

Case Report

# Cashew as a High Agricultural Commodity in West Africa: Insights towards Sustainable Production in Guinea-Bissau

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**Abstract:** In Sub-Saharan Africa, the West African region has highly diverse agro-climatic conditions, which grant the potential for a remarkable agricultural production of a great diversity of crops. Since the 1980s, the production volumes of most crops have grown vigorously for both domestic and export markets. Traditional food crops—such as rice, groundnuts and sorghum—have been replaced by cash crops, namely cashew. Among the main cashew production areas, West Africa is the most recent and dynamic in the world, accounting for 45% of the worldwide production of cashew nuts in 2015. In consequence, cashew cultivation has acquired an important position in West African smallholder farming, providing positive economic and social effects. In this paper, we provide an overview of the cashew production system in the West African region, using Guinea-Bissau as a case study. In particular, we present some viewpoints concerning the impact of cashew production and discuss how the strong dependence on a single cash crop can compromise the local livelihoods and food security. Finally, some insights are given towards the sustainable production of cashew in the face of the recent risks affecting the agricultural sector in West Africa.

**Keywords:** sustainable production; West Africa; food security; cashew; agroecosystem

## 1. Introduction

Agriculture is the key backbone for broad-based economic growth, poverty reduction and food security in Sub-Saharan Africa (SSA), having an impact at both economic and social levels. Indeed, incomes generated by agriculture in SSA are much more effective in reducing poverty than the Gross Domestic Product (GDP) growth in other sectors. SSA has been experiencing structural transformations (e.g., demographic growth, economic and political changes) which have also brought opportunities to add value to agricultural products and to reinforce the priority of developing the agri-food sector across the continent. The increase in crop production in response to strong global demand and higher prices is a new trend in SSA, as most of these countries continue to face the challenges of eradicating poverty and finding sustainable solutions to malnutrition and food insecurity [1]. In spite of the agricultural productivity improvements driving social and economic changes in SSA, there was a

general unsatisfactory progress towards the Millennium Development Goals (MDGs) and thus, it is important to assess whether enough is being done to channel the potential of agriculture development in fighting extreme poverty [2–4]. While successful examples of adopting higher standards or adapting standards to local market conditions and training producers have been found, for instance, through partnerships with the private sector [5], many West African countries are still striving to achieve sustainable production that meets the needs of the global market. Market-driven rapid intensification is often a major cause of cropland area expansion at the expense of deforestation [6]. Moreover, it is widely understood that intensive agriculture can negatively impact ecosystems by affecting the rural landscape dynamic, soil resources and water quality. This can result in the loss of carbon sequestration and biodiversity, which are critical global public goods [7].

In the view of a transforming approach towards inclusive growth and sustainable development, West African agriculture is at a turning point. Since the 1980s, the production volumes of most crops grew vigorously for both domestic and export markets, which has been driven largely by harvested area expansion. While top agricultural production in value terms was dominated by traditional food crops—such as rice, maize, millet, sorghum, yam and cassava—less common cash crops escalated in production from very low initial levels, acquiring a strong significance in the economies of some West African countries [8]. The production boom of cashew nuts is such an example, showing the highest average annual growth rate over 1980–2009 [9] and bringing large improvements to small, less resourceful countries such as Guinea-Bissau. In fact, cashew is not only an important agricultural commodity in developing countries by significantly contributing to both GDP and export exchanges at the country level, but also an essential resource for the livelihood of smallholder farmers, which represent the majority of the producers and processors worldwide [10]. For this reason, the cashew industry should be positively exploited within the scope of the MDGs for the empowerment of smallholder farmers, creating revenues and employment opportunities through the promotion of small- to medium-scale industrialization processes, especially in rural areas [10].

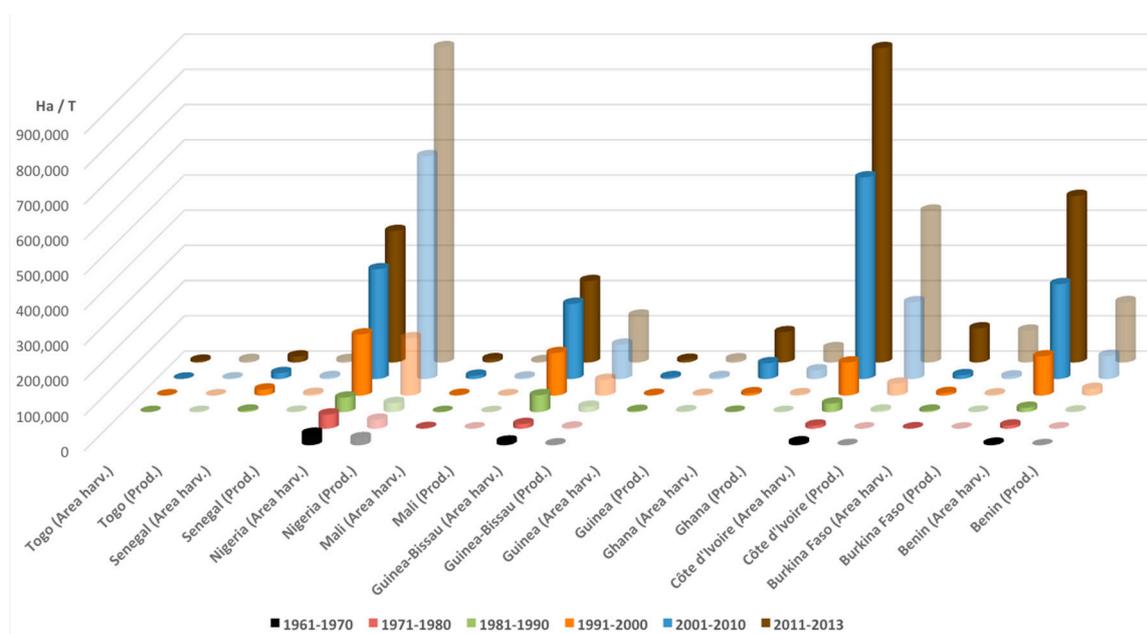
Despite the growing interest and high value of cashew as an export product, cashew cultivation does not always translate into high productivity per hectare, especially in developing countries, where standard agronomic practices are difficult to adopt. Furthermore, ensuring the ownership of fallow land by having a cashew plantation can be more important than production [11]. The relatively limited productivity per hectare has been essentially attributed to constraints in the improvement of cashew varieties through conventional breeding, for which there is still a limited understanding concerning vegetative propagation methods and other factors such as pruning, fertilization etc. [10].

