



# Sugarcane

**Sugarcane** or **sugar cane** is a species of tall, perennial grass (in the genus *Saccharum*, tribe *Andropogoneae*) that is used for sugar production. The plants are 2–6 m (6–20 ft) tall with stout, jointed, fibrous stalks that are rich in sucrose,<sup>[1]</sup> which accumulates in the stalk internodes. Sugarcanes belong to the grass family, *Poaceae*, an economically important flowering plant family that includes maize, wheat, rice, and sorghum, and many forage crops. It is native to New Guinea.<sup>[2]</sup>

Sugarcane was an ancient crop of the Austronesian and Papuan people. The best evidence available today points to the New Guinea area as the site of the original domestication of *Saccharum officinarum*.<sup>[3]</sup> It was introduced to Polynesia, Island Melanesia, and Madagascar in prehistoric times via Austronesian sailors. It was also introduced by Austronesian sailors to India and then to Southern China by 500 BC, via trade. The Persians and Greeks encountered the famous "reeds that produce honey without bees" in India between the sixth and fourth centuries BC. They adopted and then spread sugarcane agriculture.<sup>[4]</sup> By the eighth century, sugar was considered a luxurious and expensive spice from India, and merchant trading spread its use across the Mediterranean and North Africa. In the 18th century, sugarcane plantations began in the Caribbean, South American, Indian Ocean, and Pacific island nations. The need for sugar crop laborers became a major driver of large migrations, some people voluntarily accepting indentured servitude<sup>[5]</sup> and others forcibly imported as slaves.<sup>[6]</sup>

Grown in tropical and subtropical regions, sugarcane is the world's largest crop by production quantity, totalling 1.9 billion tonnes in 2020, with Brazil accounting for 40% of the world total. Sugarcane accounts for 79% of sugar produced globally (most of the rest is made from sugar beets). About 70% of the sugar produced comes from *Saccharum officinarum* and its hybrids.<sup>[7]</sup> All sugarcane species can interbreed, and the major commercial cultivars are complex hybrids.<sup>[8]</sup>

White sugar is produced from sugarcane in specialized mill factories. Sugarcane reeds are used to make pens, mats, screens, and thatch. The young, unexpanded flower head of *Saccharum edule* (*duruka*) is eaten raw, steamed, or toasted, and prepared in various ways in Southeast Asia, such as certain island communities of Indonesia as well as in Oceanic countries like Fiji.<sup>[9]</sup> The direct use of sugar cane to produce ethanol for biofuel is projected to potentially surpass the production of white sugar as an end product.



*Saccharum officinarum*

## Etymology

The term *sugarcane* is a combination of two words: "sugar" and "cane". The former ultimately derives from Sanskrit शर्करा (*sárkarā*). As sugar was traded and spread West, this became سکر (sukkar) in Arabic, *saccharum* or *succarum* in Latin, *zúcchero* in Italian, and eventually *sucre* in both Middle French and Middle English. The second term "cane" began to be used alongside it as the crop was grown on plantations in the Caribbean.

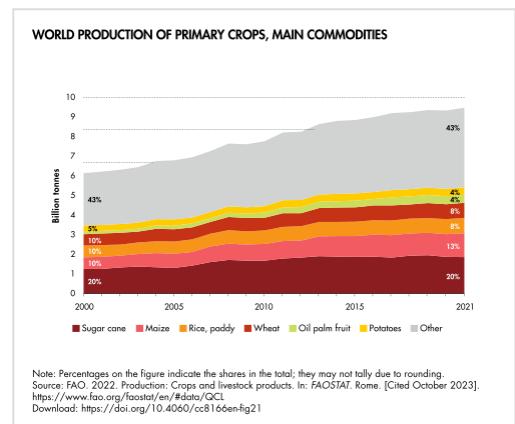
## Characteristics

Sugarcane, a perennial tropical grass,<sup>[10]</sup> exhibits a unique growth pattern characterized by lateral shoots emerging at its base, leading to the development of multiple stems. These stems typically attain a height of 3 to 4 meters (approximately 10 to 13 feet) and possess a diameter of about 5 centimeters (approximately 2 inches). As these stems mature, they evolve into cane stalks, constituting a substantial portion of the entire plant, accounting for roughly 75% of its composition.

A fully mature cane stalk generally comprises a composition of around 11–16% fiber, 12–16% soluble sugars, 2–3% non-sugar carbohydrates, and 63–73% water content. The successful cultivation of sugarcane hinges on a delicate interplay of several factors, including climatic conditions, soil properties, irrigation methods, fertilization practices, pest and disease management, the selection of specific varieties, and the timing of the harvest.

In terms of yield, the average production of cane stalk stands at 60–70 tonnes per hectare (equivalent to 24–28 long tons per acre or 27–31 short tons per acre) annually. However, this yield figure is not fixed and can vary significantly, ranging from 30 to 180 tonnes per hectare. This variance is contingent upon the level of knowledge applied and the approach to crop management embraced in the cultivation of sugarcane. Ultimately, the successful cultivation of this valuable crop demands a thoughtful integration of various factors to optimize its growth and productivity.

