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REVIEW PAPER

Maize (*Zea mays* L.) - The future potential cereal crop of an indispensable significance in agro-forestry system

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Abstract Maize popularly known as the queen of cereal crops, is one of the most cultivated and demanding staple cereal crops with higher potential productivity in the world. In the global scenario, India ranks 7th in total maize production with America being on the top. The total acreage under maize cultivation in India is 9.89 M ha having 4th rank in world while production is 34.61 million tons. In future, maize become maximum cultivated crop in place of wheat, rice etc. because of its higher productivity potential per unit area, wider adaptability to climate, soil and its multipurpose uses. However, the present cultivation practices of maize can lead to soil degradation, biodiversity loss and environmental pollution. Hence, to overcome these problems the adoption of agroforestry, the integration of trees into farming system, can provide sustainable approach to maize production by improving soil health, reduce soil erosion, enhance biodiversity and utilize degraded lands. Maize can be grown in various agroforestry systems like agri-silviculture, taungya cultivation, alley cropping, wind breaks/ shelterbelts and agri-horticulture system. Maize shows complementary effects with most agroforestry tree species specially legumes. Hence, by choosing suitable trees combination, the potential of maize as an intercrop in agroforestry is utilized effectively which will enhance the income of small and marginal farmers along with providing environmental services.

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Introduction

The most frequently widely grown crop in the world is maize (*Zea mays* L.), a domesticated cereal grain that originated in Central America (Awika, 2011; Kennett *et al*., 2020). One of the most adaptable developing crops, it has a wide range of uses. Due to its maximum genetic production potential, maize is referred to as the "queen of cereals" internationally. The only food cereal crop that can be cultivated in a variety of climates, ecosystems, and environments is maize (Murdia *et al*., 2016). Other varieties of maize include regular yellow/white grain, sweet corn, baby corn, popcorn, waxy corn, high-amylase corn, high-oil corn, and quality protein maize, among others (Dass *et al*., 2018). In addition, maize is a significant industrial raw material that offers significant potential for value addition (Murdia *et al*., 2016). Currently, maize is grown in 170 different nations. Around 193 million hectares of maize are grown globally, and 1147.7 million metric tonnes are produced globally (Thakur *et al*., 2023).

The United States produces 346 mt of maize annually on 90 million acres, which accounts for 35 per cent of all global production. With a production of 34.61 mt, and 2-3 per cent of the world's total production, maize is grown over an estimated 9.89 mha. in India. India ranks 7th in terms of global production and 4th in terms of global area (*Source:* World Maize production, 1961-2022 - knoema.com).

Agroforestry is an integrated land management system that combines trees or shrubs with crops and/or livestock on the same piece of land. Maize (corn) can be integrated into agroforestry systems in various ways, providing

several benefits. When integrating maize into agroforestry systems, it's important to consider the specific environmental conditions, the types of trees or shrubs being used, and the management practices that optimize the synergies between the components of the system. Successful agroforestry practices can lead to more sustainable and resilient agricultural systems with improved yields and environmental benefits (Khan *et al*., 2023).

Maize in agroforestry systems plays a significant multifaceted role in enhancing sustainability, improving resilience to environmental challenges along with the agricultural landscape, and providing economic and food security benefits for communities. The integration of maize with trees and other components in agroforestry systems showcases the potential for synergistic relationships that contribute to the overall health of the agricultural landscape. Since, Maize serves as a valuable staple food and cash crop for many communities and integrating maize into agroforestry diversifies income sources for farmers, providing both food security and economic stability (Araya *et al*., 2023).

Maize in agroforestry systems is being benefited through tree shades, reduce wind and water erosion, nitrogen-fixation and enhanced microclimates leading to better growth, reduced stress, and increased yields without the need for synthetic fertilizers. As a part of a diversified and resilient system, maize is better equipped to withstand extreme weather events, fluctuations in temperature, and changes in precipitation patterns that mitigates climate change by sequestering carbon and enhancing overall environmental sustainability. Maize, as a component of Silvopastoral system contributes to the feedstock for livestock, while trees provide shade and contribute to overall system productivity (Musokwa *et al.,* 2019).

Through physical and intangible benefits, agroforestry plays a significant role in the Indian economy. On the one hand, it aids in the restoration of degraded lands and boosts agriculture productivity on the other. It has been realised that the only alternative to achieving the goal of raising forest cover from its current level of less than 25 per cent to 33 per cent is agroforestry (FAO). The total area of agroforestry in India is estimated to be about 13.75 million hectares by the Central Agroforestry Research Institute in Jhansi, 11.15 million hectares by the Forest Survey of India in Dehradun, and about 28.427 million hectares (Arunachalam *et al*., 2022).

