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Cashew tree (*Anacardium occidentale* L.): A Review on Characteristics, Production, Genetic Diversity, Market, and Research Updates

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Abstract

The cross-pollinated nature of the cashew tree and the use of non-selected nuts lead to the coexistence of multiple cashew varieties with unknown and highly variable characteristics within the same plantation. This genetic diversity, combined with pedoclimatic variability, often results in the unsuitability of certain genotypes to specific environments, thereby limiting their productive potential. Furthermore, the absence of a structured classification system and the lack of standardized selection criteria pose significant systematic challenges in identifying and promoting elite varieties. To improve yields, some producers opt for grafted plants, which, although costly, do not always guarantee uniformity due to insufficient characterization of the genetic material. This practical limitation perpetuates heterogeneity within plantations and reduces the adaptability of certain grafted plants to specific pedoclimatic zones. In addition, poor agronomic practices and inadequate technical support hinder the optimal exploitation of genetic resources. On a technical level, the lack of knowledge regarding the genes responsible for key morphological and phenotypic traits represents a major obstacle to breeding and varietal selection programs. The absence of molecular markers and efficient propagation techniques further complicates the establishment of high-yielding and climate-resilient plantations. This study aims to synthesize existing knowledge on the cashew tree worldwide, establish a comprehensive database of relevant research, and identify promising strategies to enhance the valorization of the species.

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1. Introduction

The cashew tree (*Anacardium occidentale* L.), native to the coasts of Brazil (Russel, 1970) ^[81], is now a strategic crop for many tropical countries, particularly in Africa and Asia. With an expansion of its cultivated area from 5.35 million hectares in 2011 to 6.56 million hectares in 2021 (22.62%), and a global production reaching 3.7 million metric tons (FAO, 2023) ^[30], the cashew sector has become a crucial driver of economic and social development (Adégbola and Zinsou, 2010; Bassett, 2017) ^[2, 12]. In West Africa, and particularly in Benin, it constitutes a major source of income for thousands of producers and a strategic lever for food security and export (Tandjiékpon, 2010; Bello *et al.*, 2019) ^[90, 13].

Beyond its economic importance, the cashew tree plays a key role in environmental preservation. Its integration into agroforestry systems contributes to combating desertification, conserving soils, and sequestering carbon (Tokoré Orou Méré, 2022) ^[93].

Additionally, its products—nuts, bark, and apples—are valued in various sectors: timber industry, human and animal food, and traditional medicine (Seydou *et al.*, 2017) ^[84].

However, despite this expansion and these advantages, cashew cultivation faces major challenges, notably declining orchard yields, soil degradation, and low resilience to climate change. Several studies have shown that improving fertilization and technical practices can significantly increase plantation productivity (Adéjumon, 2010; Balogoun *et al.*, 2016; N'djolosse *et al.*, 2018) ^[3, 11, 62]. The application of mineral fertilizers has specifically been identified as a key factor positively influencing production (Bezerra *et al.*, 1999) ^[14]. However, responses to these inputs vary considerably depending on genotype, soil, and climate, underscoring the need for further research on genotype-environment-soil (GxExS) interactions (Djaha *et al.*, 2012) ^[27].

Genetic research on the cashew tree has primarily focused on varietal diversity, the selection of high-yielding clones, and resistance to biotic and abiotic stresses (Tandjiékpon, 2005, 2010, 2012, 2013, 2017) ^[89, 90]. However, in Benin, studies on genetic association between cashew genotypes and soil characteristics are virtually nonexistent, even though they are essential for identifying the varieties best suited to local pedoclimatic conditions. Moreover, while several molecular markers have been used for the genetic characterization of cashew, SNP (Single Nucleotide Polymorphism) markers, recognized for their high resolution in marker-assisted selection (MAS) studies, remain largely underutilized in the research conducted to date (Mnoney *et al.*, 2001; Sousa *et al.*, 2015) ^[61].

Therefore, a systematic review of the existing knowledge on cashew is necessary to provide an overview of scientific advancements and identify key research gaps. Specifically, this study will highlight the need to integrate genotype-soil association analyses and the application of SNP markers in future work to optimize the selection and varietal adaptation of the cashew tree to the agroecological realities of Benin.

2. Methodology.

Scientific curiosity, whether aimed at ensuring data reliability or verifying its completeness, has driven an in-depth literature review on the cashew tree (*Anacardium occidentale*). This systematic review was conducted using various search engines and academic databases, including Google, Google Scholar, ResearchGate, Freefull PDF, and Agora. The methodological approach was based on rigorous inclusion and exclusion criteria, enabling the identification of relevant studies focused on cashew nuts and the cashew tree itself. The selected documents encompass a wide range of scientific sources, such as peer-reviewed journal articles, books, technical reports, university theses, and other academic publications. These sources cover key topics related to the cashew tree, including its origin, geographical distribution, genetic diversity, morphological characteristics, cultivation techniques (phytotronics), and genetic markers used for identification and varietal improvement. To maximize the relevance of the retrieved information, an advanced search strategy was implemented. This involved the intelligent combination of keywords in both French and English, linked through the Boolean operator "AND". The search terms included: "cashew tree", "cashew", "acaju", "caju", "botany", "production", "variety", "uses", "economic importance", "genetic diversity", "genetic markers", "ecology", and "morphology". Through this approach, a total

of 2,000 documents, published between 1960 and 2023, were collected. To ensure the quality and relevance of the selected sources, a rigorous analysis process was conducted, including a systematic sorting step to eliminate duplicates and redundant publications. Subsequently, a refined selection was made based on the coherence of the content with the research focus and its scientific contribution. This methodical and reproducible process resulted in the final selection of 99 documents, which were used for the drafting of this analytical synthesis. This approach ensures a comprehensive coverage of the available knowledge on the cashew tree, providing an in-depth understanding of its botanical, economic, and genetic characteristics.

3. Genetic diversity and description of the cashew tree

3.1. Genetic diversity

The genus *Anacardium* (*Anacardiaceae*) includes 10 species of cashew trees native to Brazil (Mitchell and Mori, 1987) ^[60]. Some of these species, including *Anacardium nanum* A. St-Hil., and *A. humile* A. St-Hil. produce fruits (drupe or nut) and pseudo-fruits (swollen pedicel) that are smaller than those of the common cashew (*A. occidentale* L.) and, for this reason, are classified locally as "cajuí" rather than "caju" (Carbajal and Silva-Júnior, 2003) ^[18]. Cajuí trees are scattered throughout Brazil, from the Amazon to the Northeast, Central West, and Southeast regions, but their natural abundance is particularly high in the coastal areas of the state of Piauí (PI) (Crespo and Souza, 2014). Furthermore, little information is available on cajuí biodiversity.