Sugarcane is a cash crop, but it is also used as livestock fodder.<sup>[11]</sup> Sugarcane genome is one of the most complex plant genomes known, mostly due to interspecific hybridization and polyploidization.<sup>[12][13]</sup>



Sugarcane is the most widely produced primary crop in the world



Cut sugarcane

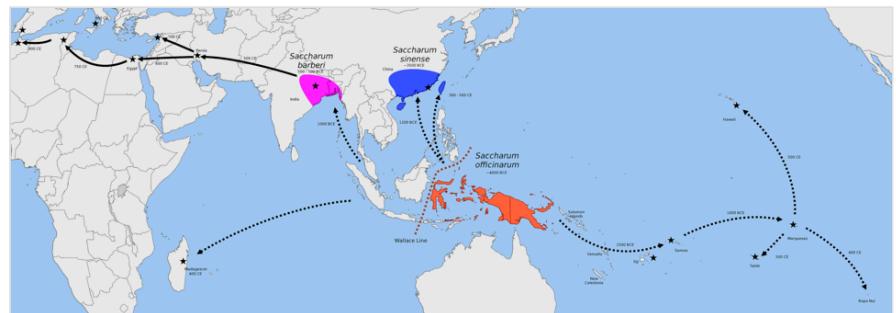


Sugarcane canopy

## History

The two centers of domestication for sugarcane are one for *Saccharum officinarum* by Papuans in New Guinea and another for *Saccharum sinense* by Austronesians in Taiwan and southern China. Papuans and Austronesians originally primarily used sugarcane as food for domesticated pigs. The spread of both *S. officinarum* and *S. sinense* is closely linked to the migrations of the Austronesian peoples. *Saccharum barberi* was only cultivated in India after the introduction of *S. officinarum*.<sup>[14][15]</sup>

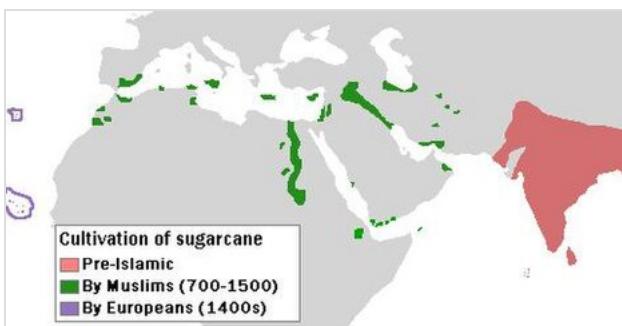
*S. officinarum* was first domesticated in New Guinea and the islands east of the Wallace Line by Papuans, where it is the modern center of diversity. Beginning around 6,000 BP, several strains were selectively bred from the native *Saccharum robustum*. From New Guinea, it spread westwards to Maritime Southeast Asia after contact with Austronesians, where it hybridized with *Saccharum spontaneum*.<sup>[15]</sup>



Map showing centers of origin of *Saccharum officinarum* in New Guinea, *S. sinensis* in southern China and Taiwan, and *S. barberi* in India; dotted arrows represent Austronesian introductions<sup>[16]</sup>

The second domestication center is southern China and Taiwan, where *S. sinense* was a primary cultigen of the Austronesian peoples. Words for sugarcane are reconstructed as \**təbuS* or \**CebuS* in Proto-Austronesian, which became \**tebh* in Proto-Malayo-Polynesian. It was one of the original major crops of the Austronesian peoples from at least 5,500 BP. Introduction of the sweeter *S. officinarum* may have gradually replaced it throughout its cultivated range in maritime Southeast Asia.<sup>[17][18][16][19][20]</sup>

From Insular Southeast Asia, *S. officinarum* was spread eastward into Polynesia and Micronesia by Austronesian voyagers as a canoe plant by around 3,500 BP. It was also spread westward and northward by around 3,000 BP to China and India by Austronesian traders, where it further hybridized with *S. sinense* and *S. barberi*. From there, it spread further into western Eurasia and the Mediterranean.<sup>[15][16]</sup>



The westward diffusion of sugarcane in pre-Islamic times (shown in red), in the medieval Muslim world (green), and in the 15th century by the Portuguese on the Madeira archipelago, and by the Spanish on the Canary Islands archipelago (islands west of Africa, circled by violet lines)<sup>[21]</sup>

The earliest known production of crystalline sugar began in northern India. The earliest evidence of sugar production comes from ancient Sanskrit and Pali texts.<sup>[22][23][24][25]</sup> Around the eighth century, Muslim and Arab traders introduced sugar from medieval India to the other parts of the Abbasid Caliphate in the Mediterranean, Mesopotamia, Egypt, North Africa, and Andalusia. By the 10th century, sources state that every village in Mesopotamia grew sugarcane.<sup>[21]</sup> It was among the early crops brought to the Americas by the Spanish, mainly Andalusians, from their fields in the Canary Islands, and the Portuguese from their fields in the Madeira Islands. An article on sugarcane cultivation in Spain is included in Ibn al-'Awwam's 12th-century Book on Agriculture.<sup>[26]</sup>

The first chemically refined sugar appeared on the scene in India about 2,500 years ago. From there, the technique spread east towards China, and west towards Persia and the early Islamic worlds, eventually reaching the Mediterranean in the 13th century. Cyprus and Sicily became important centers for sugar production.