Why maize called future cereal crop?

Because of its higher genetic yield potential than other cereals, maize is referred to be the queen of cereal crops. Grown all over the world in a variety of climatic conditions (Saritha *et al*., 2020). Maize, with its origins in America, has been cultivated by Americans for a considerable period. After being introduced in Europe, Africa, and Asia, maize is now produced in a variety of environments throughout a number of nations (Shiferaw *et al*., 2011). The primary cash crop and food source for small and medium farmers in India due to its high nutritional content, it is not only used as food but also as waste for industry and animals (Murdia *et al*., 2016). It is advised to include it in your regular diet as a result of these advantages. Over the next two decades, as India's population grows, so will the need for cereals. Maize will have to make a greater contribution to supplying India's food needs during the next 25 years. Government agencies, research institutions, and non-governmental organisations have been seen to institutionally promote maize production more and more throughout time. As a result, these circumstances will raise production in the future (Saritha *et al*., 2020).

Loamy sand to clay loam and a few of the several types of soils where maize can be cultivated successfully (Ahmed *et al*., 2018). However, soils with high water holding capacity, neutral pH, and good organic matter content are thought to be good for increased productivity (Fyre *et al*., 1882). One of the most adaptable developing crops, maize (*Zea mays* L.), has a wide range of adaptation under various agro climatic conditions (Tiwari and Yadav, 2019). It is grown with a larger variety of soil, temperature, and biodiversity. It may be cultivated in any sort of soil and in any type of climate. In practically all agro climatic zones in India, maize is grown. Temperatures between 25°C and 35°C are favourable for its cultivation. Higher production benefits from a wide range of daytime and night time temperatures. Such a temperature range cannot be experienced in Indian settings during the conventional *Kharif* season. This particular environmental condition, however, can be experienced throughout the *Rabi* season. In India, the *Kharif* crop of maize is planted when the temperature is between 35°C which is 40°C quite high. Greater genetic output in comparison to other significant cereal crops, such as rice and wheat. About 30 to 45 quintals of maize are produced per hectare to

that of 25-35 q/ha for wheat and 25-30 q/ha for rice. After rice and wheat, maize is the third-most significant cereal crop in India. It produces around 10 per cent of the nation's entire supply of food grains (*Source:* APEDA, 2020).

Approximately, 10 per cent of the nation's entire production of food grains comes from maize. In India, maize is grown by at least 15 million farmers, creating work in the agricultural sector and tying together the economic systems of more than 650 million people daily. Maize accounts for more than 2 per cent of the total production value of all crops. 3.45×10^6 mt of maize were exported by the nation in 2022–2023 for a total of Rs. 8987.13 crores/$1116.17 million. In December 2022, India exported 4,74,552 mt of maize for an average FOB of about 346 USD/MT, according to trade sources. Additionally, 1,40,342 mt and 17,836 mt of maize were exported to Bangladesh and Nepal, with average FOB prices of roughly 317.4 USD/mt and 311.22 USD/mt, respectively. Due to these factors, the Agricultural Market Intelligence Centre, PJTSAU anticipates that during the month of February 2023, maize prices may range between Rs. 1962 and Rs. 2380 a quintal. A CAGR of 4.2 per cent is anticipated for the maize market over the forecast period. In India, the quintal price of maize was 1,962 Indian rupees for the 2023 fiscal year. Compared to the purchase price from the prior fiscal year, there was an increase. Gross value contributed from maize to the economy of the south Asian nation in fiscal year 2020 exceeded 306 billion rupees (PJTSAU, 2023).

Multipurpose uses of maize

For human nutrition

Rich in Vitamin B, riboflavin, phosphorus, potassium, iron, calcium, and zinc. Due to the presence of carotenoids, yellow maize has a high vitamin-A concentration. In maize grain, there are roughly 70–85 per cent total carbohydrates, 6–13 per cent protein, 4 per cent fat, and 2–6 per cent oil. 100 grams of maize grains have 86 Kcal total calories. Due to its high nutritional value and abundance of macronutrients like starch, fibre, protein, and fat as well as micronutrients like vitamin B complex, β-carotene, and critical minerals like magnesium, zinc, phosphorus, copper, etc. Maize is a stable grain that is quite popular. There were 250 mg of potassium, 90 mg of phosphorus, 37 mg of magnesium, 4 mg of calcium, 0.52 mg of iron, 0.46 mg of zinc, 0.163 mg of manganese, and 0.054 mg of copper per 100g of maize grain. In terms of vitamins, 100 grams of maize grains have an adequate amount of each vital vitamin.

