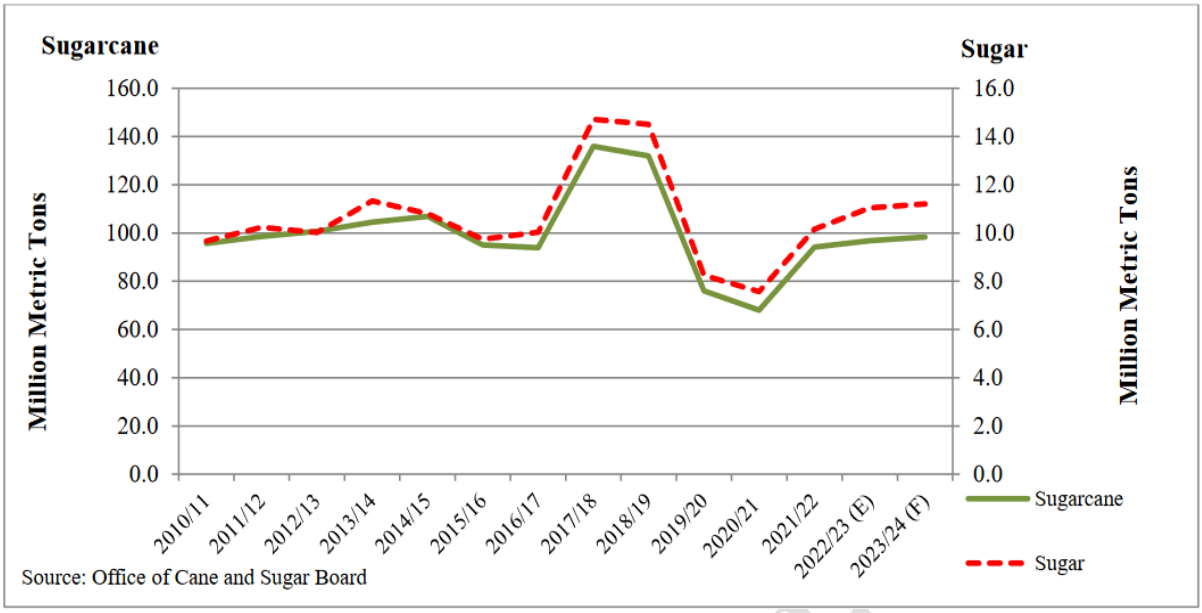

Figure 7. Thailand sugarcane and sugar production. Source: Thailand: Sugar Annual 2023.

Thai recommend that at least the consumption of the sugar should be 40 to 55 g/day, though is much low as compared to the quantity consumed median intake of sugar and sweeteners for all age groups ranging from 2.0 to 20.0g per day and 2.0 to 15.7 g per day was realized (Wantanee *et al*. 2018). Meanwhile, Thailand sugar annual report 2023 indicated that post forecasts MY2022/23 and 2023/24 sugar annual was to increase to 3.1 million metric tons and 3.2 million metric tons respectively. This was as a result of strong demand from an export- oriented food processing industry within the country.

Export and imports in Thailand

Thailand economic growth is also linked to improved sugar exports to other countries represented in **table 7**. This is as a result of million metric tons of sugar produced from the sugarcane production. The government introduced policies has also moderated and controlled the white sugar exports (Sugar annual 2023). The removal of various quotas (A, B and C) was made by the government after enacting the new cane and sugar Act, B.E 2565 (2022) from the old (enforced sugar sale administration) one in order to deregulate domestic sugar price controls (Thailand sugar annual 2023). The needful act was used to control the profit margin and control of sugar price as per the quantity of sugar produced in the country. Unlike in Thailand, Kenya regulate sugarcane and sugar production based on the tax (MoALD 2023). According to the report (Thailand sugar annual 2023), the government of Thailand also delisted sugar from the list of controlled goods and services basing on the low price of sugar in

the world market. The retail price of white sugar increased by approximately 5% to 23baht/kg in 2022. Perhaps this partly affected Kenya imports since Kenya was one of the country export white sugar from Thailand as represented in **Table 7** (Thailand. Sugar Annual 2023).

Table 8. Exports of White and refined sugar from 2017 to 2022.