In colonial times, sugar formed one side of the triangle trade of New World raw materials, along with European manufactured goods, and African slaves. Christopher Columbus first brought sugarcane to the Caribbean (and the New World) during his second voyage to the Americas, initially to the island of Hispaniola (modern day Haiti and the Dominican Republic). The first sugar harvest happened in Hispaniola in 1501; many sugar mills were constructed in Cuba and Jamaica by the 1520s.<sup>[27]</sup> The Portuguese introduced sugarcane to Brazil. By 1540, there were 800 cane sugar mills in Santa Catarina Island and another 2,000 on the north coast of Brazil, Demarara, and Suriname.

Sugar, often in the form of molasses, was shipped from the Caribbean to Europe or New England, where it was used to make rum. The profits from the sale of sugar were then used to purchase manufactured goods, which were then shipped to West Africa, where they were bartered for slaves. The slaves were then brought back to the Caribbean to be sold to sugar planters. The profits from the sale of the slaves were then used to buy more sugar, which was shipped to Europe. Toil in the sugar plantations became a main basis for a vast network of forced population movement, supplying people to work under brutal coercion.

The passage of the 1833 Slavery Abolition Act led to the abolition of slavery through most of the British Empire, and many of the emancipated slaves no longer worked on sugarcane plantations when they had a choice. West Indian planters, therefore, needed new workers, and they found cheap labour in China and India.<sup>[28][29]</sup> The people were subject to indenture, a long-established form of contract, which bound them to unfree labour for a fixed term. The conditions where the indentured servants worked were frequently abysmal, owing to a lack of care among the planters.<sup>[30]</sup> The first ships carrying indentured labourers from India left in 1836.<sup>[31]</sup> The migrations to serve sugarcane plantations led to a significant number of ethnic Indians, Southeast Asians, and Chinese people settling in various parts of the world.<sup>[32]</sup> In some islands and countries, the South Asian migrants now constitute between 10 and 50% of the population. Sugarcane plantations and Asian ethnic groups continue to thrive in countries such as Fiji, South Africa,

Myanmar, Sri Lanka, Malaysia, Indonesia, the Philippines, Guyana, Jamaica, Trinidad, Martinique, French Guiana, Guadeloupe, Grenada, St. Lucia, St. Vincent, St. Kitts, St. Croix, Suriname, Nevis, and Mauritius.<sup>[31][33]</sup>

Between 1863 and 1900, merchants and plantation owners in Queensland and New South Wales (now part of the Commonwealth of Australia) brought between 55,000 and 62,500 people from the South Pacific islands to work on sugarcane plantations. An estimated one-third of these workers were coerced or kidnapped into slavery (known as blackbirding); many others were paid very low wages. Between 1904 and 1908, most of the 10,000 remaining workers were deported in an effort to keep Australia racially homogeneous and protect white workers from cheap foreign labour.<sup>[34]</sup>

Cuban sugar derived from sugarcane was exported to the USSR, where it received price supports and was ensured a guaranteed market. The 1991 dissolution of the Soviet state forced the closure of most of Cuba's sugar industry.

Sugarcane remains an important part of the economy of Cuba, Guyana, Belize, Barbados, and Haiti, along with the Dominican Republic, Guadeloupe, Jamaica, and other islands.

About 70% of the sugar produced globally comes from *S. officinarum* and hybrids using this species.<sup>[7]</sup>

Sugar occupies 26,942,686 hectares of land across the globe and is the third most valuable crop.



Lithograph of sugarcane being ground using a windmill on a sugar plantation in the British colony of Antigua, 1823



A sugar plantation on the island of Jamaica in the late 19th century



Indian sugarcane press, *circa* 1905

## Cultivation

Sugarcane cultivation requires a tropical or subtropical climate, with a minimum of 60 cm (24 in) of annual moisture. It is one of the most efficient photosynthesizers in the plant kingdom. It is a C<sub>4</sub> plant, able to convert up to 1% of incident solar energy into biomass.<sup>[35]</sup> In primary growing regions across the tropics and subtropics, sugarcane crops can produce over 15 kg/m<sup>2</sup> of cane.

Sugar cane accounted for around 21% of the global crop production over the 2000–2021 period. The Americas was the leading region in the production of sugar cane (52% of the world total).<sup>[36]</sup>

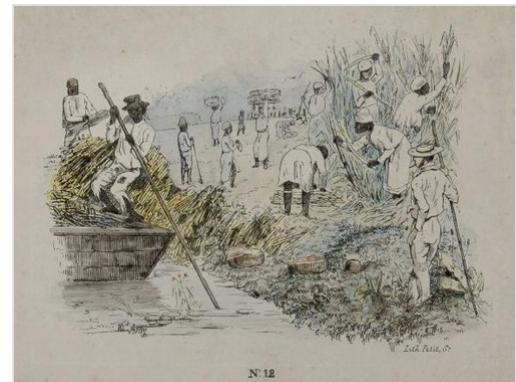
Once a major crop of the southeastern region of the United States, sugarcane cultivation declined there during the late 20th century, and is primarily confined to small plantations in Florida, Louisiana, and southeast Texas in the 21st century. Sugarcane cultivation ceased in Hawaii when the last operating sugar plantation in the state shut down in 2016.<sup>[37]</sup>