For industrial purposes

Maize is utilised in India for a variety of applications. The primary usage of 47 per cent of the maize grown in India is as chicken feed, 13 per cent for livestock and food, 12 per cent for industrial purpose, 14 per cent for starch industries, 7 per cent for processed food and 6 per cent for export and other purposes. One of the top 5 industries in India is one based on maize or starch. A direct dependence on maize starch or its byproducts exists in 40 per cent of Indian industry. A wide range of food and commercial items, such as starch, sweeteners, oil, drinks, glue, industrial alcohol, and fuel ethanol, can be made from maize.

The processing of maize involves a variety of techniques, one of which involves using industrial products such dextrose anhydrous, corn starch, corn oil, high fructose corn syrup, maltose and sorbitol. Maize serves as a basic raw material as an ingredient in thousands of industrial products, including starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package, and paper industries, in addition to serving as a staple food for humans and high-quality animal feed. Food, animal feed, and commercial items including biodegradable foams, polymers, and adhesives are all made from maize grain. The maize plant's leaves and stem, known as maize stover, are also used to make chemicals, biofuel, and feed.

Industries depending on maize products

A few common commercial products made from maize directly include the hull, oil, zein, and starches. The primary output of a maize processing facility is starch, which is used in a variety of other industries, including food, medicine, textiles, paper, etc.

Food and beverage industry

Maize starch, also referred to as corn starch, is used in the baking industry and for thickening sauces, puddings and gravies. The use of maize starch powder by bakers to enhance the texture and tenderness of cakes is one of its greatest industrial applications. This starch becomes the

most ideal for use in the preparation of cakes as a result of making the dough tougher by nature. Ice cream and ice cream cones are known to have great strengths when made using maize starch powder. In addition, it is a key ingredient in sweets, salad dressings, and other similar sweet culinary products. As a covering on fried meals to give them more crispiness are some further examples. Starch is also used as filler for culinary items, an emulsifier for milk products, and for noodles. Maize starch powder's ability to easily dissolve in hydrophilic media is another factor contributing to its widespread use in the beverage sector. The starch is one of the foods that produces energy and has a necessary amount of carbohydrates. Maize starch is utilized in various agro-food applications, serving as a thickening and gelling agent in products like toppings, desserts, cream, and pastries etc.

Paper industry

One of the most vital sources of raw materials for the paper industry is maize. In order to increase the bending strength of paper, maize powder is primarily utilised in the paper industry. Corn starch is another name for maize starch. Among the natural starches, maize starch is the most common. Maize starch, often known as corn starch, is used in paper mill industries as a binder, tub sizing, surface sizing, and wet end additive. During cooking, maize starch quickly transforms into a smooth paste. Increase dry strength and paper surface enhancement are two of corn starch or maize starch's main uses in the paper mill industry. Maize starch is used as a wet end additive to strengthen and stiffen paper. In its capacity as a surface sizing agent, it enhances appearance and erasibility, inhibits ink penetration, creates a hard surface (ideal for better writing and printing), and also gets the paper sheet ready for a following coating. Maize starch improves printability and provides a glossy, smooth surface to the paper when used as a coating agent. Since foaming is typically associated with high pH, it is not essential to add any antifoaming agents to the maize starch systems since the pH value of maize starch paste is maintained in the neutral range or below the neutral range. Maize starch does not burst when cooking, in contrast to tapioca starch, which does. In the paper industry, oxidised starch is employed as a coating adhesive as well as a surface sizing agent. A surface size is primarily used to increase fibre bonding at the paper web's surface.

Pharmaceutical industry

Maize starch is a filler, diluents, humectants, binder, and disintegrate used in the pharmaceutical business. It functions as a disintegrate to break down tablets and capsules into smaller pieces. That is, to disintegrate in order for the medication to be released for bodily absorption. For various kinds of coating, it is also employed as a dusting medium. It is commonly acknowledged in fields where dry granulation techniques are used that hygroscopic active substances are difficult to dry after wet binding. As a dry binder, maize starch powder has demonstrated to be especially effective. Maize starch is used as a filler in the pharmaceutical sector. A less well-known application for maize starch is in cosmetics. Dry maize starch powder is a great filler because of its smoothness. One of the first excipients utilised in pharmacological dosage formulations was maize starch. Maize starch can be used as a binder, diluents, or disintegrate, depending on the situation. Roll-dried, pregelatinized maize starch is used as a binding agent in the granulation the pharma industry uses maize starch as filler. Cosmetics are a less well-known use for maize starch. The smoothness of dry maize starch powder makes it excellent filler. Maize starch was one of the earliest excipients used in pharmacological dose formulations. Depending on the application, maize starch may be employed as a binder, diluents, or disintegrate.