3.2. Botanical description

The cashew tree (caju) has a pivoting root system with a main root that can reach two meters deep. When the diameter of the crown reaches two to four meters, the lateral roots produce new taps approximately two to four meters from the trunk from the lateral roots, which is very particular and essential to understand for the cultivation of the tree. The roots at the age of 9 months have a length equal to approximately 1.5 times the height of the plant. Its bole rarely exceeds 2 meters and is branched. According to Ouédraogo (2008) ^[70], the total height of the tree rarely exceeds 8 to 10 meters in the African area. In its native area, however, it can reach up to 20 meters in height. The trunk of the cashew tree is slightly gray and rough. The leaves of the cashew tree are simple, alternate, leathery, and have a thick cuticle with prominent veins on the upper area (Tandjiékpon, 2005) ^[89]. They measure 7 to 18 cm long by 5 to 12 cm wide and are carried by a petiole of approximately 1 to 2 cm, thickened at the base. The blade is brittle, and so is the petiole at its base. The color of the upper side of the leaves is dark green and lighter on the lower side. The leaves are marked with 10 to 15 pairs of lateral veins (Figure 1). The branches are extremely sensitive to fire, and when they are destroyed by fire, it takes many years before the tree rebuilds its crown, depending on its age. The bark is gray and generally smooth. Its floral panicles bear male and cross-pollinated flowers (Figure 2). The flowers appear at the end of the rainy season in areas of the crown exposed to solar radiation. Each flower has five petals, five sepals, six to fourteen staminoids (usually eight or nine), a simple ovary, atrophied in staminate flowers, and a stamen (CIRAD-GRET, 2002) ^[20]. At the end of flowering, the real fruit, also called cashew or cashew nut, forms first until it reaches its maximum size. Then occurs the development of the peduncle to become the false fruit called

the cashew apple. At this time, the nut decreases in volume, hardens, and loses moisture. When ripe, the fruit detaches from the tree and falls to the ground, where it will be picked up. The cashew nut is an achene (dry fruit that does not open but is completely detached from the mother plant) measuring

three to five centimeters, brownish gray in color, and made up of a pericarp whose interior part is very hard and the outer part is spongy. All the organs of the plant exude a strong scent of turpentine when crushed. Old trees have low productivity, but they can be regenerated by coppicing.

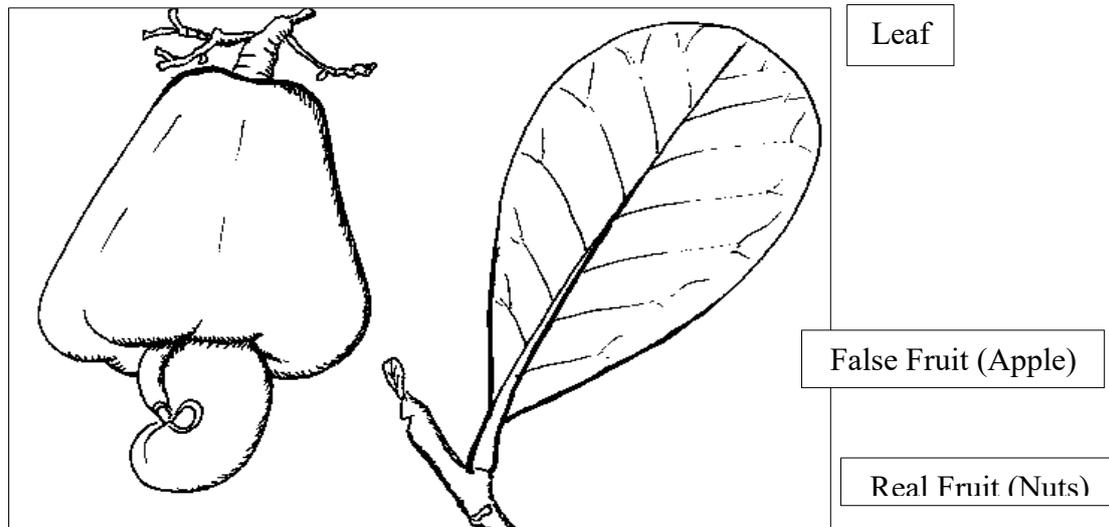


Fig 1: Apple, cashew nuts and cashew leaf (Lacroix, 2003)

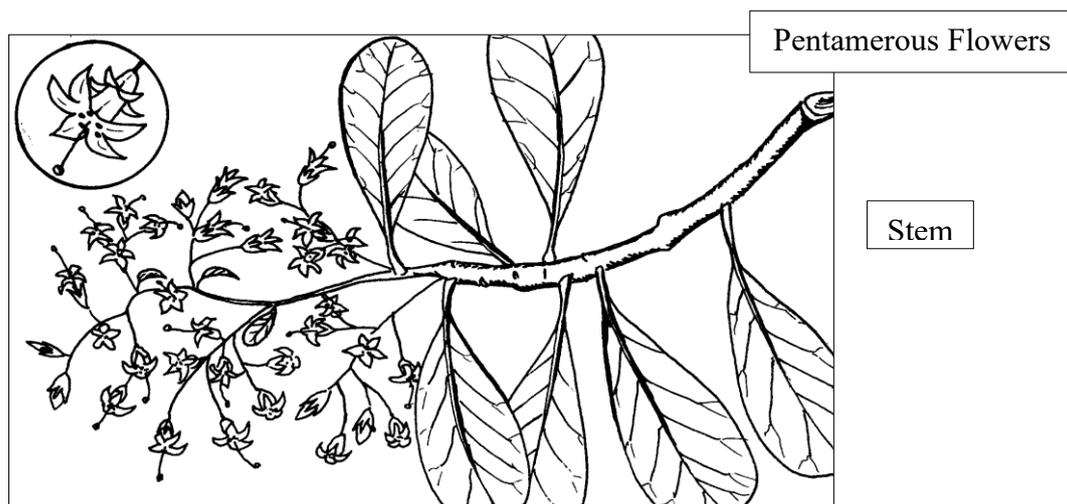


Fig 2: Terminal panicle of cashew flowers with stem, leaves and pentamerous flower close-up (Lacroix, 2003)

The systematic position of the cashew tree is presented in Table 1.

Table 1: Systematics of the cashew tree (Bognina, 2017) [16]

Reign	Vegetal
Branch	<i>Spermaphytes</i>
Sub-branch	<i>Angiosperms</i>
Class	<i>Dicotyledons</i>
Order	<i>Sapindales</i>
Family	<i>Anacardiaceae</i>
Gender	<i>Anacardium</i>
Species	<i>Occidentale</i>
Vernacular names	French: anacardier/ cajou English: cashew Portuguese: acaju

3.3. Varietal diversity

The cashew tree was grouped into common and dwarf cultivars on the basis of genetic variability. Common types are widely cultivated, with heights ranging from 5 to 8 m and

canopy diameters reaching 20 m, while dwarf types are less than 4 m tall, with an even canopy and smaller diameters than the common type. (Oliveira *et al.*, 2006) [68]. This means that the potential size of cashew trees is under genetic control, and varieties with different tree sizes can be developed through breeding. Over the years, a number of genetically diverse accessions of cashew germplasm have been introduced from their centers of origin in various cashew-producing countries in the West African sub-region. In Ghana, the first introductions came from Brazil, Benin, Nigeria, Mozambique, and Tanzania (Adu-Gyamfi, 2020) [4]. Introductions from Brazil were dwarf types, while those from Benin were common types with absolute tolerance to harsh environments (Adu-Gyamfi, 2020) [4]. Recently, the narrow genetic base of cultivated cashew clones, particularly in Africa and Asia, has been attributed to the low productivity of cashew (Archak *et al.*, 2003; Aliyu, 2011) [9, 6]. Four varieties of cashew were listed during an agro-morphological study in Benin (table 2).