Pests and diseases are among the factors significantly hindering cashew production, with the latter being by far the most important constraint. A recent study [12] has highlighted the harmful potential of diseases in affecting cashew orchards in Guinea-Bissau, allied with the lack of improvement in cashew varieties. Therefore, this has rendered the monoculture regime of cashew production extremely vulnerable and in need of guidelines for sustainability. In this case report, we focused on the cashew production system in Guinea-Bissau as a case study of crop intensification in the West African region. In particular, we intend to: (1) describe how the accelerating intensification of cashew production occurred to the detriment of traditional food crops; (2) provide some viewpoints on how the dependence on a single cash crop can compromise livelihoods and food security; and (3) discuss means of acquiring a sustainable production of cashew in the West Africa region.

## 2. Establishment of Cashew as a High-Value Agricultural Commodity in Guinea-Bissau

Cashew (*Anacardium occidentale* L.) is a tropical tree native to South America, which is currently grown in most tropical countries around the world. Although this species was introduced in West Africa in the middle of the 16th century [13], the establishment of cashew as a cash crop began in the 1950s and has only become an intensively grown cash crop since the 1990s. Among the main cashew production areas, West Africa is one of the most recent and dynamic in the world [8], accounting alone for 45% of the worldwide production of cashew nuts in 2015 [14]. The shift of land use towards cashew

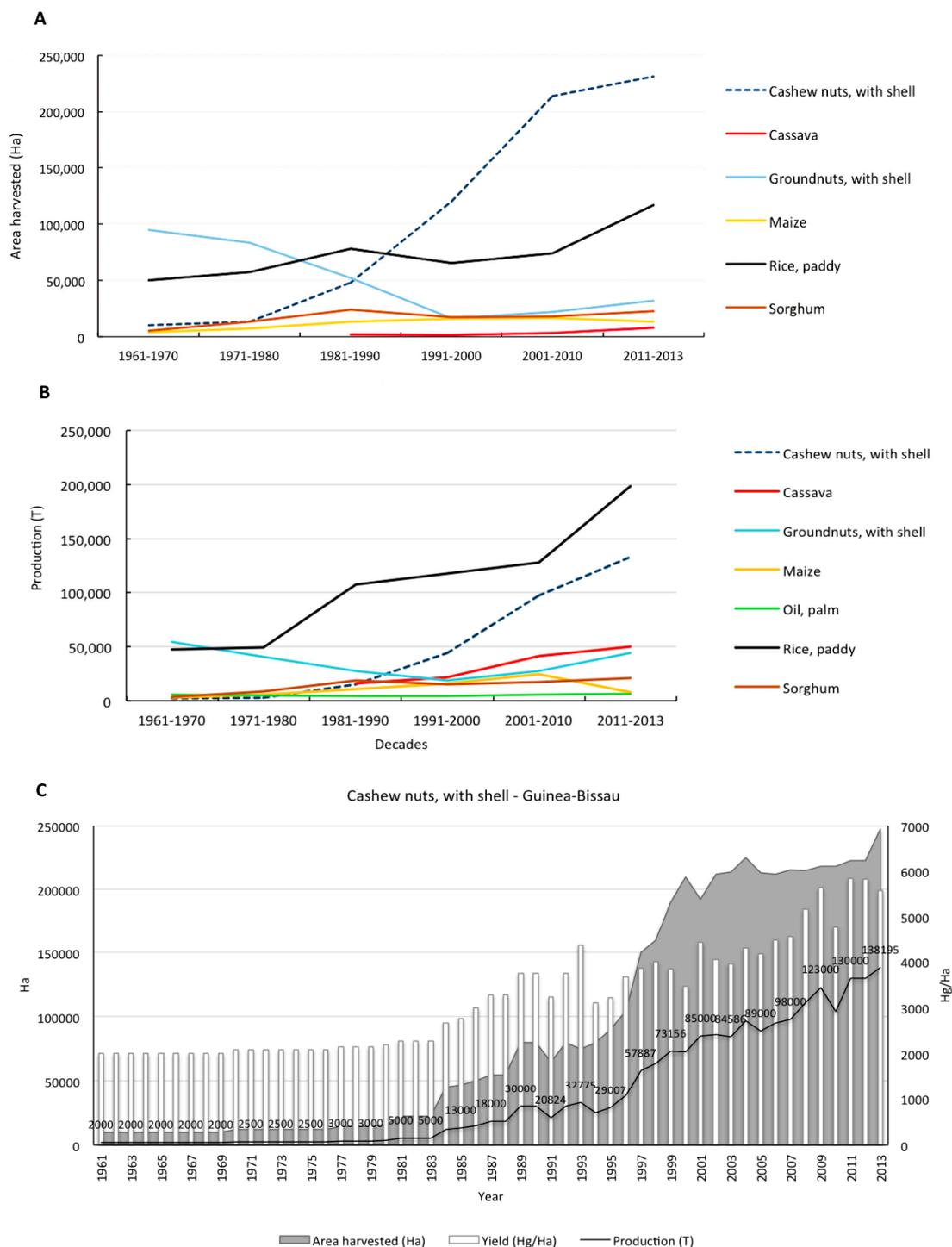
cultivation offers advantages to farmers as it allows them to engage in a commercial crop production with guaranteed revenue and lower input costs. Accordingly, the amount of land devoted to cashew cultivation in Guinea-Bissau has been continuously expanding. The country has the fourth largest area of cashew-cultivated land (Figure 1), with resulting implications for the national economy and rural livelihoods. Thus, the improvement in performance of the cashew sector is essential for inclusive growth and poverty alleviation, since it involves about 85% of the rural population [15]. Interestingly, the expansion of cashew farming is also linked to securing land, which is likely to become more frequent in future. Furthermore, stronger market linkages could maximize this situation, as reported in a recent study associating the increase of cashew plantations establishment with the maintenance of ownership of fallow land [11].