Textile industry

Corn-fibre outerwear is more environmentally friendly than nylon and polyester. For summer clothing that is lightweight, maize yarns are ideal. Although not as dense as cotton, the texture is similar. Corn fibre can be used to create corn leather, non-woven materials, yarn, and cloth. A relatively recent breakthrough in the textile sector is maize fibre. The Dow Chemicals and Cargill Inc. teamed up to create Cargill Dow Polymers LLC, which created maize fibre. Ingo fibre is another name for maize fibre.

Large amounts of starch are present in maize, an agricultural product, which manufacturers take from the plant fibres and convert to sugars, which are then fermented and divided into polymers. The maize fibres are now paste-like materials that are extruded into fine strands before being chopped, carded, combed and spun into yarn. The remainder of the process, excluding the chemical steps, is comparable to how wool is processed. Industrial-scale production of the polymer needed to create maize fibre is

based on the fermentation, distillation, and polymerization of maize dextrose, a simple plant sugar. In important active wear applications, maize fibres perform better than or equally as well as polyester. elevated melting point. high degree of crystallisation and excellent clarity. The fibre also has a high strength that is comparable to regular poly fibre, making it very useful. Corn fibre resembles lustrous silk in appearance, hand feel, brightness, and other ways. According to reports, clothing made of maize fibre exhibited outstanding after-wash look, quick drying, and effective soil release. In a novel approach, maize fibre blends the benefits of natural and synthetic fibres. In textiles, comfort, softness, and drape are matched with strength and resilience. Corn fibre has exceptional moisture management properties and is naturally flame retardant. It has good qualities for stain resistance.

Drilling starch

Making pre-gelatinized starch is another typical application for maize starch. A processed carbohydrate used as a binder and texturizer is pre-gelatinized starch. Drilling starch is frequently used as an addition in all forms of water-based drilling fluid systems to increase the viscosity of the drilling mud and reduce fluid loss by sealing the walls of the borehole. This prevents the seepage of soil filtrates into the wells. A refined carbohydrate that is employed as a binder is pre-gelatinized starch. Usually, it is made from corn, waxy corn or tapioca. Gelatine has nothing to do with it. It is risk-free for vegans and vegetarians. The drill bit's excavated rock is raised to the surface by drilling fluid. Its capacity to do so depends on the cutting's size, shape, density, and rate of fluid ascent. Features and Functions It works well as a filtering agent and enhances drilling fluids' abilities to clean holes. Pre-gelatinized starch is used for its water-holding capabilities in the drilling of oil wells to reduce water loss. It may be used with all types of water, stabilises rheology, offers well bore stability, and controls filtration, among other things. Drilling starch is non-ionic corn, tapioca and potato-based polymers for use in all water-based drilling, completion and stimulation fluids. Drilling starch is extensively used as an additive to prevent the

Source of all maize based industries

Poultry industry

Because of its high energy content, low fibre content, and inclusion of pigments and important fatty acids, maize is the preferred energy grain utilised in chicken feed compositions (Panda *et al*., 2014). In 2025, there would be a total need for maize of around 112 million tonnes, with 28 million tonnes designated for poultry (45% of chicken diet). Due to its high energy value, palatability, presence of colours, and necessary fatty acid content, maize is the main energy source used in the diets of chickens in the majority of countries. Among cereal grains, it has the most energy (ME 3350 kcal/kg). It contains 8 to 13 per cent crude protein. 85–90 per cent of its TDN is high. Maize is very pleasant and has little fibre.