Table 2: Some varieties of *Anacardium bleue* grown in Benin (Touré *et al.*, 2017)

Varieties	Tree	Phenology	Apple		Nut	
			Color	Size	Color	Size
Henry	Branched bottom multi-stemmed	Fruit setting stage: the apple is 3 to 4 times smaller than the walnut	Summer yellow	Small	Light gray enamelled with purple spots	Small
Benin yellow	Low branched with multi-stemmed and basal branching	Fruit setting stage: the apple and the walnut are relatively the same length	Yellow	Fat	Greenish spotted with purple on the chin	Big
Costa Rica	Low branched multi-stemmed tree, spreading crown like a parasol	Fruit setting stage: the apple and the walnut are relatively balanced	Yellowish	Fat	Light gray spotted with black	Big
James	Low branched multistem with spreading habit	Fruit setting stage: the apple is smaller than the walnut	Red to bright red	Small	Gray, chin spotted with black	Medium to small

4. Typology

4.1. History and situation of the cashew sector in the world

From the coasts of Brazil and introduced to Africa and Asia by the Portuguese, the cashew tree was discovered during the 16th century and is found in several regions of the world (Laynaz, 2006; Soro, 2012) ^[53, 87]. Initially used to combat soil erosion, it gradually became a commercially significant crop worldwide. The first descriptions of the cashew tree were made by French, Portuguese, and Dutch explorers. The indigenous Tupi people of Brazil called it "acaju," which means "self-producing nut" or "fruit that propagates itself." This refers to the prolific nature of the cashew tree, whose seed can quickly germinate and produce a new tree. The term later evolved into "caju" under the influence of Portuguese colonizers. The English named it "cashew," derived from the Portuguese "caju," with a phonetic transformation into English. In Spanish, it is called "cajuil," originating from the Portuguese term, with a Spanish adaptation. In French, it is referred to as "acajou" or "cajou," derived from "acaju," but it is often confused with the mahogany wood (*Swietenia spp.*), a completely different tree. "Cajou" is closer to the original term (Soro, 2012) ^[87]. In several African languages, the cashew tree has received names inspired by its use and colonial origin. In Bambara (Mali), it is called "Gwé," often meaning a fruit or edible tree; in Wolof (Senegal), it is "Kashu," the phonetic transcription of the Portuguese word; in Baoulé (Ivory Coast), it is "Blê-blê," evoking the shape or taste of the fruit; and in Fon (Benin), it is "Kanju," influenced by the Portuguese term with local adaptation. These different names demonstrate how the cashew has been perceived and adopted worldwide. While the indigenous people of Brazil emphasized its regenerative capacity ("acaju"), Europeans and Asians adapted its name based on their languages and writing systems. In Africa, colonial influence prevailed, but local names exist, often linked to the culinary or medicinal uses of the fruit and nut (Soro, 2012) ^[87].

The spread of cashew cultivation occurred in several stages. Initially introduced to India, it then spread to West Africa, East Africa, and Southeast Asia. Today, its production spans six major climatic regions: India; West Africa (Côte d'Ivoire, Benin, Nigeria, Senegal, Burkina Faso, Guinea-Bissau, Gambia, Ghana, and Togo); South America (Brazil); East Africa (Kenya, Tanzania, Mozambique, and Madagascar); South Asia (Malaysia, Thailand, Cambodia, and Sri Lanka); and East Asia (Vietnam, Indonesia, China, and the Philippines). Africa currently accounts for more than 50% of global production (Manigui and Bedié, 2016) ^[56].

4.2. Cashew production in the world

Cultivated in more than 32 countries worldwide, the cashew tree (*Anacardium occidentale* L.) holds a prominent position in nut production. Africa contributes approximately 40% of global raw cashew nut production, with 80% of this coming from West Africa. FAO statistics indicate that 33 countries produce cashew nuts globally, with 16 of these located in Africa. The ten largest producers are Vietnam, India, Ivory Coast, Benin, Nigeria, the Philippines, Guinea-Bissau, Indonesia, Tanzania, and Brazil (FAOSTAT, 2017) ^[33]. These ten countries alone account for 91% of the world's cashew supply. There are two main trends in production across these countries: a decline in Vietnam, Tanzania, India, and Brazil, and an increase in Ivory Coast, Benin, Nigeria, the Philippines, Guinea-Bissau, and Indonesia (Ndiaye *et al.*, 2021) ^[66].

The cashew tree is an important source of income for many producers. In 2019, global raw cashew nut production was estimated at 3.4 million metric tons, with Africa contributing a significant 2.3 million metric tons (FAOSTAT, 2022) ^[31]. Côte d'Ivoire has become the world's leading producer since 2015, surpassing India and Vietnam with over 700,000 metric tons exported. Benin, which accounts for approximately 3.5% of global production, has also seen consistent growth in its export volumes (Hinnou *et al.*, 2022) ^[43]. Despite this growth, the African sector faces several structural challenges, including insufficient infrastructure, post-harvest losses, and limited local processing capacity.

Due to the high global demand, cashew production has steadily increased, especially in the last five years. Ivory Coast, leading as the top producer and exporter since 2015, has experienced remarkable growth. By 2019, global production of raw cashew nuts reached 3.4 million metric tons, with African production accounting for more than 50% of the total. West Africa alone contributed 1.7 million metric tons (FAOSTAT, 2022) ^[31]. In 2020, global production surpassed 5.5 million metric tons, with Africa, Asia, and South America being the primary contributors. African production alone accounted for around 60% of global volume, supplying more than 90% of the world's raw cashew nuts (FAOSTAT, 2022) ^[31].

A significant yield gap exists between Africa and Asia: while yields in Africa range from 250 to 600 kg/ha, yields in Asia average between 1,000 and 1,500 kg/ha (Tchétangni *et al.*, 2016) ^[92]. This disparity is due to factors such as the use of improved varieties, advanced varietal selection, better plantation management practices (including pruning, thinning, and fertilization), and more developed access to

agricultural inputs in Asia. Additionally, the role of irrigation and climate adaptation in Asia contrasts with Africa's reliance on rainfall for cashew cultivation. In some Asian regions, irrigation systems help mitigate the effects of dry spells, a benefit not typically available in many parts of Africa.

India has long been a significant player in the cashew industry, remaining the largest producer, processor, consumer, and exporter. From 2015 to 2016, India produced 172,719 metric tons (kernel basis), accounting for 23% of global production. Meanwhile, Benin's cashew nut exports have grown substantially, from 36,487 metric tons in 2001 to 151,250 metric tons in 2017 (Hinnou *et al.*, 2022) ^[43]. Though Brazil is the native country of the cashew, it ranked only tenth in global production in 2014, behind countries such as Nigeria, India, Ivory Coast, Vietnam, and Benin (FAO, 2017) ^[33]. Brazil remains, however, the leading producer of cashew apples, accounting for over 90% of global production.

In recent years, the average yields and cultivated areas for cashew production have increased significantly. From 2001 to 2011, cultivated areas grew by 47.6%, from 3.2 to 4.7 million hectares, and between 2012 and 2021, this increased further from 5.86 million to 7.41 million hectares. Average yields also grew by 20.1%, reaching 1.3 t/ha, with Peru recording the highest yield of 5.1 t/ha in 2011. Global production evolved from 29.32 million metric tons in 2014 to 37.08 million metric tons in 2021 (FAO, 2023) ^[30].

In more than 32 countries around the world, the cashew tree (*Anacardium occidentale* L.) is in first place when it comes to nut production. 40% of the total production of raw nuts is provided by Africa, of which 80% comes from West Africa. FAO statistics indicate that there are thirty-three (33) cashew-nut-producing countries in the world, including sixteen (16) in Africa. The ten largest producers are Vietnam, India, Ivory Coast, Benin, Nigeria, the Philippines, Guinea Bissau, Indonesia, Tanzania, and Brazil (FAOSTAT, 2017) ^[33]. These ten (10) countries alone provide 91% of the world's supply of nuts. There are two trends in the evolution of production in these countries, namely a downward trend in production that concerns Vietnam, Tanzania, India, and Brazil and an upward trend which concerns the Ivory Coast, Benin, Nigeria, the Philippines, Guinea-Bissau, and Indonesia (Ndiaye *et al.*, 2021) ^[66].

Due to the high demand in the market, the production of cashew nuts has continued to increase, especially in the last five years. In African and global production, Ivory Coast has made a remarkable breakthrough and, since 2015, has become the world's leading producer and exporter of cashew nuts with more than 700,000 metric tons (FAO, 2017) ^[33]. The global production of raw cashew nuts was estimated at 3,396,680 metric tons from a cultivated area of 3,276,756 ha

in 2019. Africa, with a production of 2,334,405 metric tons, is the world's leading producer and exporter of cashew nuts, representing more than 50% of production. West Africa's production in 2019 was 1,696,417 metric tons.