**Figure 1.** Increase of harvested cashew area (Ha) and nuts production (T) in West Africa during 1961–2013. Source: Food and Agricultural Organization (FAO) database [8] on 27 April 2016.

### 2.1. Cashew Agroecosystem

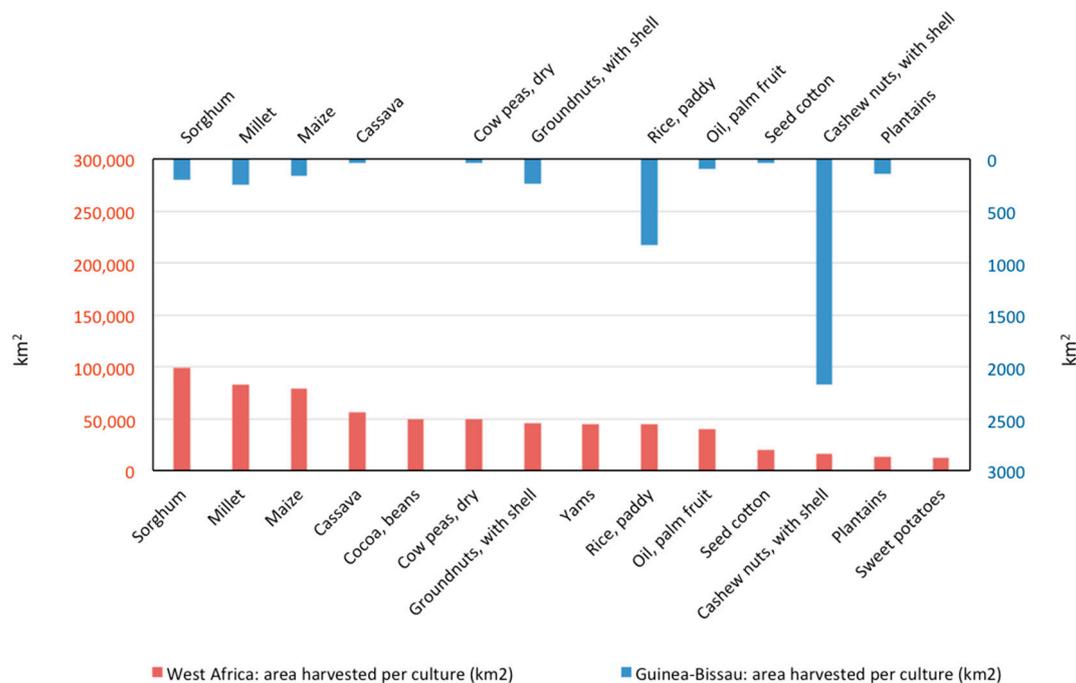
Presently, cashew orchards cover a large area of agricultural land (approximately 45% of the total agricultural area) and are the most typical agroecosystem in this country. The clear importance of cashew nuts as the main commodity for Guinea-Bissau can be depicted by the significantly larger harvesting area for cashew nuts, which has occurred at the detriment of traditional food crops (Figure 2A). Other agricultural products also contribute to the country's economy, such as rice, which has increased in the last few decades (Figure 2B), possibly responding to the needs imposed by the significant population growth. However, cashew production offers the opportunity of obtaining a higher profitability, since it allows farmers to reduce their production costs—especially in terms of labor inputs—when compared, for instance, to cereal [16]. Consequently, given the advantages in commercial profit and reduced to cashew cultivation in Guinea-Bissau has been constantly expanding (Figures 2C and 3).



**Figure 2.** (A) Harvested area of main agricultural commodities in Guinea-Bissau during 1961–2013 (data unavailable for “oil, palm”); (B) Trends in production for the main agricultural commodities in Guinea-Bissau over the period of 1961–2013; (C) Trends in production for the main agricultural commodities in Guinea-Bissau over the period of 1961–2013; (C) Harvested area, yield and production of cashew nuts with shell in Guinea-Bissau. Source: Food and Agricultural Organization (FAO) database [8] on 27 April 2016.

Cashew plantations are typically implemented in fallow lands within semi-natural or savanna woodlands. The latter two are the most conspicuous vegetation types occurring in the country [17], where the native vegetation is burned for both celerity and enhancement of soil fertility.

In Guinea-Bissau, cashew orchards are arranged within two cropping systems: (1) “Ponteiro” is a commercially-oriented cropping system, harboring a great heterogeneity in terms of size and care dispensed to the orchards; and (2) “Peasantry” which represents the backbone of the African rural economy, comprising small-scale farming for household subsistence and product sale in the market. In the first three or four years of an orchard establishment, cashew trees may be maintained under an intercropping system with food crops such as rainfed rice, millet, sorghum, maize or groundnuts, as viable means for smallholder incomes.



**Figure 3.** Major agricultural commodities (ranked by harvested area) for West Africa (lower X axis) in comparison with Guinea-Bissau (upper X axis); values presented are calculated using the arithmetic mean from 2000 to 2013. Data retrieved from the Food and Agricultural Organization (FAO) database [8] on 27 April 2016.

## 2.2. Field Prospection of Cashew Expansion in Guinea-Bissau

Little is known about the effects resulting from the decrease in biodiversity and concomitant loss of ecosystem services caused by the implementation of cashew plantations. Cashew orchards are portrayed as a single crop agroecosystem, which associated with the limited varietal selection, creates the potential for the emergence of pests and diseases, a situation that is additionally favored by the climate change scenarios. The likely occurrence of pests and diseases threaten the sustainable production of such an important crop. In a preliminary study for cashew agroecosystem characterization, plant species composition was assessed in a total of 15.5 ha area of cashew orchards during field prospections in 21 villages in the regions of Bafatá and Gabu, located in the eastern region of Guinea-Bissau (Figure S1).