Sugarcane is cultivated in the tropics and subtropics in areas with a plentiful supply of water for a continuous period of more than 6–7 months each year, either from natural rainfall or through irrigation. The crop does not tolerate severe frosts. Therefore, most of the world's sugarcane is grown between  $22^{\circ}\text{N}$  and  $22^{\circ}\text{S}$ , and some up to  $33^{\circ}\text{N}$  and  $33^{\circ}\text{S}$ .<sup>[38]</sup> When sugarcane crops are found outside this range, such as the Natal region of South Africa, it is normally due to anomalous climatic conditions in the region, such as warm ocean currents that sweep down the coast. In terms of altitude, sugarcane crops are found up to 1,600 m or 5,200 ft close to the equator in countries such as Colombia, Ecuador, and Peru.<sup>[39]</sup>

Sugarcane can be grown on many soils ranging from highly fertile, well-drained mollisols, through heavy cracking vertisols, infertile acid oxisols and ultisols, peaty histosols, to rocky andisols. Both plentiful sunshine and water supplies increase cane production. This has made desert countries with good irrigation facilities such as Egypt some of the highest-yielding sugarcane-cultivating regions. Sugarcane consumes 9% of the world's potash fertilizer production.<sup>[40]</sup>

Although some sugarcanes produce seeds, modern stem cutting has become the most common reproduction method.<sup>[41]</sup> Each cutting must contain at least one bud, and the cuttings are sometimes hand-planted. In more technologically advanced countries, such as the United States and Australia, billet planting is common. Billets (stalks or stalk sections) harvested by a mechanical harvester are planted by a machine that opens and recloses the ground. Once planted, a stand can be harvested several times; after each harvest, the cane sends up new stalks, called ratoons.<sup>[42]</sup> Successive harvests give decreasing yields, eventually justifying replanting. Two to 10 harvests are usually made depending on the type of culture. In a country with a mechanical agriculture looking for a high production of large fields, as in North America, sugarcanes are replanted after two or three harvests to avoid a lowering yields. In countries with a more traditional type of agriculture with smaller fields and hand harvesting, as in the French island of Réunion, sugarcane is often harvested up to 10 years before replanting.

Sugarcane is harvested by hand and mechanically. Hand harvesting accounts for more than half of production, and is dominant in the developing world. In hand harvesting,



A 19th-century lithograph by Theodore Bray showing a sugarcane plantation: On the right is the "white officer", the European overseer. Slave workers toil during the harvest. To the left is a flat-bottomed vessel for cane transportation.



Sugarcane plantation, Mauritius



Sugarcane plantation in Bangladesh



Planting sugarcane in Puerto Rico

the field is first set on fire. The fire burns up dry leaves, and chases away or kills venomous snakes, without harming the stalks and roots. Harvesters then cut the cane just above ground-level using cane knives or machetes. A skilled harvester can cut 500 kg (1,100 lb) of sugarcane per hour.<sup>[43]</sup>

Mechanical harvesting uses a combine, or sugarcane harvester.<sup>[44]</sup> The Austoft 7000 series, the original modern harvester design, has now been copied by other companies, including Cameco / John Deere. The machine cuts the cane at the base of the stalk, strips the leaves, chops the cane into consistent lengths and deposits it into a transporter following alongside. The harvester then blows the trash back onto the field. Such machines can harvest 100 long tons (100 t) each hour, but harvested cane must be rapidly processed. Once cut, sugarcane begins to lose its sugar content, and damage to the cane during mechanical harvesting accelerates this decline. This decline is offset because a modern chopper harvester can complete the harvest faster and more efficiently than hand cutting and loading. Austoft also developed a series of hydraulic high-lift infield transporters to work alongside its harvesters to allow even more rapid transfer of cane to, for example, the nearest railway siding. This mechanical harvesting does not require the field to be set on fire; the residue left in the field by the machine consists of cane tops and dead leaves, which serve as mulch for the next planting.



Sugarcane fields



Plantations in Brazil, the largest producer in the world

## Pests

The cane beetle (also known as cane grub) can substantially reduce crop yield by eating roots; it can be controlled with imidacloprid (Confidor) or chlorpyrifos (Lorsban). Other important pests are the larvae of some butterfly/moth species, including the turnip moth, the sugarcane borer (*Diatraea saccharalis*), the African sugarcane borer (*Eldana saccharina*), the Mexican rice borer (*Eoreuma loftini*), the African armyworm (*Spodoptera exempta*), leafcutter ants, termites, spittlebugs (especially *Mahanarva fimbriolata* and *Deois flavopicta*), and *Migdolus fryanus* (a beetle). The planthopper insect *Eumetopina flavipes* acts as a virus vector, which causes the sugarcane disease ramu stunt.<sup>[45][46]</sup> *Sesamia grisescens* is a major pest in Papua New Guinea and so is a serious concern for the Australian industry were it to cross over.<sup>[47]</sup> To head off such a problem, the Federal Government has pre-announced that they would cover 80% of response costs if it were necessary.<sup>[47]</sup>

## Pathogens

Numerous pathogens infect sugarcane, such as sugarcane grassy shoot disease caused by *Candidatus Phytoplasma sacchari*,<sup>[48]</sup> whiptail disease or sugarcane smut, pokkah boeng caused by *Fusarium moniliforme*, *Xanthomonas axonopodis* bacteria causes Gumming Disease, and red rot disease caused by *Colletotrichum falcatum*. Viral diseases affecting sugarcane include sugarcane mosaic virus, maize streak virus, and sugarcane yellow leaf virus.<sup>[49]</sup>