In 2020, total global production is estimated at more than 5,535,510 metric tons (FAOSTAT, 2022) ^[31]. Asia, Africa, and South America are the main continents involved in cashew nut production.

African production represents approximately 60% of the global volume and constitutes more than 90% of the supply on the international raw nut market. Since 2015, Ivory Coast has become the world's leading producer and exporter of cashew nuts with more than 700,000 metric tons, taking the lead over India, Vietnam, and Brazil. (Bognina *et al.*, 2019) ^[17]. Most cashew nut production in Africa is carried out by minor producers, with individual trees standing among annual crops. It is therefore difficult to compare their yields with those obtained on plantations devoted exclusively to cashew nuts. However, African yields are only 250 to 600 kg/ha, compared to around 1000 to 1500 kg/ha in Asia. (Tchétangni *et al.*, 2016) ^[92].

India has consistently been a major player in cashew production. It is the most influential producer, processor, consumer, and exporter of cashew nuts in the world and dominated cashew production from 2015 to 2016 with a harvest of 172,719 metric tons (kernel basis), which accounted for 23% of world production.

Benin accounts for approximately 3.5% of world production of raw nuts, with the potential to increase production in quantity and quality to improve its export capacities (Hinnou *et al.*, 2022) ^[43]. In recent years, exports of cashew nuts have experienced remarkable growth, from 36,487 metric tons of raw nuts exported in 2001 to 146,332 metric tons in 2011 and then to 151,250 metric tons in 2017 (Hinnou *et al.*, 2022) ^[43]. Although it is a Brazilian culture, according to the FAO (2017) ^[33], in 2014, Brazil was the tenth-producing country in the world of cashew nuts, with Nigeria, India, Ivory Coast, Viet Nam, and Benin ahead. When it comes to fresh fruit (cashew apple) production, Brazil ranks first, accounting for more than 90% of global production.

Average yields and areas planted for cashew nut cultivation have increased considerably in recent years (FAO, 2023) ^[30]. Cultivated areas increased by an average of 47.6% between 2001 and 2011, going from 3.2 to 4.7 million hectares, then from 5.86 million to 7.41 million hectares between 2012 and 2021. The average cashew nut yield increased by 20.1% to reach 1.3 t/ha. It is in Peru that the yield is the highest, with a production of 5.1 t/ha in 2011. World production has also evolved in recent years, from 29.32 million metric tons in 2014 to 37.08 million (Figure 3) in 2021 (FAO, 2023) ^[30].

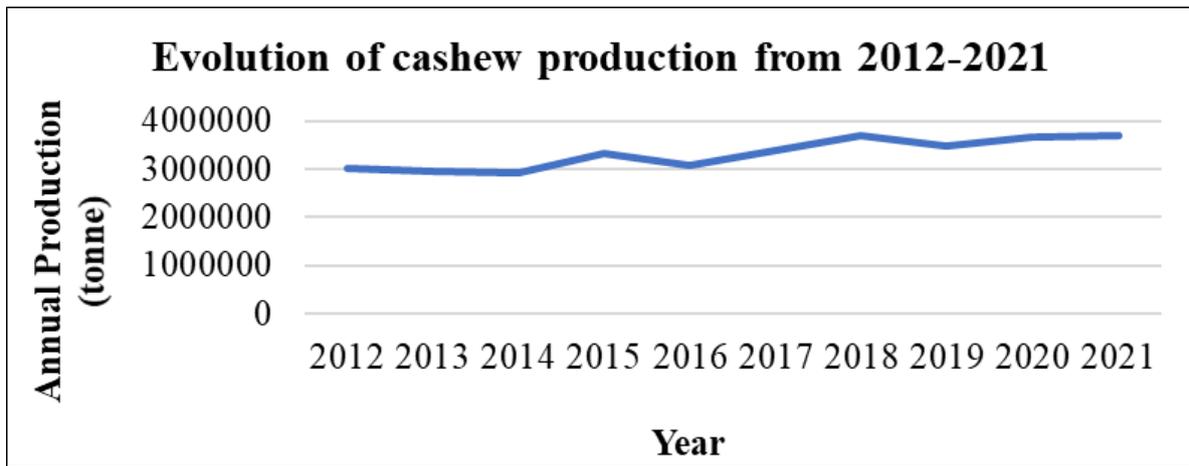


Fig 3: Global cashew production from 2012-2021 (FAO, 2023)

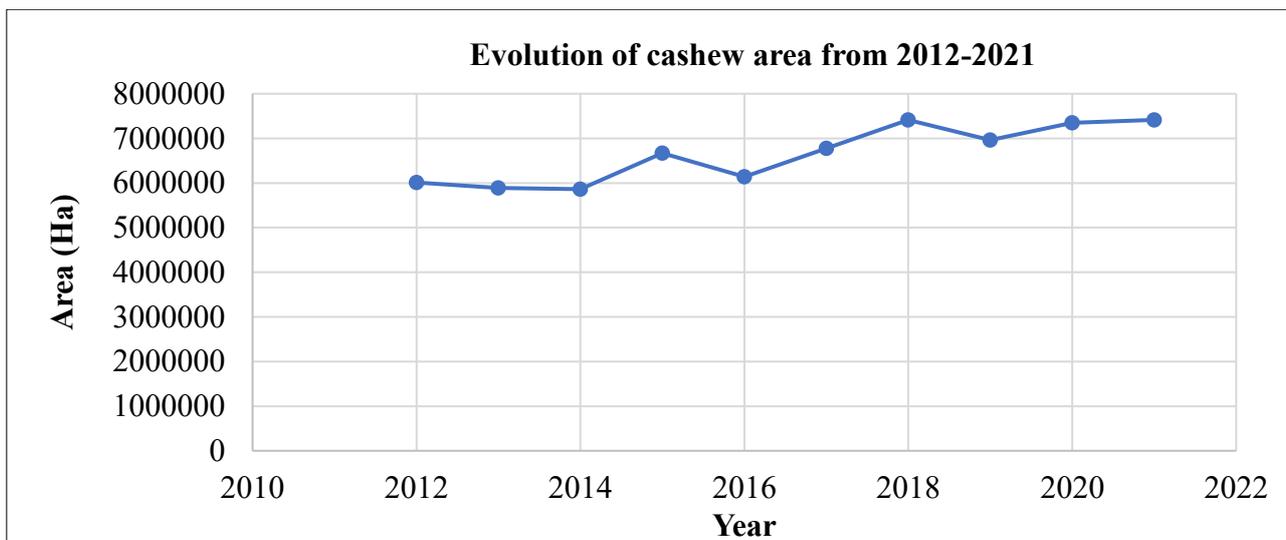


Fig 4: Global growth of cashew area from 2012-2021(FAO, 2023)

Brazil left its top position in 201 due to drought, which resulted in the loss of 99% of its cashew nut crop. following the loss of 99% of its cashew nut production. Between 2013 and 2014, global cashew nut production reached about 2.67 million metric tons (Idah *et al.*, 2014) ^[45]. Asian countries supplied half of the total production. West Africa provided roughly a third (36%) of the total, while Latin America and East Africa contributing approximately 11 and 8%, respectively (Idah *et al.*, 2014; Das and Arora, 2017) ^[45, 22]. During this time, India produced the most cashew nuts (0.774 million metric tons), followed by Ivory Coast (0.480 million metric tons), Vietnam (0.267 million metric tons), Indonesia (0.134 million metric tons), and Brazil (0.134 million metric tons) (Das and Arora, 2017) ^[22]. West Africa is the leading producer, accounting for 1,795,000 T, or 49% of global cashew production (FAO, 2023) ^[30]. The cashew ability to reduce poverty and stimulate rural development has been well recognized (Wongnaa and Awunyo-Vitor, 2013; Dendena and Corsi, 2014) ^[104, 25].