### 2.2.1. Methodology

Biodiversity surveys were performed in the administrative regions of Bafatá and Gabu as case-study areas selected in Guinea-Bissau. In these locations, cashew orchards are the main agroecosystems. Considering that cashew orchards are mainly held under a smallholder regime, sampling was based on a nested design on small rural settlements (i.e., villages) within the two regions. The dataset from a sample of 21 villages was collected through fieldwork from January to May 2013. The selection of villages for field survey was based on three main features, as performed in a former

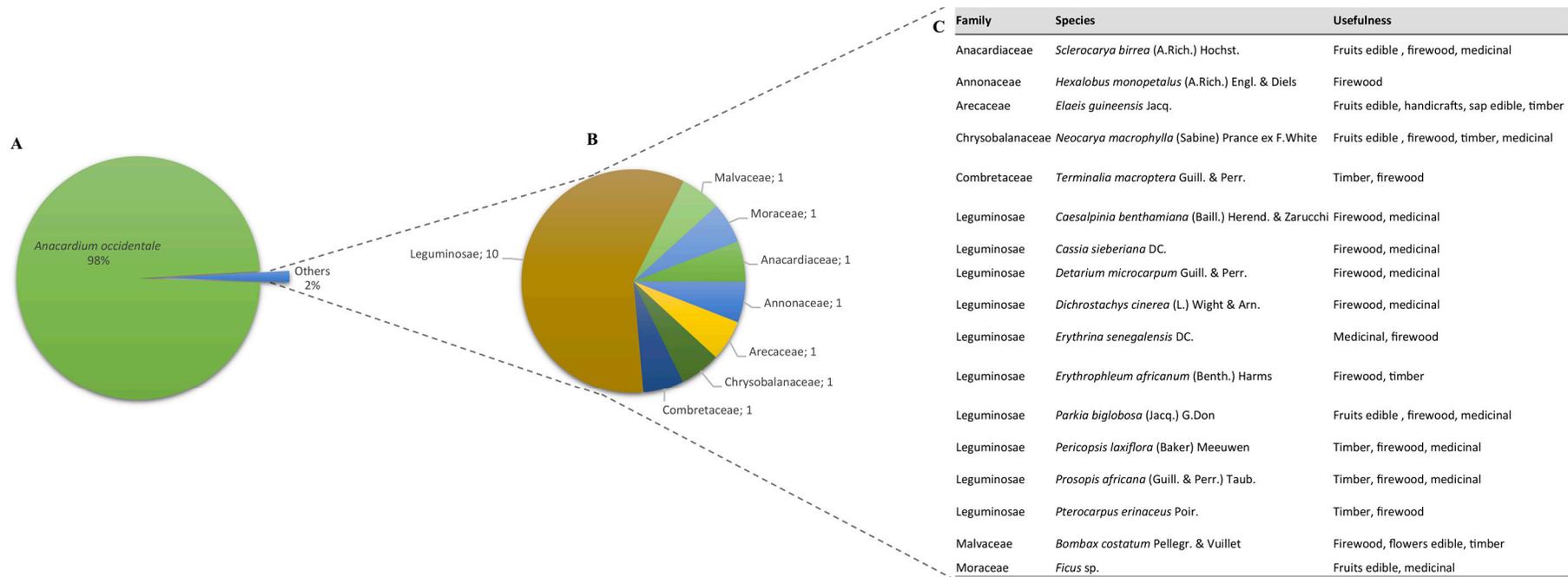
study [18], namely: (1) medium-sized (100–500 inhabitants) villages; (2) presenting sufficient coverage of cashew orchards to allow three sampling plots in each village at a minimum distance of 500 m from each plot; and (3) ease of access due to logistic issues on fieldwork. In each village, the survey was conducted by fieldwork in three fixed-radius (20 m) circular plots of cashew plantations, selected within the range of 1 km from the village center. Plots were sampled at least >500 m from each other to avoid autocorrelation in the data. For each plot, tree and palm biodiversity in the cashew agroecosystem was assessed through the number of individuals/species/ha with more than 10 cm of diameter at breast height (Table S1), while plant uses were assessed by literature review [19] and by asking the heads of households, who hold responsibility for all household affairs, including plant species uses. The number of individuals of each taxon was recorded, with care taken to avoid double counting. Plant species identification was performed and confirmed with herbarium specimens from LISC Herbarium (University of Lisbon), which holds the most important worldwide collection from Guinea-Bissau flora. After species identification, the occurrence data of each plot screened were converted to plant densities, i.e., Number of plants per hectare.

### 2.2.2. Cashew Agrosystem Characterization

This study determined that 98% of the total area of orchards contained only cashews as adult trees (Figure 4A), while the remaining area displayed some wild species occurring sympatrically (Figure 5A,B). Most of the species observed belonged to the Leguminosae family (Table S1), which have important functions as food crops at subsistence level. As wild plant species have multiple uses in local communities and are responsible for important ecosystem services (Figure 5C), the single species orchards make the collection of forest products more difficult and increase the pressure on the remaining patches of natural vegetation (Figure 5C). The dependence on the cashew nut as a single agriculture commodity and the loss of plant biodiversity reduces the availability of ecosystem services and creates a strong pressure on a single agroecosystem sector. Natural biodiversity together with the diversification of the cashew agroecosystem, with cover crops or green manure crops, are essential measures to naturally increment ecosystem services with high socio-economic impact [20], and more importantly, to ensure the sustainability of this agroecosystem. However, at the smallholder farmer's level, it is difficult to implement such measures, as farmers traditionally tend to eliminate wild species from their land in order to increase land utilization efficiency. This is a practice that often harms beneficial wild species, such as pollinators, insect-eating birds and other species that prey on agricultural pests [21].



**Figure 4.** (A,B) Cashew orchards with close tree spacing and low undercover species diversity at Bafatá villages. Photos by Catarino & Monteiro.



**Figure 5.** (A) Percentage of cashew trees in association with other wild species in a 15.5 ha field surveyed in the eastern region of Guinea-Bissau (2016); (B) Biodiversity of plant families and number of species in each family occurring in sympatry with cashew trees; and (C) Plant species and uses.