Yang *et al.*, 2017 provides a genetic map developed for USDA ARS-run breeding programs for brown rust of sugarcane.<sup>[50]</sup>

## Nitrogen fixation

Some sugarcane varieties are capable of fixing atmospheric nitrogen in association with the bacterium *Gluconacetobacter diazotrophicus*.<sup>[51]</sup> Unlike legumes and other nitrogen-fixing plants that form root nodules in the soil in association with bacteria, *G. diazotrophicus* lives within the intercellular spaces of the sugarcane's stem.<sup>[52][53]</sup> Coating seeds with the bacteria was assayed in 2006 with the intention of enabling crop species to fix nitrogen for its own use.<sup>[54]</sup>

## Conditions for sugarcane workers

At least 20,000 people are estimated to have died of chronic kidney disease in Central America in the past two decades, most of them sugarcane workers along the Pacific coast. This may be due to working long hours in the heat without adequate fluid intake.<sup>[55]</sup> Additionally, some of the workers are being exposed to hazards such as: high temperatures, harmful pesticides, and poisonous or venomous animals. This occurs during the process of cutting the sugarcane manually, causing physical ailments due to constant repetitive movements for hours every work day.<sup>[56]</sup>

In India, especially in Maharashtra, sugarcane production is linked to forced labour, as a result of an exploitative advance payment system for workers that puts them deeply in debt and requires them to return year after year, earning less than \$5 a day. Working conditions are generally very poor, with workers migrating during the harvest season and living in makeshift tents in the fields they harvest, with no toilets, electricity, or running water. Child labour is common, and child marriage between sugar harvester is frequent, despite both being illegal. Indian sugarcane production is also linked to an unusually high rate of hysterectomies (some 1 in 5 sugarcane harvesting women), which women are pressured to receive by sugarcane producers and the lack of sanitary facilities, family planning options, or medical leave. India is the world's second largest sugar producer, and Maharashtra produces one-third of the country's sugar, which then enters the global supply chain—making its provenance hard to track. The Coca-Cola Company and PepsiCo have bought significant amounts of sugar from Maharashtra since at least the 2010s, mostly for use in Indian soft drinks, but deny that they are complicit in labor abuses.<sup>[57]</sup>

## Processing

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Traditionally, sugarcane processing requires two stages. Mills extract raw sugar from freshly harvested cane and "mill-white" sugar is sometimes produced immediately after the first stage at sugar-extraction mills, intended for local consumption. Sugar crystals appear naturally white in color during the crystallization process. Sulfur dioxide is added to inhibit the formation of color-inducing molecules and to stabilize the sugar juices during evaporation.<sup>[58][59]</sup> Refineries, often

located nearer to consumers in North America, Europe, and Japan, then produce refined white sugar, which is 99% sucrose. These two stages are slowly merging. Increasing affluence in the sugarcane-producing tropics increases demand for refined sugar products, driving a trend toward combined milling and refining.<sup>[60]</sup>



Non-centrifugal cane sugar (jaggery) production near Inle Lake (Myanmar), crushing and boiling stage

## Milling

Sugarcane processing produces cane sugar (sucrose) from sugarcane. Other products of the processing include bagasse, molasses, and filter cake.

Bagasse, the residual dry fiber of the cane after cane juice has been extracted, is used for several purposes:<sup>[61]</sup>

- fuel for the boilers and kilns
- production of paper, paperboard products, and reconstituted panelboard
- agricultural mulch
- as a raw material for production of chemicals

The primary use of bagasse and bagasse residue is as a fuel source for the boilers in the generation of process steam in sugar plants. Dried filter cake is used as an animal feed supplement, fertilizer, and source of sugarcane wax.



Manually extracting juice from sugarcane

Molasses is produced in two forms: blackstrap, which has a characteristic strong flavor, and a purer molasses syrup. Blackstrap molasses is sold as a food and dietary supplement. It is also a common ingredient in animal feed, and is used to produce ethanol, rum, and citric acid. Purer molasses syrups are sold as molasses, and may also be blended with maple syrup, invert sugars, or corn syrup. Both forms of molasses are used in baking.



A truck hauls cane to a sugar mill in Florida.

## Refining

Sugar refining further purifies the raw sugar. It is first mixed with heavy syrup and then centrifuged in a process called "affination". Its purpose is to wash away the sugar crystals' outer coating, which is less pure than the crystal interior. The remaining sugar is then dissolved to make a syrup, about 60% solids by weight.<sup>[62]</sup>



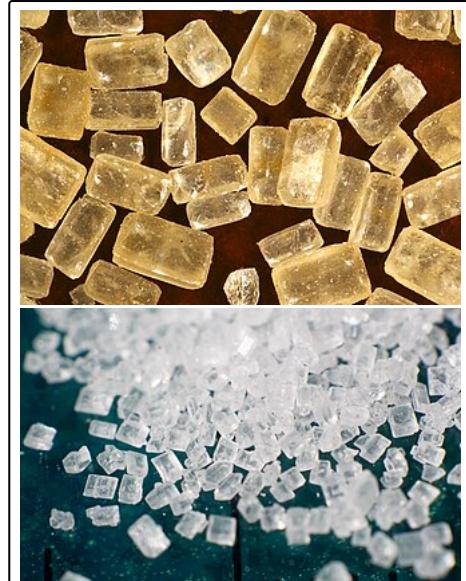
Santa Elisa sugarcane processing plant in Sertãozinho, one of the largest and oldest in Brazil

The sugar solution is clarified by the addition of phosphoric acid and calcium hydroxide, which combine to precipitate calcium phosphate. The calcium phosphate particles entrap some impurities and absorb others, and then float to the top of the tank, where

they can be skimmed off. An alternative to this "phosphatation" technique is "carbonatation", which is similar, but uses carbon dioxide and calcium hydroxide to produce a calcium carbonate precipitate.