4.3. Contribution of cashew production globally

The economic impact of the cashew industry in Africa is substantial, serving as a vital source of income for millions of smallholder farmers, particularly in countries such as Côte d'Ivoire, Benin, Nigeria, and Guinea-Bissau. However, beyond its economic benefits, the sector faces significant social and structural challenges. Working conditions in processing units are often precarious, with a workforce predominantly made up of women in low-skilled, poorly compensated roles, while supervisory positions are mostly occupied by men (Houssou *et al.*, 2016) ^[44]. Moreover, the absence of protective measures exposes female workers to toxic fumes during the manual shelling of cashew nuts, raising serious public health concerns (Padonou *et al.*, 2015) ^[72]. Furthermore, the cashew apple, a valuable by-product, is largely underutilized. In West Africa, for instance, nearly 90% of cashew apples are discarded due to the lack of infrastructure for processing them into products such as juice, vinegar, or other derivatives (Hinnou *et al.*, 2022) ^[43].

A more structured value chain, including investments in infrastructure modernization, the enhancement of female workers' rights, and the development of local processing capacities, would improve the sector's competitiveness while ensuring a more equitable distribution of its benefits. This, in turn, would support the sustainability of both producers' and workers' livelihoods in the industry.

Cashew cultivation, introduced to India in the 16th century to combat soil erosion, has since become a major income source for many coastal communities in the country (Laynnaz, 2006)^[54]. Today, cashew cultivation is a key component of international trade (N'kalo, 2016)^[63]. The trade is organized around two main types of partnerships. The first involves exchanges between less developed countries and emerging economies, where unshelled cashew nuts are exported from West and East Africa to India and Vietnam. The second involves trade between emerging countries and industrialized nations, where shelled cashew nuts are exported from India and Vietnam to North America, Western Europe, and, to a lesser extent, Japan and Australia. The primary market players are Vietnam, India, and Côte d'Ivoire. Vietnam imports a substantial quantity of raw cashew nuts, primarily from Africa, as its national production covers only 25 to 30% of processing demands (N'kalo, 2016)^[63]. In recent years, exports of shelled cashew nuts to other emerging countries such as China, the United Arab Emirates, and Russia have grown significantly (Tandjiékpon, 2010)^[90]. India, the world's leading consumer of cashew nuts, has experienced a steady increase in cashew consumption over the past two decades, surpassing the United States in consumption. The market for ready-to-eat cashew nuts is predominantly concentrated in Europe and North America.

In almost all producing countries, the cashew nut is harvested as the primary product, while the cashew apple is often left to rot on plantations as waste (Rocha *et al.*, 2007; Giro *et al.*, 2009; Das and Arora, 2017)^[80, 37, 22]. In recent years, women's groups have begun to focus on the valorization of cashew apple juice, which presents an opportunity for economic

growth (Padonou *et al.*, 2015)^[72]. The primary methods for valorizing the cashew apple are through its transformation into juice and vinegar (Houssou *et al.*, 2016)^[44].

The global cashew market began to take shape around the 1920s, initially dominated by two major players: India, the sole exporter of cashew nuts, and the USA, the sole importer (Dendena and Corsi, 2014)^[25]. Brazil and Vietnam later emerged as significant contributors to the market. Due to its versatility, the cashew tree holds particular importance in cultivation. Typically, cashew nuts are produced by smallholder farmers with minimal capital, labor, and processing technology (AlMani and Yudha, 2021)^[5], and are sold as shelled cashew nuts (Indrawanto *et al.*, 2003)^[46]. Originally planted as a reforestation tree, the cashew tree has now become a high-value crop, making it essential to emphasize agro-oriented development models in the industry (Hêdible *et al.*, 2017)^[42]. The cashew industry has been recognized as a key regional product, given its economic value. Processed cashews contribute to the economy of communities living on marginal lands (Lacroix, 2003)^[50]. The cashew tree is often referred to as the "gold mine of wastelands" due to its resilience and drought tolerance, thriving in nutrient-poor soils (Ramteke *et al.*, 2020)^[78]. The nut, which is the main commercial product (Lacroix, 2003; Martinez *et al.*, 2011)^[50, 57], has applications in various industries, including food, cosmetics, medicine, and automobiles (Aliyu, 2007; Soro, 2012)^[8, 86]. It remains a significant income generator for numerous producers (Djaha *et al.*, 2012)^[27].

In Benin, the cashew sector employs over 200,000 people, is the second-largest agricultural export after cotton, and contributes 7% of the national agricultural GDP and 8% of export revenues (Hinnou *et al.*, 2022)^[43]. The sector's growing economic importance underscores the potential for further development and modernization to improve the livelihoods of both producers and workers involved in the cashew industry.

4.4. Use of cashew tree products

4.4.1. Composition

Nutritional Value Present in 100g of Cashew Apple

Table 3: The Average Composition for 100 grams of fresh cashew apples (Kombate, 2012)^[49]

Components	Composition 100g	Recommended daily intake
Water	84 - 88g	1400g
Proteins	0.101 - 0.162g	60-75g
Fat	0.05 - 0.50 g	68g
Carbohydrate	9.08 - 9.75 g	375g
Fibers	0.4 - 1.0 g	
Ashes	0.19 - 0.34g	
Calcium	0.9 - 5.4 mg	0.68 g
Potassium	565 mg	1600 mg
Magnesium	260 mg	300 mg
Phosphorus	6 - 21 mg	800 – 1200 mg
Iron	0.19 - 0.71 mg	0.015g
Carotene – A	0.03 - 0.742 mg	5000 IU
Thiamine – B1	0.023 - 0.03 mg	1.5 mg
Riboflavin – B2	0.13 - 0.4 mg	1.7 mg
Niacin – B3	0.13 - 0.539 mg	19mg
Ascorbic acid - C	146 - 372 mg	60 mg

Nutritional Value of 100g of Cashew Kernel

Table 4: Average composition of cashew nuts per 100 g net (Kombate, 2012) ^[49]

Components	Composition 100 g of almonds	Recommended daily intake
Calories	600	3000-3500
Proteins	21g	60-75g
Carbohydrate	22g	375g
Fat	47g	68g
Phosphorus	0.45g	1.44g
Calcium	0.05g	0.68 g
Iron	5 mg	0.015g
Vitamin A	322 IU	4000 IU
Vitamin B	111 IU	400 IU
Vitamin E	1.5 mg	46 g

4.6.1. Nutritional and medicinal use of cashew

The cashew apple consists of a fleshy, sweet, and aromatic mass. It is involved in the manufacture of vinegar and alcoholic beverages (4 to 5° wine); jam with the pulp, and livestock feed with the dried apple. It is also used in food enrichment because it is rich in carbohydrates and proteins and contains easily digestible ascorbic acid. As for the cashew kernel, it has a low unsaturated fat content. It is used as “appetizers,” roasted, salted, or not. For human or animal consumption, its oil is used for its great biological value in the same way as olive or soybean oil. It also offers possibilities for manufacturing cashew butter and various uses in medicine (Kombate, 2012) ^[49].

4.6.2. Industrial use of cashew

The mesocarp is an extract of cashew balm or cashew nut shell liquid (CNSL). It is a dense, viscous essential oil rich in phenolic materials. After polymerization, it allows several industrial and artisanal uses (varnishing; protection of metals; electrical insulator; pesticides; brake linings; anti-emulsifier and solvent). The tannin (4-9%) contained in the bark makes it possible to make tanning, the manufacture of indelible ink and filler metal for welding metals, thanks to its cardol and anacardic acid content. As for cashew wood, it is used in the manufacture of packaging boxes. Its sticky properties are used in the manufacture of adhesive.