Yellow maize, which is fair in terms of phosphorus content but extremely poor in calcium and vitamin B12, supplies carotene and xanthophyll pigments for colouring egg yolk, poultry fat, and skin when it is employed at 30 per cent and higher in the diet. Although linoleic acid, which helps determine egg size, is abundant in maize, tryptophan and lysine are primarily lacking in the protein. Aflatoxin is produced by aspergillus flavus, which is more likely to infest damaged, immature, and inadequately stored maize with a greater moisture content. To reduce the danger of mycotoxins problems, diets containing damaged maize grain must be supplemented with toxin binders. If the moisture content in the grain is higher than 16 per cent, organic acids should be supplied to the maize while it is being stored. For a higher-quality pellet, supplementation with pellet binders, molasses, rice bran, or oil is necessary when maize is utilised at a percentage of >30 per cent in the diet for pellets. Up to 70 per cent of the corn used in chicken feed might be maize (Demeke, 2018). The most frequent cereal grain included in the diets of chickens raised intensively is maize. It contributes about 65 per cent of the metabolizable calories and 20 per cent of the protein in a grill starting diet (Cowieson, 2005).

For medicinal purposes

- Controls and maintains the body's sugar levels, and it aids in the prevention of anaemia.
- Good for the skin; anti-cancer.
- Fibre helps the digestive system.
- Good for your eyes.
- Aids in human pellagra illness prevention.
- Good for the heart.
- Provides the necessary amino acids. (https://health.clevelandclinic.org/benefits-of-corn/)

Recipes of maize

- *Corn soup:* This hearty corn soup only requires a few basic ingredients and takes around 30 minutes to prepare.
- *Making masala corn:* Kids and the majority of us love it. You may always adjust the recipe by excluding or including certain spices, adjusting the amount you use, or both.
- *Corn and vegetable soup:* Fresh sweet corn and veggies are used to make a delicious, creamy soup. The maize kernels are what give the dish its sweetness and creaminess. This soup can also be made with corn kernels from cans. The best maize, though, is fresh.
- *Corn salad:* Easy recipe of salad made with sweet corn, cucumber, onion and spices + herbs. i have used fresh sweet corn. Though even tinned corn be used. But I do suggest using fresh corn as the taste is better with fresh corn.
- *Corn sandwich:* This corn sandwich has an Italian-inspired filling made of tomatoes, garlic and fresh basil. There is some heat in these corn sandwiches. To make these less spicy and fiery, use less black pepper and red chilli flakes.
- *Corn kheer:* The maize kernels are ground and then cooked with milk in this straightforward kheer recipe. The kheer can be made as thin or thick as you choose.
- *Corn capsicum sandwich*: A sandwich with grilled corn and peppers is simple to make. Steamed corns are the primary component required to prepare this sandwich.
- *Roasted corn:* One of the main sources of income in India's rural communities. Since maize is grown throughout the year in India, there are always rural jobs dependent on the crop available.

Maize based some medicinal products

Corn syrup

Essentially, corn syrup is a liquid sweetener produced by digesting corn starch. This mildly sweet food syrup is manufactured from maize starch, which, depending on its grade, contains a variety of sugars, including glucose, maltose, and higher oligosaccharides. Depending on the grade, corn syrup is a food syrup derived from the starch of corn that contains various levels of glucose, maltose, and higher oligosaccharides. Foods are cooked with corn syrup to soften the texture, provide volume, stop the crystallisation of the sugar, and improve flavour (Singh, 2014).

Corn oil

Corn germ oil, often known as maize oil in Britain and North America, is a type of oil. Refined maize oil is mostly used for cooking, where its high smoke point makes it an excellent frying oil. Additionally, it is a vital component of several margarins. Compared to most other types of vegetable oil, maize oil is often less expensive.

Another feedstock for biodiesel is corn oil. Corn oil also finds application in the manufacturing of soap, salve, paint, erasers, inks, textiles, nitro glycerine, and pesticides, among other things. It is occasionally employed in medicinal formulations as a drug molecule carrier. Although maize oil has certain beneficial properties, such as phytosterols and vitamin E, it is not generally regarded as a healthy fat. This is due to the food's high levels of inflammatory omega-6 fats, which should be restricted in a typical Western diet. It is also extremely processed.

High fructose corn syrup

A sweetener derived from maize starch is high-fructose corn syrup (HFCS), often referred to as glucose-fructose, isoglucose, and glucose-fructose syrup (White and Nicklas, 2016). A sweetener manufactured from maize starch, high-fructose corn syrup is sometimes referred to as glucose-fructose, isoglucose, and glucose-fructose syrup. Similar to how regular corn syrup is made, enzymes convert the starch in the starch into glucose (White and Nicklas, 2016). According to studies, high fructose corn syrup causes more fat and stimulates hunger than ordinary sugar. "High fructose corn syrup also contributes to diabetes, inflammation, high triglycerides, and something we call non-alcoholic fatty liver disease (U.S Department of Health and Human Services). The differences between high fructose corn syrup and sugar are too tiny to matter when consumed in moderation, and both substances are unhealthy when consumed in excess (Stanhope, 2016).