After filtering any remaining solids, the clarified syrup is decolorized by filtration through activated carbon. Bone char or coal-based activated carbon is traditionally used in this role.<sup>[63]</sup> Some remaining color-forming impurities are adsorbed by the carbon. The purified syrup is then concentrated to supersaturation and repeatedly crystallized in a vacuum, to produce white refined sugar. As in a sugar mill, the sugar crystals are separated from the molasses by centrifuging. Additional sugar is recovered by blending the remaining syrup with the washings from affination and again crystallizing to produce brown sugar. When no more sugar can be economically recovered, the final molasses still contains 30–35% sucrose and 10–25% glucose and fructose.<sup>[64]</sup>

To produce granulated sugar, in which individual grains do not clump, sugar must be dried, first by heating in a rotary dryer, and then by blowing cool air through it for several days.



Brown and white sugar crystals

## Ribbon cane syrup

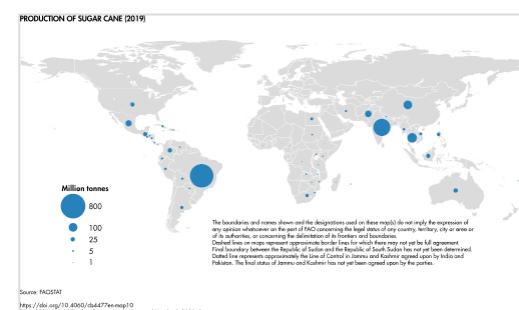
Ribbon cane is a subtropical type that was once widely grown in the Southern United States, as far north as coastal North Carolina. The juice was extracted with horse- or mule-powered crushers; the juice was boiled, like maple syrup, in a flat pan, and then used in the syrup form as a food sweetener.<sup>[65]</sup> It is not currently a commercial crop, but a few growers find ready sales for their product.

## Production

In 2022, global production of sugarcane was 1.92 billion tonnes, with Brazil producing 38% of the world total, India with 23%, and China producing 5% (table).

Worldwide, 26 million hectares were devoted to sugarcane cultivation in 2020.<sup>[67]</sup> The average worldwide yield of sugarcane crops in 2022 was 74 tonnes per hectare, led by Peru with 121 tonnes per hectare.<sup>[67]</sup> The theoretical possible yield for sugarcane is about 280 tonnes per hectare per year, and small experimental plots in Brazil have demonstrated yields of 236–280 tonnes of cane per hectare.<sup>[68][69]</sup>

From 2008 to 2016, production of standards-compliant sugarcane experienced a compound annual growth rate of about 52%, while conventional sugarcane increased at less than 1%.<sup>[70]</sup>



Source: FAOSTAT  
http://faostat.fao.org/10400/10407?ew=map10  
FAO. 2021. World Food and Agriculture - Statistical Yearbook 2021. Rome.

# Environmental impacts

## Soil degradation and erosion

The cultivation of sugarcane can lead to increased soil loss through the removal of soil at harvest, as well as improper irrigation practices, which can result in erosion.<sup>[71][72]</sup> Erosion is especially significant when the sugarcane is grown on slopes or hillsides, which increases the rate of water runoff.<sup>[71][72]</sup> Generally, it is recommended that sugarcane is not planted in areas with a slope greater than 8%.<sup>[71]</sup> However, in certain areas, such as parts of the Caribbean and South Africa, slopes greater than 20% have been planted.<sup>[71]</sup> Increased erosion can lead to the removal of organic and nutrient-rich material, which can decrease future crop yields. It can also result in sediments and other pollutants being washed into aquatic habitats, which can result in a wide range of environmental issues, including eutrophication and acidification.<sup>[71][72]</sup>

Sugarcane cultivation can also result in soil compaction, which is caused by the use of heavy, infield machinery.<sup>[71]</sup> Along with impacting invertebrate and fauna within the upper layers of the soil, compaction can also lead to decreased porosity.<sup>[71][72]</sup> This in turn can increase surface runoff, resulting in greater leaching and erosion.<sup>[71]</sup>

## Habitat destruction

Due to the large quantity of water required, sugarcane cultivation heavily relies on irrigation.<sup>[73]</sup> Additionally, since large amounts of soil are removed with the crop during harvest, significant washing occurs during the processing phase.<sup>[73]</sup> In many countries, such as India and Australia, this requirement has placed a strain on available resources, requiring the construction of barrages and other dams.<sup>[71][73]</sup> This has altered the amount of water reaching aquatic habitats, and has contributed to the degradation of ecosystems such as the Great Barrier Reef and Indus Delta.<sup>[71][73]</sup>