In addition, major drawbacks to sustainable cashew production were encountered, namely: (1) the very close tree spacing (i.e., less than 5 m; Figure 4A) applied in the establishment of orchards, which does not favor high yields; and (2) the maintenance of older orchards, which contribute significantly to the harvested area size, but very little to productivity and may be regarded as foci for outbreaks of possible pests and diseases. In our study area, the close tree spacing (Figure 4A,B) as well as the presence of low productive and older cashew trees were common features detected in all 21 villages screened, as no agronomic practices are applied, such as pruning (Figure 4B, absence of pruning in cashew trees), selection of high-yield varieties, fertilization and others as previously reported [10]. Also, farmers tend to maintain deceased trees, which is particularly unfavorable considering that pathogens can thus be easily transferred to other healthy trees. The land use management is almost absent in Guinea-Bissau and a considerable proportion of the harvested area is mainly made up of older orchards with lower production yields (Figure 2B). Furthermore, no high-yield cashew varieties are used and inadequate agronomic management practices prevail. In comparison, Nigeria offers an example of a sustainable cashew agroecosystem, where a smaller harvested area provides increased yields of cashew production, which is mainly achieved through the selection of high-yield cashew varieties [9]. Considering the wide variety of agronomic practices already available and applied in cashew cultivation worldwide (see [10]), approaches to provide awareness at local institutions and smallholder's associations should be followed to increment the sustainability of cashew orchards, while taking into account the traditional knowledge from different ethnic groups.

### 2.3. The Emerging Potential of Pests and Diseases in Cashew

Agricultural landscapes in Guinea-Bissau have been changing in the last decades and although that transformation has been economically important, it has not come without risks. Furthermore, since this change was inadequately planned, it has caused significant and sudden changes at social and environmental levels. The effects of such changes are not yet completely understood and the impacts should be evaluated to define strategies conducive to effective sustainability. Similar to other crops that are grown outside the center of origin, cashew production in Guinea-Bissau is potentially less able to deal with pests and diseases occurring in the cultivation areas or to new strains that could subsequently arise [22]. This highly dynamic effect is exacerbated by cashew being an introduced crop cultivated under a monospecific regime. These conditions promote the susceptibility towards both native and exotic pests and diseases, which is an alarming situation due to the significance of cashew nut production and trading for the country's economy and livelihood of families. Several pests [23] and fungal diseases have been identified in most cashew-producing countries [24]. However, only a few pests and diseases were identified in Guinea-Bissau (Table 1), with no reports on the impact on cashew productivity. Pests that were widely reported in other West African countries as causing significant losses in cashew production [21] could also be identified in Guinea-Bissau (e.g., *Apate terebrans* Pallas, *Analeptes trifasciata* Fabricius) [25]. For instance, the trunk and root borer—*Plocaederus ferrugineus* L.—which is considered a pest of increasing importance in Nigeria [26], was recorded for the first time in Guinea-Bissau in 2014. However, its effect on production losses remains to be determined [25]. Moreover, diseases caused by fungi can lead to severe damage across cashew-producing countries. In Guinea-Bissau, symptoms on cashew trees were first observed by the authors and recognized as anthracnose (*Colletotrichum gloeosporioides* Penz. & Sacc. s.l.) or gummosis (*Lasiodiplodia theobromae* (Pat.) Griffon & Maubl.) [12], which are two of the most devastating diseases in cashew-producing countries that have a direct impact on economic revenues.

Considering that some pest insects (e.g., [27,28]) and fungi diseases [23] are already causing losses in cashew production in West Africa, we are already conducting field inspections in Guinea-Bissau as part of a recent project with the cooperation of local research institutions. This aims to evaluate the occurrence and damages caused by these pathogens, before defining appropriate control measures. Given the limited knowledge of pests and diseases of cashews in Guinea-Bissau as well as the poorly

managed system of cashew monocultures, the spread of pests may become a serious problem in the future, with negative impacts affecting the smallholders' livelihoods and the economy of the country. These considerations uncover the risks of the huge reliance on a single crop for the country's economy and the need for structured agroecosystems-driven approaches, aiming at the sustainable intensification of cashew production and the protection of natural resources.

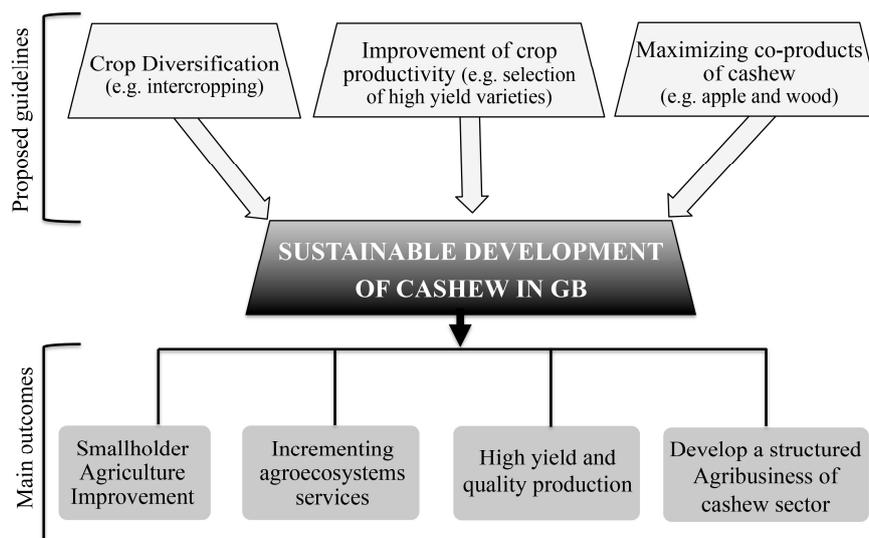
**Table 1.** Cashew diseases and pests reported in Guinea-Bissau.