4.6.3. Agrarian potential of the cashew nut

The cashew tree provides thick shade for rest, especially in hot periods. The ashes from tree burning are used for soil amendments because of their high potassium content. All these potentialities of cashew tree products allow producing countries in the South to provide industrialized countries with semi-finished products with high commercial value to help fight poverty (Kombate, 2012) ^[49].

4.7. Cashew Tree Requirements

To give a good yield and healthy fruits, the cashew tree needs favorable ecological conditions (Goujon *et al.*, 1973) ^[38].

4.7.1. Climatic factors

Rainfall and distribution of rain throughout the year, temperature, sunshine during the flowering and maturation period, and then relative humidity are the climatic factors that have a major influence on the behavior of the cashew tree. The cashew tree adapts to very diverse rainfall regimes. However, in the event of heavy rainfall, it is necessary for the soil to be perfectly drained because the cashew tree cannot withstand flooding, even for a short period of time. It should

also be noted that, in regions with abundant and regularly distributed rainfall throughout the year, the cashew tree displays a great abundance of vegetation, but it flowers and bears little fruit. In general, to fruit well, the cashew tree requires an annual rainfall of between 800 and 1,800 mm spread over five to seven months, as well as a well-marked dry season of seven to five months. It is sensitive to cold and altitude; its production decreases very significantly at 600 meters. The temperature in the hottest months is between 35 and 48°C, while in the cool months it is 16 to 24°C. The tree requires good insolation to produce an abundant harvest. All fruiting takes place at the ends of the branches on the shoots of the year, and for production to be good, the crown must be well cleared and receive the sun's rays from all sides. In general, regions located at an altitude below 600 meters and subject to a tropical climate characterized by a well-marked dry season of 5 to 7 months, enjoy sunshine. During the dry season, the humidity should be low. Indeed, the phytosanitary state of trees subjected to a humid climate all year is generally poor (anthracnose, various insects). However, it should be noted that in areas with low rainfall (less than 1,000 mm), higher relative humidity during part of the dry season perhaps plays a role in the behavior of trees by limiting their water needs.

4.7.2. Edaphic factors

Knowledge of the soils best suited to the cashew tree is relatively imprecise. The variety of terrain on which it is found in different tropical areas leads us to believe that it is a tree adapting to quite diverse soil conditions. It does not require high fertility, but we see that it has a preference for light and sandy soils that are deep and, above all, well drained because its taproot is very sensitive to flooding. It is important to keep in mind that the taproot of the cashew tree grows very quickly: 0.80 meters at four months 02 meters- and sometimes more at two years (measurements taken at the IFAC Majunga station). For this rapid growth to take place, the soil must be very loose and have sufficient depth. Similarly, a study in Nigeria indicated that the cashew tree is well adapted to poor soils and dry sandy locations, is drought tolerant, but grows best on well-drained sandy soils with a pH of between 4.5 and 6.5 (Aliyu and Awopetu, 2007) ^[7].

4.8. Reproduction of the cashew tree

4.8.1. Choice of seeds

The condition of the seed is crucial for the good reproduction of the cashew tree. The seeds must be large, well filled, and very dry, without any piece of apple sticking to it, coming from a selected tree or “plus tree,” according to the

terminology of forest geneticists (Lacroix, 2003) ^[50]. Quality seed is first harvested from a good-quality tree in a quality stand. Seed companies must be identified on homogeneous plantations. The stand must be isolated from another stand of poor-quality cashew trees by more than 100 to 300 meters in order to avoid “contamination” by bad pollen. Once the seeds are harvested, they are sorted. The first time, you must eliminate every second seed, keeping only the best-formed and largest. The operation is repeated in order to have the best of the best (Lacroix, 2003) ^[50]. The nuts finally retained are subjected to the flotation test, which involves putting the nuts in a bucket of salt water (a 10% salt solution) and using only the nuts that settle to the bottom. This operation lasts between 24 and 72 hours at room temperature, with water replacement every 6 hours. Floating seeds are removed. This operation is carried out when the rains are already well established. In the dry season, seeds should not be soaked before sowing (Lacroix, 2003) ^[50].

4.8.2. Planting Operation

This is the phase during which the genetic material is put into the ground. It is either direct (making small holes in the ground where the seeds are buried) or done in pots (plantation or nursery). Sowing is done in vertical and dorsal positions (Lacroix, 2003) ^[50]. Direct sowing of seeds is done at the rate of two seeds per pocket. To speed germination, seeds are often soaked for 24 hours just before sowing. For planting seedlings in pots, you need holes with a depth of 60 cm and a diameter of 50 cm. This planting practice causes mortality at replanting, which can reach 40 to 50% in situations of poor rainfall or if the plants are not vigorous. The ideal density is 92 plants/ha which can vary to 100 plants/ha. On the other hand, since production is not regulated, we encounter spacings of 5m x 10m, or a density of 150 plants/ha (Kombate, 2012) ^[49].

4.8.3. Plant nutrition and Maintenance

Despite its great capacity for adaptation to various growing environments, the cashew tree expresses nutritional needs that require satisfaction for better agricultural performance. Thus, for one hectare of cashew plantation, nutritional requirements are estimated at 100g of NPK/ha and 100g of urea/ha. (Lacroix, 2003) ^[50]. As for maintenance, the practice of intercropping is the most frequent mode of maintenance. Thinning is rarely practiced in peasant plantations, which reduces tree productivity. Maintenance costs are in the order of 20,000 FCFA/ha in a farming environment and nearly 35,000 FCFA on an industrial site. Poor cleaning or its non-performance exposes the plantation to bush fires (Son and Traore, 2002).

4.8.4. Cashew harvest and yield

The nuts are collected when the cashew apples fall to the ground, and then they are dried before storage. The yield varies greatly depending on the fertility of the soil and the care provided (Lacroix, 2003) ^[50]. The average yield in Benin is 300-400 kilograms per hectare (Issaka, 2019) ^[47].

4.9. Diseases and pests

The cashew tree is subject to several phytosanitary constraints that compromise the yield of cashew nuts from a quantity and quality point of view (Viana *et al.*, 2007; NARI, 2009) ^[97, 64]. Several diseases, such as red rust, anthracnose, powdery mildew, and bacteriosis, are identified on the

cashew tree in Benin. These same diseases had also been reported on the cashew tree in Tanzania (NARI, 2009) ^[64]. Of all these diseases, anthracnose, bacteriosis, and red rust are those that are present throughout the cashew nut production area in Benin. Consequently, they can be considered the main diseases of the cashew tree in Benin in view of their incidence and severity. Powdery mildew is a formidable disease caused by *Oidium anacardii* Noack, widespread and the most devastating of cashew plantations. Anthracnose is the second disease that has a real economic impact on cashew production. It is caused by *Colletotrichum gloeosporoides* Pensch, which is a fungus of the *Melanconiales* family (Kambou, 2014) ^[48].

Harmful species of the cashew tree have been identified, including leaf-eating (*Eutelia* sp.) or leaf-rolling (*Sylepta* sp.) caterpillars, scale insects, and certain bugs that attack flowers and young fruits. Furthermore, the host plants of *sylepta* sp are cotton and okra, which are also cultivated in cashew production areas. The cashew mosquito (*Helopeltis* sp.) is a sap-sucking insect that can cause serious damage to flowers. It is the main pest of cashew trees in South-East Asia, particularly in Sri Lanka, India, and Africa. A massive attack by this insect can cause the destruction of 80% of the main branches, which are characterized by the appearance of gum-resin, which causes the death of the tree in the event of a severe attack (Tandjiekpon *et al.*, 2001) ^[91].