Dextrose

A simple sugar derived from corn or wheat with the term dextrose is chemically equivalent to glucose, or blood sugar. Dextrose is a typical sweetener used in baked products and is present in things like processed foods and corn syrup. There are many medical uses for dextrose. A form of sugar called dextrose typically comes from corn or wheat. The sugar contained in the bloodstream, glucose, and dextrose are nearly identical. Because of this, the human body can swiftly use it as a source of energy. Foods frequently contain dextrose as a preservative or an artificial sweetener. Dextrose, also known as corn sugar: The sugar dextrose, sometimes known as corn sugar, is probably the most widely used of the sugars mentioned in brewing. It can instantly supply necessary energy and aid in stabilising severely low blood sugar. However, consuming too much additional dextrose on a regular basis can have negative impacts on your diet. Since dextrose is a simple sugar, it is generally recognised that taking too much of it is unhealthy (Singh *et al*., 2014).

Fodder purpose

In India, second to sorghum, fodder maize (*Zea mays* L.) is the most significant *Kharif* feed crop and takes up 0.9 mha of land. Both human and animal nourishment must be provided in. The digestibility and taste of maize feed are both quite high. At the milk to early dough stage, it comprises, on average, 9-11 per cent CP, 60-64 per cent NDF, 38-41 per cent ADF, 28-30 per cent cellulose, and 23-25 per cent hemicellulose. It is great for making silage and may be offered as green or dry food (Subrahmanya *et al*., 2019). One of the healthiest non-legume green feeds is maize. A good indicator of maize's great acceptability as fodder is the absence of any anti-nutritional elements. Rapid growth, high biomass yields, and excellent palatability characterise maize. While grain production takes roughly 90-110 days, the fodder is available in between 60 and 70 days. Between 350 and 450 quintals of fodder are produced per hectare. It is a maintenance type of fodder with 8–10 per cent crude protein content. It can be grown all year round if there is an irrigation system.

Whole ensiled maize plants are used to create maize silage (*Zea mays* L.). Everywhere maize can grow, from temperate climates to the tropics, it is one of the most excellent forages for ruminant animals (Wilkinson and Rinne, 2018). Cutting fresh (green) fodder, compacting it, and storing and fermenting it in a silo, where air cannot touch the silage, are all steps in the silage-making process (Kabirzi *et al*., 2015).

Silage can be fed to animals at any time and is very palatable to them. Whole-plant maize silage is a premium product that is always included in the diets of dairy cattle. It is preferred not just for its abundant supply of fibre and inherent high energy content, but also because the yield is maximised when the entire plant is harvested, providing up to 50 per cent more energy than dried maize kernels (Khan *et al*., 2015).

Making bio plastics, biofuel, ethanol and tyres

Currently, disposable objects like bottles, cups, and bio plastics make by maize by-products. The biodegradable, carbon-neutral, and edible PLA (Polylactic Acid) is a type of bioplastic that is mainly manufactured from corn sugars (Roymahapatra and Khatua, 2016). Currently, both developed and developing nations use maize starch to make vehicle tyres. Making bioethenol from maize starch, which is also used as syrup, car gasoline, and alcohol (Talebnia, 2015).

For traditional uses

Basket making in Bihar and Uttar Pradesh (by tharu tribes of Lakhimpur). After harvesting used as fuel purpose for cooking. Flour used as making "Sattu". Making shelters by after harvested plant of maize which is locally known as "Chhappar".

Potential of agroforestry

The average agroforestry potential across 96 million ha is 25 t C ha 1. Thus, India's agroforestry sector has a total capacity to store nearly 2,400 million tonnes of carbon (Sathaye and Ravindranath, 1998). The goal of agroforestry is to increase the biomass of trees and agricultural crops. Practically all of the requirements for firewood, fruit, fibre, feed, and timber breakdown, etc. which improves the state of the soil. This site can be used for agricultural production after the soil is upgraded (Patra, 2022). Agroforestry has the potential to benefit maize production in several ways. By integrating trees and maize on the same land, agroforestry systems can provide