Sugarcane has also contributed to habitat destruction through the clearance of land.<sup>[71]</sup> Seven countries around the world devote more than 50% of their land to the cultivation of sugarcane.<sup>[71]</sup> Sugarcane fields have replaced tropical rain forests and wetlands.<sup>[71]</sup> While the majority of this clearance occurred in the past, expansions have occurred within the past couple decades, further contributing to habitat destruction.<sup>[72]</sup>

## Mitigation efforts

A wide variety of mitigation efforts can be implemented to reduce the impacts of sugarcane cultivation.<sup>[71]</sup> Among these efforts is switching to alternative irrigation techniques, such as drip irrigation, which are more water efficient.<sup>[71]</sup> Water efficiency can also be improved by employing

5.  <u>Pakistan</u>	88 (4.58%)
6.  <u>Mexico</u>	55.3 (2.88%)
7.  <u>Colombia</u>	35 (1.82%)
8.  <u>Indonesia</u>	32.4 (1.69%)
9.  <u>United States</u>	31.5 (1.64%)
10.  <u>Australia</u>	28.7 (1.49%)

**World total** 1,922.1

Source: FAOSTAT<sup>[67]</sup>



Steam produced from sugarcane processing.

methods such as trash mulching, which has been shown to increase water intake and storage.<sup>[71][74]</sup> Along with reducing the overall water use, this method can also decrease soil runoff, and therefore prevent pollutants from entering the environment.<sup>[71]</sup> In areas with a slope greater than 11%, it is also recommended that zero tillage or cane strip planting are implemented to help prevent soil loss.<sup>[71]</sup>

Sugarcane processing produces a wide variety of pollutants, including heavy metals and bagasse, which can be released into the environment through wastewater discharge.<sup>[71]</sup> To prevent this, alternative treatment methods such as high rate anaerobic digestions can be implemented to better treat this wastewater.<sup>[75]</sup> Stormwater drains can also be installed to prevent uncontrolled runoff from reaching aquatic ecosystems.<sup>[71]</sup>



Land cleared for sugarcane production.

## Ethanol

Ethanol is generally available as a byproduct of sugar production. It can be used as a biofuel alternative to gasoline, and is widely used in cars in Brazil. It is an alternative to gasoline, and may become the primary product of sugarcane processing, rather than sugar

In Brazil, gasoline is required to contain at least 22% bioethanol.<sup>[76]</sup> This bioethanol is sourced from Brazil's large sugarcane crop.

The production of ethanol from sugarcane is more energy efficient than from corn or sugar beets or palm/vegetable oils, particularly if cane bagasse is used to produce heat and power for the process. Furthermore, if biofuels are used for crop production and transport, the fossil energy input needed for each ethanol energy unit can be very low. EIA estimates that with an integrated sugarcane to ethanol technology, the well-to-wheels CO<sub>2</sub> emissions can be 90% lower than conventional gasoline.<sup>[76]</sup> A textbook on renewable energy<sup>[77]</sup> describes the energy transformation:

Presently, 75 tons of raw sugarcane are produced annually per hectare in Brazil. The cane delivered to the processing plant is called burned and cropped (b&c), and represents 77% of the mass of the raw cane. The reason for this reduction is that the stalks are separated from the leaves (which are burned and whose ashes are left in the field as fertilizer), and from the roots that remain in the ground to sprout for the next crop. Average cane production is, therefore, 58 tons of b&c per hectare per year.



A fuel pump in Brazil, offering cane ethanol (A) and gasoline (G)

Each ton of b&c yields 740 kg of juice (135 kg of sucrose and 605 kg of water) and 260 kg of moist bagasse (130 kg of dry bagasse). Since the lower heating value of sucrose is 16.5 MJ/kg, and that of the bagasse is 19.2 MJ/kg, the total heating value of a ton of b&c is 4.7 GJ of which 2.2 GJ come from the sucrose and 2.5 from the bagasse.

Per hectare per year, the biomass produced corresponds to 0.27 TJ. This is equivalent to 0.86 W per square meter. Assuming an average insolation of 225 W per square meter, the photosynthetic efficiency of sugar cane is 0.38%.

The 135 kg of sucrose found in 1 ton of b&c are transformed into 70 litres of ethanol with a combustion energy of 1.7 GJ. The practical sucrose-ethanol conversion efficiency is, therefore, 76% (compare with the theoretical 97%).

One hectare of sugar cane yields 4,000 litres of ethanol per year (without any additional energy input, because the bagasse produced exceeds the amount needed to distill the final product). This, however, does not include the energy used in tilling, transportation, and so on. Thus, the solar energy-to-ethanol conversion efficiency is 0.13%.