Type/Species	Family	Common Names	Ref.
<b>Diseases</b>			
<i>Colletotrichum gloeosporioides</i> Penz. & Sacc. s.l.	Glomerellaceae	Anthracnose	[12]
<i>Lasiodiplodia theobromae</i> (Pat.) Griffon & Maubl.	Botryosphaeriaceae	Gummosis	[12]
<b>Pests</b>			
<i>Analeptes trifasciata</i> Fabricius	Cerambycidae	Cashew stem girdler	[29]
<i>Apate terebrans</i> Pallas	Bostrychidae	Stem borer	[25]
<i>Helopeltis</i> sp.	Miridae	Tea mosquito bug	[30]
<i>Mecocorynus loripes</i> Chev.	Curculionidae	Cashew weevil	[29]
<i>Plocaederus ferrugineus</i> L.	Cerambycidae	Stem and root borer	[25]
<i>Pseudococcus longispinus</i> Targioni Tozzetti	Pseudococcidae	Red-banded thrips	[26]
<i>Udinia cator</i> Green	Coccidae	Scale insect	[25]

### 3. Guidelines towards Sustainable Cashew Production

Overall, Guinea-Bissau accounts for 15% of the raw cashew exports worldwide in 2015, which is only surpassed by Ivory Coast [14]. Cashew represents more than 90% of the country's exports [28] and at the same time is responsible for poverty alleviation at the smallholder's level. The accountability of cashew exports in Guinea-Bissau is given from the export of raw cashew kernels. However, the cashew kernels that are probably smuggled through the port of Banjul (Gambia) are not accounted for and represent a very serious revenue constraint. Thus, an increase in cashew exports could be obtained if security measures were implemented to avoid the smuggling of cashews during annual campaigns [31]. Previous data from a 2010 household survey [32] show that cashew accounts for 26% of the income (net of remittances) in female-headed households and for 35% in male-headed households. As such, cashew is the most important source of monetary income, in addition to being the core of both economic performance and poverty reduction. Currently, West Africa processes only 5–6% of its cashew nut production, while 20–30% is processed in East Africa. Vietnam and India hold the majority of raw cashew nuts processed outside Africa [33]. The cashew industry in West Africa is attracting increased interest from international investors; thus, the potential for market expansion at the processing level exists in the cashew sector.

Considering the smallholder agriculture, and cashew in particular, as one of the main sources of economic revenue in the West Africa region, we present some viable means to promote both food security and the sustainable intensification of cashew production in this case report. We summarized some of the main vectors that should be taken into consideration, which are: (1) the promotion of less dependence on cashew nuts; (2) maximizing the benefits from the co-products of cashew; and (3) the improvement in cashew production and productivity (see also Figure 6).



**Figure 6.** Guidelines for the sustainable production of cashew in Guinea-Bissau and expected outcomes. Among the guidelines proposed for the sustainable development of the cashew sector lies the (1) crop diversification, namely through rice for domestic market and household subsistence or other crops, such as leguminous and native species, as oil palm, that will augment agrobiodiversity with social impacts (i.e., medicinal purposes); (2) improvement of crop productivity and production by using high-yield and high-quality cashew varieties; and (3) development of a structured agricultural business in the cashew sector.

(1) The promotion of less dependence on cashew nuts—To achieve the benefits that may come with the process of crop diversification, farming should be changed from very simple forms of crop rotations to more intensive systems, such as intercropping or specialization. This is achieved by diversifying into various crops. By diversifying crops and sources of income, there are several advantages, namely high net returns from crops, a decrease in the economic dependence on cashew nuts, the optimization of resource uses and increased job opportunities. Thus, intercropping can be a tool in diversifying crops, keeping the soil fertility and mitigating the monoculture drawbacks. Sesame can be an interesting alternative or complementary crop, which has been increasingly cultivated in the last years in Guinea-Bissau as a cash crop. With a short life cycle and low requirements of water and soil fertility, sesame can be cropped as a second culture after upland rice, maize or millet. Furthermore, increasing biodiversity together with the diversification of the cashew agroecosystem are essential measures to naturally increase the socio-economic impact of ecosystem services [20].

(2) Maximizing the benefits from the co-products of cashew—Cashew sector valorization beyond the cashew nuts may permit to increase farmer's income in addition to reducing the pressure on natural resources and ecosystem services. This occurs namely by exploring the use of cashew apple and wood. The cashew apple is available in huge quantities during the cropping season (March–July) and can provide several products for human consumption and livestock. The exploitation of both these by-products from cashew orchards, apple and wood (used as fuelwood), would increase the financial profitability for farmers. However, without a proper value chain, functional difficulties hamper the profitability of some by-products, as for instance the use of apples for juice production, since the juice is quickly converted into alcohol, especially during cashew apple preservation. Other major by-products derived from cashew processing are important, such as the cashew nut shell liquid (CNSL), cashew skin extract, cashew shell cake and bark. There are expectations of a strong market potential for these highly valued by-products [10].

(3) The improvement of cashew production and productivity—An important objective for the cashew sector in Guinea-Bissau is to increase the production without a proportional increase in the orchard area. However, the prevalent cropping system in the country is characterized by a lack of

varietal selection for higher productivity and as stated above, by the typical close tree spacing of 5 m, which is not ideal for improving production. Learning from the experience of other West African countries is important, particularly from Nigeria. Nigeria has acquired skills on the cashew sector, which involves the characterization of germplasm collections from the existing cashew diversity in plantations [27]. This could be an important solution to Guinea-Bissau for a sustainable intensification of cashew production. For instance, cashew long-term breeding programs have been developed for the improvement of agronomic traits, such as nut yield and quality [34]. This study has shown a narrowing of genetic diversity on cashew accessions in Nigeria germplasm, thus highlighting the need to supplement its gene pool with other accessions, especially from Brazil, which is the origin of cashew. A screening of the most productive cashew varieties in Guinea-Bissau would ultimately allow the identification of the genotypes with agronomic traits linked to nut quality and/or yields. Also, it could allow the identification of genotypes harboring resistance or tolerance traits against diseases. However, no genetic or morphological characterizations of Guinean cashew varieties have been performed so far. Its germplasm exploitation will be an important streamline to be pursued. Indeed, only two varieties are reported [16] and known locally as “Caju di Mozambique”, with yellow apples and high caliber/greater commercial value nuts; and “Caju di Terra”, with yellow and reddish apples and smaller nuts. In Guinea-Bissau, the majority of cashew orchards are cultivated with the “Caju di Terra” variety, despite having smaller nuts, since the apples are sweeter and used for juice that is locally sold to increment the farmer’s income from cashew products. However, few or no value chains exist in such an important agriculture sector. Without proper characterization of the productivity of varieties, smallholders continue to plant cashews to increase their incomes without land use planning, thus continuing to follow the expansion trend of cashew area in the country (Figure 2C).