numerous advantages for maize cultivation. Trees in agroforestry systems contribute organic matter through leaf litter, improving soil structure and nutrient cycling. This enhanced soil fertility can positively influence maize growth and productivity. Tree canopies in agroforestry systems provide shade and reduce temperature extremes, creating a more favorable microclimate for maize. This can help mitigate the negative effects of heat stress on maize plants during critical growth stages (Vyamana *et al*., 2021). Planting trees as windbreaks in agroforestry systems can protect maize crops from strong winds, reducing physical damage and preventing soil erosion. This is particularly beneficial in areas prone to wind erosion. Agroforestry systems promote biodiversity by integrating different tree species alongside maize. This diversification can enhance ecological stability, making the agroecosystem more resilient to pests, diseases, and climate variability (Bertomeu, 2012). Improved water management: Trees in agroforestry systems can help regulate water availability for maize plants. They can reduce water evaporation from the soil surface, increase water infiltration, and enhance water-use efficiency, thereby supporting maize growth and yield (Liu *et al*., 2020). Complex agroforestry encourages the sustainable development of degraded lands by maintaining human activity, while conserving natural resources. Through its combined economic, environmental and social functions, complex agroforestry can make a significant contribution to sustainable development (Octavia *et al*., 2022).

Agroforestry potential with maize

When compared to maize monocultures, the application of the replicated agroforestry increases maize yield under current and future climatic circumstances, especially in areas where yield losses due to climate change are anticipated (Chemura *et al*., 2021). Agroforestry systems are one of the finest ways to increase maize productivity or output. All of those risks are diminished as a result of monoculture. For the sake of browsing, mulch, green manure, soil conservation, and other uses, various woody hedges, particularly fast-growing and coppicing fodder shrubs and trees, are planted in this system. Typically utilised species include *Erythrina sp., Leucaena luecocephala, and Sesbania grandiflora* (Muschler, 2016).

Role of agroforestry in agriculture

By the end of the twenty-first century, it's predicted that there will be 8 billion people on the planet, which means that 120 million tonnes of food will be needed to feed them all. The demand for food is predicted to rise by 60 per cent globally and by 100 per cent in developing nations by the year 2050 (FAO).

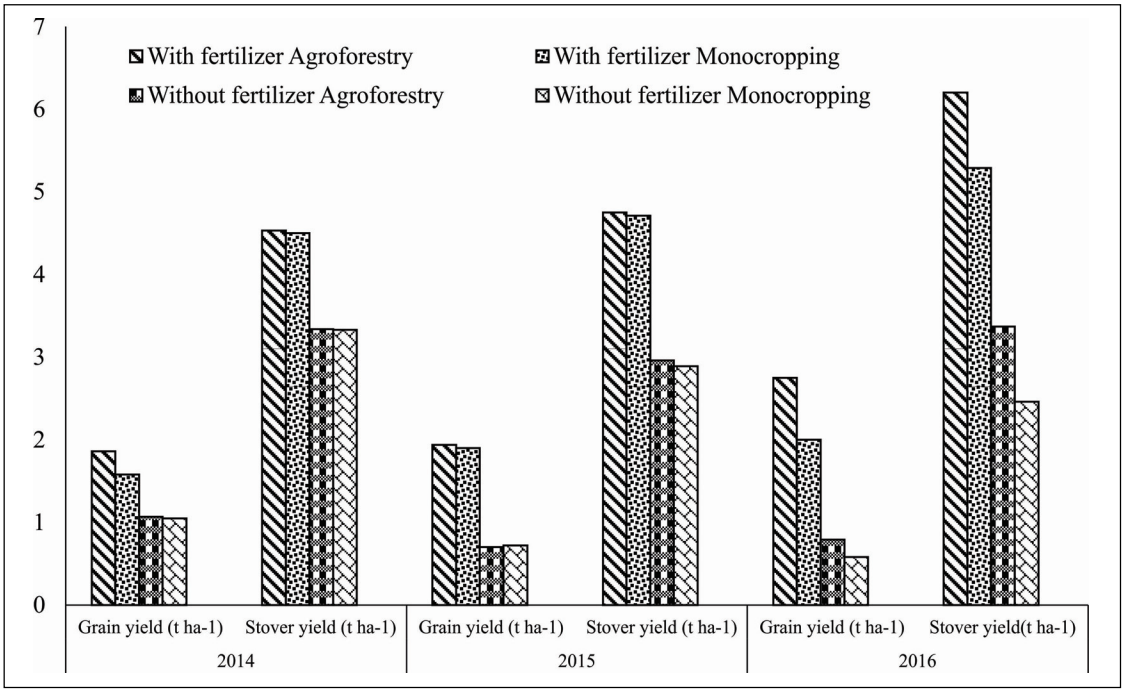

Figure 1. Showing Potential productivity of maize under bamboo based agroforestry (*Source:* modified from Akoto *et al*., 2020)

In both irrigated and rain-fed environments, agroforestry is practised to produce food, fuel, fodder, timber, fertiliser, and fibre. It also contributes to food, nutritional, and ecological security, supports livelihoods, reduces poverty, and encourages resilient and productive cropping and farming environments (Gupta *et al*., 2023).