## Bagasse applications

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Sugarcane bagasse

Sugarcane is a major crop in many countries. It is one of the plants with the highest bioconversion efficiency. Sugarcane crop is able to efficiently fix solar energy, yielding some 55 tonnes of dry matter per hectare of land annually. After harvest, the crop produces sugar juice and bagasse, the fibrous dry matter. This dry matter is biomass with potential as fuel for energy production. Bagasse can also be used as an alternative source of pulp for paper production.<sup>[78]</sup>

Sugarcane bagasse is a potentially abundant source of energy for large producers of sugarcane, such as Brazil, India, and China. According to one report, with use of latest technologies, bagasse produced annually in Brazil has the potential of meeting 20% of Brazil's energy consumption by 2020.<sup>[79]</sup>

## Electricity production

A number of countries, in particular those lacking fossil fuels, have implemented energy conservation and efficiency measures to minimize the energy used in cane processing, and export any excess electricity to the grid. Bagasse is usually burned to produce steam, which in turn creates electricity. Current technologies, such as those in use in Mauritius, produce over 100 kWh of electricity per tonne of bagasse. With a total world harvest of over one billion tonnes of sugarcane per year, the global energy potential from bagasse is over 100,000 GWh.<sup>[80]</sup> Using Mauritius as a reference, an annual potential of 10,000 GWh of additional electricity could be produced throughout Africa.<sup>[81]</sup> Electrical generation from bagasse could become quite important, particularly to the rural populations of sugarcane producing nations.

Recent cogeneration technology plants are being designed to produce from 200 to over 300 kWh of electricity per tonne of bagasse.<sup>[82][83]</sup> As sugarcane is a seasonal crop, shortly after harvest the supply of bagasse would peak, requiring power generation plants to strategically manage the

storage of bagasse.

## Biogas production

A greener alternative to burning bagasse for the production of electricity is to convert bagasse into biogas. Technologies are being developed to use enzymes to transform bagasse into advanced biofuel and biogas.<sup>[79]</sup>

## Sugarcane as food

In most countries where sugarcane is cultivated, several foods and popular dishes are derived directly from it, such as:

- Raw sugarcane: chewed to extract the juice
- *Sayur nganten*: an Indonesian soup made with the stem of trubuk (*Saccharum edule*), a type of sugarcane
- Sugarcane juice: a combination of fresh juice, extracted by hand or small mills, with a touch of lemon and ice to make a popular drink, known variously as *air tebu*, *usacha rass*, *guarab*, *guarapa*, *guarapo*, *papelón*, *aseer asab*, *ganna sharbat*, *mosto*, *caldo de cana*, or *nước mía*
- Syrup: a traditional sweetener in soft drinks worldwide but now largely supplanted in the US by high fructose corn syrup, which is less expensive because of corn subsidies and sugar tariffs<sup>[87]</sup>
- Molasses: used as a sweetener and a syrup accompanying other foods, such as cheese or cookies
- Jaggery: a solidified molasses, known as *gur*, *gud*, or *gul* in modern Indo-Aryan, is traditionally produced by evaporating juice to make a thick sludge, and then cooling and molding it in buckets. Modern production partially freeze dries the juice to reduce caramelization and lighten its color. It is used as sweetener in cooking traditional entrees, sweets, and desserts.
- Falernum: a sweet, and slightly alcoholic drink made from sugarcane juice
- Cachaça: the most popular distilled alcoholic beverage in Brazil; it is a liquor made of the distillation of sugarcane juice.
- Rum is a liquor made from sugarcane products, typically molasses, but sometimes also cane juice. It is most commonly produced in the Caribbean and environs.
- Basi is a fermented alcoholic beverage made from sugarcane juice produced in the Philippines and Guyana.
- Panela, solid pieces of sucrose and fructose obtained from the boiling and evaporation of sugarcane juice, is a food staple in Colombia and other countries in South and Central America.

### Cane juice<sup>[84]</sup>



Freshly squeezed sugarcane juice

#### Nutritional value per 100 grams

<b>Energy</b>	242 kJ (58 kcal)
<b>Carbohydrates</b>	13.11 g
Sugars	12.85 g
glucose	2.27 g
fructose	0.55 g
Dietary fiber	0.56 g
<b>Fat</b>	0.40
<b>Protein</b>	0.16 g

#### Vitamins and minerals

Nutrient Information from Indian Food Composition Database

<sup>†</sup>Percentages estimated using US recommendations for adults,<sup>[85]</sup> except for potassium, which is estimated based on expert recommendation from the National Academies.<sup>[86]</sup>

- Rapadura is a sweet flour that is one of the simplest refinings of sugarcane juice, common in Latin American countries such as Brazil, Argentina, and Venezuela (where it is known as *papelón*) and the Caribbean.
- Rock candy: crystallized cane juice
- Gâteau de Sirop
- Viche, a homebrewed Colombian alcoholic beverage

In the 21st century, it is estimated that sugar is potentially responsible for approximately 20% of the caloric content of modern diets.<sup>[88]</sup>

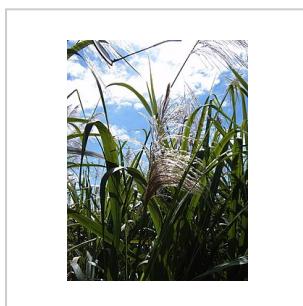
## Sugarcane as feed

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Many parts of the sugarcane are commonly used as animal feeds where the plants are cultivated. The leaves make a good forage for ruminants.<sup>[89]</sup>

## Gallery

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Sugarcane flowering



Flowers of sugarcane



Evaporator with baffled pan and foam dipper for making ribbon cane syrup



A video of sugarcane juice extraction

## See also

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- Sugar plantations in the Caribbean
- Sugar plantations in Hawaii
- Sugar industry of the Philippines
- Trapiche

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## External links

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- Global sugar & sugar cane production stats from oecd (<https://www.oecd-ilibrary.org/sites/969526b0-en/index.html?itemId=/content/component/969526b0-en>).
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