Cashew is a case of a crop under agricultural expansion, which currently has an urgent need for safe guidelines for sustainable production. Overall, our paper proposes guidelines (see Figure 6) that should contribute to the sustainability of the cashew sector in Guinea-Bissau and ultimately contribute to other West African countries, which would allow for:

- **Increasing agroecosystem services through crop diversification**, which would provide crops for the domestic market, augment agrobiodiversity with positive social impacts (e.g., medicinal and edible plants) in addition to diminishing the risk of pests and diseases by changing the monoculture regime that currently is applied in cashew orchards in Guinea-Bissau;
- **Improving crop productivity** by using high-yield and high-quality cashew varieties, which ultimately will enhance yields per cropland area as opposed to cropland expansion;
- **Developing a structured agricultural business in the cashew sector** by maximizing the use of co-products of cashew, such as apple and wood, in addition to the nuts, for commercialization through a solid supply chain and decreasing market volatility due to cashew nuts being sold alone.

#### 4. Final Remarks

In West Africa, cashew is a case of a crop under agricultural intensification, which is currently in urgent need of secure guidelines for sustainable production following the Green Revolution values. Despite the success of the Green Revolution, which included technologies as modern irrigation, pesticides, synthetic fertilizers and improved crop varieties, its implementation outside industrialized nations was quite disappointing. For Africa, several factors have been pointed out as reasons why the Green Revolution has not been successful. For example, it was considered to be partly due to environmental factors, such as the reduced availability of water as well as the high diversity in slope and soil types [35]. The African Union (AU) declared “The Year of Agriculture and Food Security” in 2014 and following this milestone, there has been an increasing number of studies mostly focusing on issues related to food security, which also covered a wide range of regions and crops. Considering the growing population and the increase in smallholder’s agriculture, sustainable production of any cropping system, including cashew, needs to address enhanced productivity together with the maintenance of other ecosystem services [36]. Our study presents cashew as an example of a crop under

the agricultural extensification regime in West Africa, particularly in Guinea-Bissau. Considering the sustainability of this sector, in this report we have performed an integrated approach based on the authors' field experience and long-term collaborations with local institutions. On the long road to reach sustainable crop production in West Africa, the preservation of biodiversity and the maintenance of other ecosystem services must be ensured for the sake of the environment and well-being of the local population. Such a strategy should consider the large heterogeneity in socio-cultural and technical conditions, farmer typologies and production objectives, which portray the African smallholder agriculture. Improving SSA agricultural growth is particularly important in countries such as Guinea-Bissau, where most of the population still suffers from high levels of poverty.

**Supplementary Materials:** The following are available online at [www.mdpi.com/2071-1050/9/9/1666/s1](http://www.mdpi.com/2071-1050/9/9/1666/s1), Figure S1: Study sites: Location of the 21 villages from the administrative regions of Bafatá (n = 9) and Gabu (n = 12) in the eastern region of Guinea-Bissau where the fieldwork was carried out. An ID number identifies each village and geographic locations are also indicated, Table S1: Plant species composition within each of the 21 villages screened in the administrative regions of Gabu and Bafatá. For each village identified by its name and an ID Number, three sampling plots (\_1, \_2, \_3) were used to assess plant species diversity. Trees per plot and density were determined by the number of individuals per taxon, as well as percentage (%) of plant density within in each plot.

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## References

1. Chivandi, E.; Mukonowenzou, N.; Nyakudya, T.; Erlwanger, K.H. Potential of indigenous fruit-bearing trees to curb malnutrition, improve household food security, income and community health in Sub-Saharan Africa: A review. *Food Res. Int.* **2015**, *76*, 980–985. [[CrossRef](#)]
2. FAO. FAO in the 21st CENTURY, Ensuring Food Security in a Changing World. 2011. Available online: <http://www.fao.org/docrep/015/i2307e/i2307e.pdf> (accessed on 14 September 2017).
3. Pretty, J.; Bharucha, Z.P. Sustainable intensification in agricultural systems. *Ann. Bot.* **2014**, *114*, 1571–1596. [[CrossRef](#)] [[PubMed](#)]
4. Unnevehr, L. Food safety in developing countries: Moving beyond exports. *Glob Food Secur.* **2015**, *4*, 24–29. [[CrossRef](#)]
5. Unnevehr, L.J.; Ronchi, L. *Food Safety Standards: Economic and Market Impacts in Developing Countries*; World Bank Group: Washington, DC, USA, 2014.
6. Byerlee, D.; Stevenson, J.; Villoria, N. Does intensification slow crop land expansion or encourage deforestation? *Glob. Food Secur.* **2014**, *3*, 92–98. [[CrossRef](#)]
7. Laurance, W.F.; Sayer, J.; Cassman, K.G. Agricultural expansion and its impacts on tropical nature. *Trends Ecol. Evol.* **2014**, *29*, 107–116. [[CrossRef](#)] [[PubMed](#)]
8. FAO. Food and Agricultural Organization of the United Nations Statistics Division. 2016. Available online: <http://faostat3.fao.org/download/Q/QC/E> (accessed on 27 April 2016).
9. Hollinger, F.; Staatz, J.M. *Agricultural Growth in West Africa: Market and Policy Drivers*; African Development Bank (AfDB): Abidjan, Côte d'Ivoire; Economic Community of West African States (ECOWAS): Lagos, Nigeria, 2015.
10. Dendena, B.; Corsi, S. Cashew, from seed to market: A review. *Agron. Sustain. Dev.* **2014**, *34*, 753–772. [[CrossRef](#)]