Agroforestry is especially important for smallholder farmers and other rural residents because it can improve their access to food, income, and health. Multipurpose agroforestry systems can offer a variety of economic, societal, and environmental advantages (Gupta *et al*., 2023).

Agroforestry can also enhance the storage of soil organic carbon and nitrogen, the availability of soil nitrogen and phosphorus to crops, and the reduction of soil acidity, among other soil quality characteristics (Muchane *et al*., 2020). Systems that practise agroforestry (AF) are very important for protecting natural resources, particularly soil. The soils are shielded from erosion brought on by wind and water. AF systems mitigate the negative impacts of temperature and wind on soil fertility, soil flora, and soil fauna. Agroforestry makes it possible for agricultural land to survive climate change and adverse weather conditions like floods and droughts. Agroforestry improves the soil's nutritional content while also reducing soil erosion. The production of food, fuel, timber, and numerous agricultural products is just one advantage of the agroforestry system. It also helps to restore the ecosystem's balance and promotes agricultural conservation (FAO World Forestry Congress, 2005). Agroforestry practises have the ability to promote water infiltration and retention in the soil profile, which can relieve moisture stress in years with low rainfall by increasing soil porosity, decreasing runoff, and increasing soil cover (Jose, 2009).

Different agroforestry systems in which growing maize

Agri-silviculture system

Multipurpose agroforestry systems can offer a variety of economic, societal, and environmental advantages. Agroforestry systems can be divided into three primary categories: Agrisilvicultural practises, like alley cropping, taungya cultivation, and wind barriers, combine crops with trees (Atangana *et al*., 2014).

Alley cropping

In alley cropping, planted shrubs and trees, particularly leguminous species, are hedged off with arable crops. The hedgerows are routinely maintained to prevent the companion crop from being shaded. It has been investigated how well *L. kucocephala* and *G. sepium* perform in alley cropping with maize, cassava, and cowpea. Alley cropping led to higher maize and cassava yields than in control plots. Alley cropping, often referred to as hedgerow intercropping, is a practise where perennial trees or bushes, preferably leguminous ones, are cultivated alongside an arable crop (Kang *et al*., 1984).

Taungya cultivation

The procedure entails clearing the land, planting trees, cultivating crops for one to three years until the shade is too intense, and then repeating the process in another location it's one of the old agroforestry systems which was instead of shifting cultivation (Edberg *et al*., 2022). Maize is grown alongside other tree species like teak and sal (Yadessa *et al*., 2001). Taungya is a method of managing forests whereby land is cleared and originally planted with food crops. The same plot is then planted with seedlings of desirable tree species, eventually producing a stand of timber that may be harvested (Wiro and Ansa, 2019).

Wind breaks/shelter belts

This is the linear strip of trees or shrubs which are reduce wind velocity. Wind breaks to protect crops against lodging due to wind breaks reduce wind velocity. Decrease soil erosion which is caused by wind. Windbreaks are used mainly to diminish the impact of strong winds that may damage crops and cause soil erosion. They also reduce the effect on crops by drought, extreme heat and even frost, due to the microclimate that trees foster (Puri *et al*., 1992)

Agri-horticulture system

Combination of crops and fruit trees such as *Annona squamosa* with maize, *Psidium guvajava* with maize, and *Aegle marmelos* with maize etc. is called agri-horticulture system. Source of double income to the farmers. Potential productivity of maize increase under this system. It is highly profitable a sustainable as aonla is a regular bearer and exerts comparatively less effect on

associated crop and requires low management and inputs (Dagar and Tewari, 2016).

Conclusion

We can say maize as future cereal crop because of higher genetic yield potential, good economic value and demand, wider adoptability to climate and soils and multipurpose uses etc compare to other major cereal crops like wheat and rice. Agroforestry another option for increasing and sustaining the maize yield per unit area as well as increasing the overall food production in the world because agroforestry reduces soil erosion, improve soil fertility and health, increase nutrient availability to agricultural crop, make micro-climate of crop, increases moisture level, maintains temperature, reduces crop lodging due to high wind velocity, reduces risk of insect pest attack and make agricultural ecosystem of particular crop etc.

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