5. Improved productivity

The low productivity of cashew trees has not gone unnoticed by researchers. In response, several improvement strategies and tree crop breeding programs have been developed and finalized (Ofori *et al.*, 2014; Padi *et al.*, 2017) ^[67, 71]. Initially, the focus was on introgressing exotic alleles into local varieties that were cultivated and adapted to local environmental conditions (Ofori *et al.*, 2014) ^[67]. The presence of common local cashew clones recommended to farmers, as well as early exotic varieties derived from the Brazilian and Beninese dwarf germplasm, offers a better opportunity not only to reduce tree vigor and size but also to improve nut weight and overall crop efficiency (Ofori *et al.*, 2014; Padi *et al.*, 2017) ^[67, 71]. However, the development of information regarding the combining abilities of these clones and the type of genetic action governing the inheritance of key economic traits is critical for breeding programs that focus on progeny as varieties.

Varietal selection is essential for increasing production yields. Selection criteria include yield, resistance to biotic and abiotic stresses, fruit size, and the physicochemical characteristics of the fruits (nuts and apples), tree height, etc. (Coly, 2017) ^[21]. Extensive breeding programs have emerged in many producing countries, with varied selection criteria, such as yield, tree size, resistance to stresses (e.g., powdery mildew for biotic stress), fruit size, and the physicochemical characteristics of both the nuts and peduncles. Brazil provides a notable example. Breeding programs in this country began in 1965 in the Northeastern states (Ceará region) with a program that included four dwarf cashew clones (CCP 06, CCP 09, CCP 76, and CCP 1001). Their small size (ranging from 2 to 5 meters) greatly facilitates manual harvesting. These clones also have a longer fruiting period (8 months) and a production yield between 1300 and 3000 kg/ha/year, with some varieties reaching 5000 kg/ha/year. The apples are less astringent, and production can begin as early as the first year, unlike common cashew trees, which typically start

producing after 3 to 4 years (Lautié *et al.*, 2001; Soro, 2012)^[51, 86]. Breeding programs also exist in India, Thailand, Tanzania, and China, reflecting the awareness of these countries regarding low yields, heterogeneous production, and the high rate of atypical plants generated by seed-based plantations (Soro, 2012; de Abreu *et al.*, 2013)^[86, 1].

Despite these advancements, several challenges remain concerning access to improved clones. In many producing countries, certified nurseries and plant certification systems are still underdeveloped, making it difficult for farmers to access improved varieties. The high cost of clonal plants and their limited availability present barriers to the widespread adoption of these varieties. Furthermore, research and dissemination infrastructures for improved clones remain underfunded, slowing the expansion of high-yielding varieties. Another issue is plant multiplication. Grafting is a key technique for propagating improved clones, but it requires technical expertise that not all farmers possess. The lack of adequate training in vegetative multiplication techniques reduces the effectiveness of deploying improved varieties. Additionally, the success of genetic improvement programs depends not only on the availability of improved clones but also on the adoption of new techniques by farmers. However, several obstacles stand in the way: lack of technical training, limited access to information, and input costs. To address these challenges, training and support initiatives have been implemented by some agricultural development organizations and research institutes. However, their reach remains limited, requiring increased efforts to engage a larger number of farmers.

Finally, the introduction of improved clones and new farming practices sometimes encounters resistance from farmers' traditional practices. In many rural communities, farmers still prefer to use local seeds, often from their own harvest or exchanges with other farmers. Adopting clonal plants involves a change in mindset and a transition to a more structured production system, which can meet resistance. Moreover, some farmers are reluctant to plant dwarf cashew trees, as they believe that larger trees have better longevity and produce more wood for domestic and commercial uses. Therefore, the integration of these new varieties must take into account the socio-economic needs of farmers and their perceptions of the advantages and disadvantages of the proposed innovations.

In addition to these breeding programs, there are production techniques such as cashew-based agroforestry, which have positive effects on both productivity and the environment. Producing countries have realized the drawbacks of plantations based on direct seeding or seeds, which result in heterogeneous production, a high rate of atypical plants, and low yields (De Logu *et al.*, 1994)^[23]. Cashew-based agroforestry involves intercropping cashew trees with annual crops. The promotion of this technique is linked to the benefits it offers to farmers. It is one of the most suitable solutions identified by farmers to mitigate the effects of environmental degradation (Tandjiékpon, 2005)^[89]. According to farmers' perceptions, the advantages of these associations include efficient use of agricultural space, diversification of production, dual income generation, ease of maintaining cashew plantations, and the benefits that cashew trees derive from fertilizers applied to annual crops.

According to Lawal *et al.* (2007) and Yabi *et al.* (2013), this land management method contributes to reducing atmospheric carbon levels and promotes a healthy

environment conducive to human development (Lawal *et al.*, 2007; Yabi *et al.*, 2013)^[52, 105]. The use of maize, sorghum, or peanuts in cashew fields enhances the agronomic performance of the cashew tree (Opoku-Ameyaw *et al.*, 2011)^[69]. However, it is essential to note that this practice is only applicable to young cashew trees under six years of age, as the shading of the cashew trees reduces the photosynthetic activity of plants growing under their canopy. Furthermore, not all annual crops associated with cashew trees have the same effects on its development. According to farmers' perceptions, some crops such as sorghum, millet, soybeans, and pigeon peas (*Cajanus cajan*) negatively affect cashew production by promoting the appearance of spots on the nuts.

6. The cashew tree and genetic markers

The cashew (*Anacardium occidentale*) is a globally important crop due to its multiple uses. This tree, which is cross-pollinated and entomophilous (Nambiar and Pillai, 1985)^[65], has a chromosome number of $2n = 42$, although its ploidy remains uncertain (Purseglove, 1968)^[75]. In addition to being cultivated for its nuts, its apples (hypocarps) are used to produce a popular beverage (Rao *et al.*, 1998)^[79]. To date, 35 varieties of cashew have been documented in India, of which 24 are derived from the selection of local germplasms, and the others are hybrids (Archak *et al.*, 2003)^[9].

6.1. Characterization of Cashew Tree Genetic Diversity

For an advanced study of varieties, the characterization of genetic diversity is essential for exploiting genetic resources in plant improvement. Currently, this characterization largely relies on morphological traits (Swamy *et al.*, 1998)^[88]. However, these traits often present issues of low penetrance and inheritance, particularly in fruit trees with long juvenile periods.

Molecular markers, which are highly heritable and widely available, often exhibit sufficient polymorphism to distinguish closely related genotypes (Archak *et al.*, 2003)^[9]. Among these, PCR-based techniques such as RAPD (Welsh and McClelland, 1990; Williams *et al.*, 1990)^[101, 103], ISSR (Gupta *et al.*, 1994; Zietkiewicz *et al.*, 1994)^[40, 107], and AFLP (Vos *et al.*, 1995)^[99] are popular because they do not require prior genomic information of the target species.

RAPD has been widely used in studies of diversity, mapping, and genotype identification (Weising *et al.*, 1995; Harris, 1999)^[100, 41]. ISSR markers are considered superior to RAPD for these analyses (Qian *et al.*, 2001)^[76]. AFLP, on the other hand, offers several advantages, including a high multiplexing rate (Powell *et al.*, 1996; Milbourne *et al.*, 1997)^[74, 59].

6.2. Limitations of Genetic Markers in Large-Scale Selection

Despite their advantages, the use of genetic markers for large-scale characterization presents limitations. The high cost of technologies associated with high-throughput genotyping techniques, such as SNPs, and the infrastructure required for these analyses pose significant barriers for many institutions, particularly in developing countries where cashew cultivation is predominant.