Destination	2017	2018	2019	2020	2021	2022	% Change
Cambodia	863,428	792,923	787,578	453,096	549,136	627,614	14.3
Laos	180,519	147,197	278,583	114,554	140,918	460,281	226.6
Philippines	59,324	180,929	6,793	153,946	171,815	401,816	133.9
China	328,553	324,685	382,279	269,127	140,582	246,495	75.3
Indonesia	109,274	105,576	132,849	64,392	123,111	196,940	60.0
Burma	639,831	965,135	241,548	123,447	109,772	116,063	5.7
Tanzania	2,848	12,257	100,182	7,386	26,750	113,270	323.4
Singapore	106,875	140,519	-	119,871	103,336	105,256	1.9
Kenya	3,808	8,137	67,743	691	-	96,926	-
South Korea	96,080	122,056	219,989	107,544	98,802	93,287	-5.6
Vietnam	135,455	116,347	103,138	809,392	238,108	73,212	-69.3
Malaysia	101,490	180,929	23,557	92,646	106,327	72,682	-31.6
Sri Lanka	50,778	40,557	7,223	-	27,037	15,110	-
Brunei	3,980	8,019	6,368	5,899	6,006	4,626	-23.0
UAE	18,216	7,486	22,598	19,738	5,161	3,100	-39.9
Pakistan	1,022	455	-	-	54	2,113	-
Maldives	-	749	-	-	1,202	1,498	-
Russia	-	-	-	-	-	54	-
Saudi Arabia	107	1,712	168,313	-	-	24	-
Bangladesh	2,167	2,836	27,052	910	910	8	-99.1
India	3,853	535	-	-	-	-	-
Iran	5,861	1,629	-	-	-	-	-
Jordan	-	268	-	-	-	-	-
Others	1,142,906	1,585,010	2,034,587	501,584	304,594	575,331	88.9
Total	**3,856,375**	**4,745,946**	**4,610,380**	**2,844,223**	**2,153,621**	**3,205,706**	**48.9**

Source: Thailand: Sugar Annual 2023.

e). China

Sugarcane production in China take another notch where modern technologies are used in the farming process. China's sugarcane production amounted to over 103,38 million metric tons (Statist 2023; Knoema 2022). In regard to this China is the world's third largest country. Unlike other top 5 countries, china has approximately 270 sugar mills that are set to meet the basic sugar supply in the country (Zhang and Govindaraju 2018). At least of all the mills, 37 are for used in sugar beets and 11 for refinery. Zhang and Govindaraju 2018 reported that sugar industry contributes about 6 – 8 billion RMB. China use different sugar varieties during planting on order to realize a massive sugarcane production that will boost livelihood of the farmers and boost counties economy. For this reason,

Zhang and Govindaraju 2018 reported that the average sucrose content increased from 13% to more than 14.5%.

In china cane production, yield, quality and quantity has increased steadily in the past 60 years (Zhang and Govindaraju 2018). Total area used to plant sugarcane extent from 0.108 million to 1.827 million producing a yield of 24 to 67.4 tons/ha while the production ranging from 0.15 million tons to 10.6 million tons as represented in figure 8 (Zhang and Govindaraju 2018).

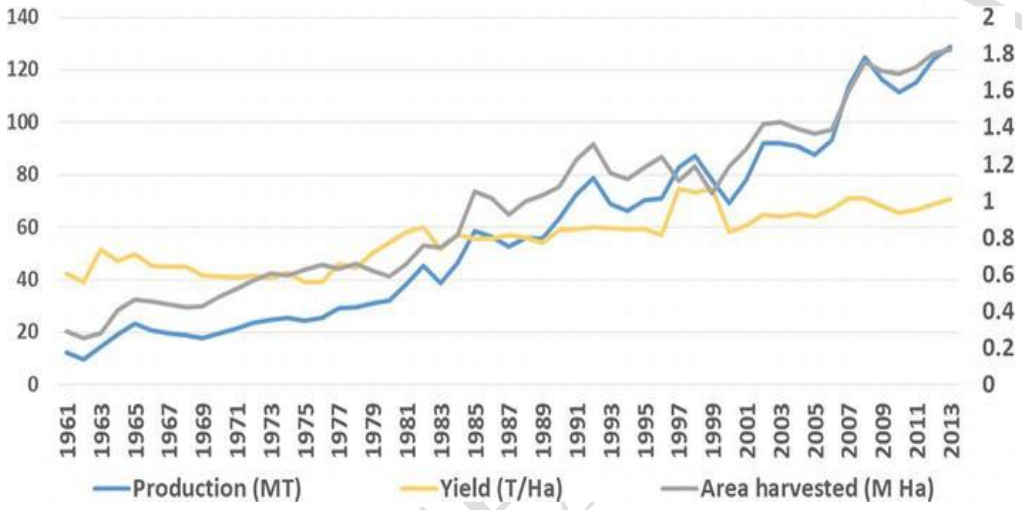

Figure 8. Sugar production in China from 1961 to 2013. Source: (Zhang and Govindaraju 2018. Sugar production in China).