11. Ollenburger, M.H.; Descheemaeker, K.; Crane, T.A.; Sanogo, O.M.; Giller, K.E. Waking the Sleeping Giant: Agricultural intensification, extensification or stagnation in Mali's Guinea Savannah. *Agric. Syst.* **2016**, *148*, 58–70. [[CrossRef](#)]
12. Monteiro, F.; Romeiras, M.M.; Figueiredo, A.; Sebastiana, M.; Baldé, A.; Catarino, L.; Batista, D. Tracking cashew economically important diseases in the West African region using metagenomics. *Front. Plant Sci.* **2015**, *6*, 482. [[CrossRef](#)] [[PubMed](#)]
13. Salam, M.A.; Peter, K.V. *Cashew-A Monograph*; Studium Press (India) Pvt. Ltd.: New Delhi, India, 2010.
14. Rabany, C.; Rullier, N.; Ricau, P. The African Cashew Sector in 2015. Available online: [http://www.rongead.org/IMG/pdf/african\\_cashew\\_market\\_review\\_rongead\\_ica\\_2015.pdf](http://www.rongead.org/IMG/pdf/african_cashew_market_review_rongead_ica_2015.pdf) (accessed on 14 September 2017).
15. Kyle, S. *Cashew Production in Guinea Bissau*; Cornell University: Ithaca, NY, USA, 2009.
16. Catarino, L.; Menezes, Y.; Sardinha, R. Cashew culture in Guinea-Bissau—Risks and challenges of the success of a cash crop. *Sci. Agric.* **2015**, *72*, 459–467. [[CrossRef](#)]
17. Catarino, L.; Havik, P.J.; Indjai, B.; Romeiras, M.M. Ecological data in support of an analysis of Guinea-Bissau's medicinal flora. *Data Brief* **2016**, *7*, 1078–1097. [[CrossRef](#)] [[PubMed](#)]
18. Vasconcelos, S.; Rodrigues, P.; Palma, L.; Mendes, L.F.; Palminha, A.; Catarino, L.; Beja, P. Through the eye of a butterfly: Assessing biodiversity impacts of cashew expansion in West Africa. *Biol. Conserv.* **2015**, *191*, 779–786. [[CrossRef](#)]
19. Catarino, L.; Martins, E.S.M.; Pinto-Basto, M.F.; Diniz, M.A. *Plantas Vasculares e Briófitos da Guinea-Bissau*; Instituto Português do Apoio ao Desenvolvimento: Lisbon, Portugal, 2006.
20. Catarino, L.; Havik, P.; Romeiras, M.M. Medicinal plants of Guinea-Bissau: Therapeutic applications, ethnic diversity and knowledge transfer. *J. Ethnopharmacol.* **2016**, *183*, 71–94. [[CrossRef](#)] [[PubMed](#)]
21. Pretty, J. Agricultural sustainability: Concepts, principles and evidence. *Philos. Trans. R. Soc. Lond. B* **2008**, *363*, 447–465. [[CrossRef](#)] [[PubMed](#)]
22. Strange, R.N.; Scott, P.R. Plant disease: A threat to global food security. *Annu. Rev. Phytopathol.* **2005**, *43*, 83–116. [[CrossRef](#)] [[PubMed](#)]
23. Hammed, L.A.; Anikwe, J.C.; Adedeji, A.R. Cashew nuts and production development in Nigeria. *Am. Eurasian J. Sci. Res.* **2008**, *3*, 54–61.
24. Freire, F.C.O.; Cardoso, J.E.; dos Santos, A.A.; Viana, F.M.P. Diseases of cashew nut plants in Brazil. *Crop. Prot.* **2002**, *21*, 489–494. [[CrossRef](#)]
25. Vasconcelos, S.; Mendes, L.F.; Beja, P.; Hodgson, C.J.; Catarino, L. New records of insect pest species associated with cashew, *Anacardium occidentale* L. (Anacardiaceae), in Guinea-Bissau. *Afr. Entomol.* **2014**, *22*, 673–677. [[CrossRef](#)]
26. Topper, C.P.; Caligari, P.D.S.; Camara, M.; Diaora, S.; Djaha, A.; Coulibay, F. *West African Regional Cashew Survey Report (Guinea, Guinea Bissau, Cote D'Ivoire, Ghana and Nigeria)*; Sustainable Tree Crop Programme (STCP): Earley, UK, 2001.
27. Adeigbe, O.O.; Olasupo, F.O.; Adewale, B.D.; Muyiwa, A.A. A review on cashew research and production in Nigeria in the last four decades. *Sci. Res. Essays* **2015**, *10*, 196–209. [[CrossRef](#)]
28. Asogwa, E.U.; Ndubuaku, T.C.N.; Hassan, A.T. Distribution and damage characteristics of *Analeptes trifasciata fabricius 1775* (Coleoptera: cerambycidae) on cashew (*Anacardium occidentale* Linnaeus 1753) in Nigeria. *Agric. Biol. J. N. Am.* **2011**, *2*, 421–431. [[CrossRef](#)]
29. Mendes, L.F.; Catarino, L.; Bivar de Sousa, A. Xilófagos do cajueiro (*Anacardium occidentale*), em especial na Guiné-Bissau. *Bol. Soc. Port. Entom.* **2012**, *12*, 201–212.
30. Topper, C.P. Issues and Constraints Related to the Development of Cashew Nuts from Five Selected African Countries (Cote d'Ivoire, Ghana, Guinea, Guinea-Bissau Nigeria). Available online: <https://issuu.com/agropec/docs/developmentcashewnutsafricancountries+&cd=1&hl=en&ct=clnk&gl=sg> (accessed on 14 September 2017).
31. Hanusch, M. Guinea-Bissau and the Cashew Economy. Available online: <http://documents.worldbank.org/curated/en/443831467999735473/102933-REVISED-PUBLIC-MFM-Practice-Note-11.pdf> (accessed on 19 September 2017).
32. ILAP. *Survey Small of Poverty Assessment II*; Ministério da Economia de Bissau: Bissau, Guiné-Bissau, 2010.

33. ACA. African Cashew Alliance Annual Report 2011: Growing the African Cashew Industry. 2011. Available online: [http://www.africancashewalliance.com/sites/default/files/documents/aca\\_annual\\_report\\_2011.pdf](http://www.africancashewalliance.com/sites/default/files/documents/aca_annual_report_2011.pdf) (accessed on 14 September 2017).
34. Aliyu, O.M. Genetic Diversity of Nigerian Cashew Germplasm. In *Genetic Diversity in Plants*; Caliskan, M., Ed.; Springer: Berlin, Germany, 2012.
35. Frison, E. *Biodiversity—Indispensable Resources*; Development and Cooperation: Frankfurt, Germany, 2008.
36. Spiertz, H. Challenges for crop production research in improving land use, productivity and sustainability. *Sustainability* **2013**, *5*, 1632–1644. [[CrossRef](#)]



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