Access to these technologies is also a major constraint. Specialized equipment and the training of qualified personnel to perform these analyses can make their implementation challenging in local contexts. Moreover, although molecular markers allow for the identification of specific genotypes,

their application in large-scale breeding programs remains complex and requires substantial resources.

Finally, the practical application of genetic markers in selecting the best cashew varieties requires integration with traditional methods, such as phenotypic selection, which can make the process lengthy and costly. Therefore, it is necessary to find a balance between the use of molecular techniques and more traditional approaches, while considering the cost-effectiveness and feasibility of implementing them on a large scale.

6.3. Modern Technologies and Future Perspectives

More recent techniques, such as single nucleotide polymorphism (SNP), microsatellites, and simple sequence repeats (SSR), are now widely used for high-throughput genotyping of cashew (Mzena *et al.*, 2018; Filho *et al.*, 2018; Adu-Gyamfi *et al.*, 2020) [36, 35, 4]. These modern genomic tools are essential for the sustainability of cashew products (Wilkinson, 2007) [102]. Finally, effective collaboration and germplasm exchange between producing countries are essential prerequisites for increased cashew productivity (Adu-Gyamfi, 2020) [4].

7. Collection and marketing of cashew

In the absence of collection and marketing structures, buyers come from neighboring countries, as the production areas are close to the borders. As a result, a significant portion of the production escapes statistical and customs data (FENAPAB, 2017) [34]. Likewise, the quality standards used are those of the purchasing countries, particularly European clients (FENAPAB, 2017) [34]. Additionally, some producers and importers refer to the ISO 6477 standard of February 1988, which includes two types of classifications: one used by India and African countries, and the other by Brazil, providing a single criterion to evaluate the quality of nut batches (Lautié *et al.*, 2001) [51]. This classification is based on several criteria: whether the nut is whole or not, its appearance (white, colored, or stained), and its size. For whole nuts, size is determined by the number of nuts per pound. On the other hand, for broken nuts, distinctions are made between halves, pieces, small pieces, and fragments. For each of these categories, a tolerance of 5% for nuts belonging to a lower category is allowed. For example, whole white nuts correspond to the WW (White Wholes) category. These nuts must be kidney-shaped and show no signs of contamination, insect damage, mold, rancid taste, skin residue, or foreign materials. They must be white, with shades ranging from gray

to ivory. In this category, slightly wrinkled nuts are allowed as long as their shape is homogeneous. The Indo-African classification specifies the codes WW180, WW210, WW240, WW320, WW400, WW450, and WW500, where the number indicates the number of nuts per pound (size indication), while the Brazilian classification only specifies three size categories: SLW1 (160 to 180 nuts per pound), LW1 (180 to 210 nuts per pound), and W1 (for smaller nuts), with a maximum allowed moisture content of 5% (Lautié *et al.*, 2001) [51]. However, cashew commercialization faces several major challenges, including weak infrastructure, fragmented markets, and the need to comply with international standards. The lack of transportation and storage infrastructure exposes the nuts to climatic variations, which can affect their quality (FAO, 2021) [30], while the deteriorated state of roads makes product transportation difficult and increases logistical costs (Gayi and Tsowou, 2016). Furthermore, commercialization remains dominated by a multitude of intermediaries, reducing the profit margin for producers and increasing their dependency on foreign buyers, particularly from Asia (World Bank, 2020). Better structuring of supply chains, supported by strengthening producer organizations, would improve farmers' bargaining power and ensure better remuneration for producers (GIZ, 2019). Moreover, the adoption and adherence to quality standards is a crucial issue for access to European and American markets. The rigorous application of ISO standards and certifications such as Fairtrade or Rainforest Alliance could promote better valorization of products (ITC, 2018), while training producers and traders on good post-harvest practices, including drying and storage, is essential to ensure quality in line with international requirements (UNCTAD, 2022). Regarding pricing, while the purchase price from producers was 125 FCFA per kg of nuts in 2000, it has increased in recent years, ranging between 225 and 350 FCFA per kg. Meanwhile, shelled and roasted nuts cost between 3000 and 4000 FCFA/kg, or even 4500 FCFA/kg during periods of shortage (DGSCN, 2001). Despite this relatively low purchase price, some producers generate annual revenues of 250,000 to 300,000 FCFA from cashews (Son and Traoré, 2002). Between 2012 and 2021, the purchase price of raw nuts in Benin fluctuated between 0.79 and 1.91 USD/kg (Figure 5) (FAO, 2023) [30]. Thus, improving infrastructure, structuring markets, and aligning with international standards appear to be key levers for a more competitive and sustainable commercialization of cashew nuts.

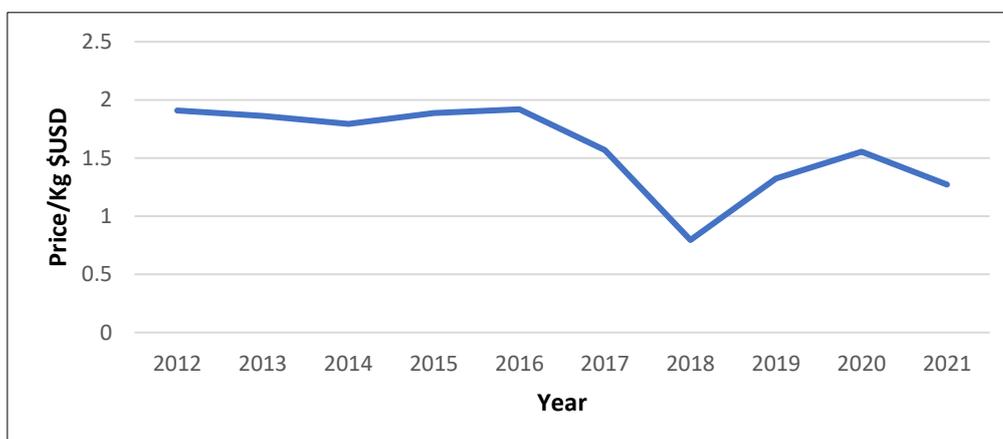


Fig 5: Evolution of the price of cashew nuts in Benin from 2012 to 2021 (FAO, 2023)

6. Conclusion

The cashew tree (*Anacardium occidentale*) is a strategic cash crop for many tropical countries, particularly in Africa and Asia, due to the high international demand for its nuts and apples. However, the sector still faces several major challenges that limit its full potential. On one hand, varietal selection remains a fundamental issue, as direct-seed planting results in high heterogeneity and inconsistent quality of nuts and apples. Limited access to improved clones adapted to local agroecological conditions hinders productivity optimization, despite advances in genetic research. On the other hand, collection and marketing infrastructures remain insufficient, leading to a fragmented market where a significant portion of production escapes official channels, making it difficult to effectively regulate prices and optimize product value. Dependence on foreign buyers, particularly from Asia and Europe, exposes producers to fluctuations in the global market and strict quality standards, such as those defined by the ISO 6477 standard. Furthermore, although local processing could increase added value and reduce dependence on raw nut exports, it is still underdeveloped due to a lack of investment in modern processing units. Nonetheless, there are opportunities to enhance the competitiveness of the sector, particularly through the development of improved varieties suited to pedoclimatic constraints, the implementation of group sales, the organization of producers into cooperatives, and access to more profitable markets through certifications such as Fair Trade or organic production. To address these challenges and seize the opportunities, it is crucial for governments to implement incentive policies that support agronomic research and access to quality inputs, for producers to receive better training in good agricultural and post-harvest practices, and for the private sector to invest more in local processing to ensure a more integrated and sustainable value chain. An approach combining agronomic innovation, market structuring, and capacity-building of stakeholders will thus ensure a more competitive and sustainable cashew production.

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