China Sugar processing

In china, processes such as planting, weeding, spraying pesticides, harvesting and other hands on activities are done with small scale farmers and this is seen as a new challenge due to low quantity of sugarcane produced (Zhang and Govindaraju 2018). Otherwise, in more developed areas, sugarcane production is done using modern technologies. Other challenges such as over use of nitrogenous fertilizers have been reported as a challenge in China sugar production. (Zhang and Govindaraju 2018). Excessive use of fertilizers as reported in recent research has contributed to destruction and interference of micro fauna and flora in the soil.

Sugar processing in China takes the same mechanism just like in the aforementioned countries; that includes sugar crushing to extract juice, filtration, crystallization, and refinery of raw sugar to obtain

purified sugar (Zhang and Govindaraju 2018). Although corn and cassava has been a main feed stock for ethanol production in China, the byproducts from sugarcane production such as molasses and bagasse are also used in the ethanol production (Zhang *et al*. 2017).

Chinese sugar consumption is estimated to be 15 to 16 million tonnes of sugar and approximate annual sugar production in China is about 10 million tonnes (Rosa Li 2023). China sugar exports was estimated to be 180 thousand metric tons in 2022, which is slightly lower than the aforementioned countries but higher than that exported by Kenya (Statista 2023).

2.3 **Possible suggested ways to improve Kenya sugarcane value chain**

Kenya sugarcane value chain has majorly suffered from lack of crucial policy that will be viable for the sustainability of sugar industry. This can be done through mutual understanding between the farmers, millers, and the government through Memorandum of understanding which will involve the entire parties. Similar routine can be employed in determining the cost of production as illustrated by Onyango *et al*. 2018.

Alarming issues such as theft, delayed harvesting, change in weather patterns such as drought and el Nino rains, high input costs, cane fires, declining land size due to shift in agricultural activities, infective extension systems, political instability and agricultural unawareness in terms of education are the main challenges that has affected the Kenya sugar industry (Onyango *et al*. 2018). As reported by Mati 2019 and Onyango *et al*. 2028, Kenya has been an importer of sugar since 1980s and since then the gap has been widening to date. As such, there is need to set different policies such as those set in Thailand in order to reduce the quantity imported annually. However, this can be possible if the root of challenge is identified. Implementation of irrigation schemes to curb the gap caused by change in weather patterns. Onyango et al. 2018 reported that Kenya had the lowest recoverable sugar yields of less than 5 tons per ha which was relatively low as compared to its counter parts: 9.3 tons/ha in Brazil and 6.8 tons/ha in Tanzania. He reported that, the highest recoverable sugar yield was in Mozambique which was attributed sufficient irrigation systems, use of modern early maturing sugarcane varieties and good post-harvest practices such as crushing sugarcane within a 12 hour unlike in Kenya which takes 48 hours (Onyango et al. 2018). The longer the sugarcane stay the faster the sucrose deteriorate.

Kenya and Tanzania has had low extracting rate ((11%)) of sugar from sugarcane as compared to Brazil (13%) and Mozambique 12.5% due to low and poor machinery and use of local methodologies. Use of modern technology in Kenya sugar industry perhaps will stimulate and effectively improve.

County government and the Agriculture and food Authority (AFA) agencies should be supported by the National government to undertake their key functions and regulatory to enable efficient operation of all activities in Sugar industry in Kenya (Onyango *et al*. 2018). In addition, production cost should be regulated in order to compete favorably with other sugarcane producing countries for economies of scale. Minimize and/or remove political interference in sugar industry.

Conclusion

The sugarcane value chain system requires proper adjustments and the relevant government policies that can enhance suitable profit margins. Moreover, research on suitable sugarcane variety should be done in order to identify most suitable cane that take shortest time possible to mature. Farmers and millers should be trained more concerning sugarcane production Kenya sugar industry can be the most viable agricultural activity that will contribute to the gross domestic product (GDP) of the country. Therefore, there is need to revive the sector with an immediate effect.

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