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Chapter - 2
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Chapter - 2

Useful Weeds of the Cashew (*Anacardium occidentale* L.) Orchards in Côte d'Ivoire

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Abstract

Weeds are always considered as pests that are continuously destroyed by farmers because of their impact on agricultural production. But like many other plants, some can have several virtues. This work aims to determine the uses of weeds by cashew producers in 4 regions of Côte d'Ivoire.

In each region, we inventoried weed species in cashew orchards and conducted an ethnobotanical survey among cashew farmers to identify which ones were useful. This ethnobotanical survey was conducted using semi-structured interviews with 108 farmers. A total of 73 were cited by farmers as useful for maintaining them in their orchards. Five categories of use were recorded of which weeds used as food represent 42%. Weeds used in traditional medicine account for 35% while those used for fodder and handicrafts each account for 9%; the remaining 5% of weeds are used in other areas. The most used organs are fruits and leaves with a rate of 39% each.

The conservation or introduction of useful weeds by farmers shows that some cashew orchards in Côte d'Ivoire are models of agroforestry systems.

Keywords: Cashew, Côte d'Ivoire, weeds, richness and ethnobotanical uses

1. Introduction

The definition of the term weed has always been the subject of debate among specialists. It is considered by some authors as species that lives in a place where it should not be, causing serious problems for crops (Labrada 2005) ^[1]. This term weed is sometimes rejected by others authors because of the negative connotation for the plant thus designated (Ipou 2005) ^[2]. In view of the discrepancies on the notion of 'weeds' in this work, all species encountered in cashew orchards are considered as weeds. Weed can also be defined as a plant introduced voluntarily by humans or spontaneously into cultivated biotopes. Indeed, some weeds provide socio-economic services to

farmers. In Mexico, farmers maintain certain species in association with the main crop, which they call “buen monte” (good plants) and only eliminate “mal monte” (bad plants) in traditional agroecosystems (Altieri 1987) [3]. Indeed, these species are maintained in the fields and used for various purposes: food, medicine, religious ceremonies, soil improvement (Ruthenberg 1976, Gliessman 1988) [4, 5].

In Côte d’Ivoire, previous studies on the identification of the weed flora were conducted on several cultivated species areas. Aman *et al.* (2004) [6] and Ipou (2005) [2] investigated on the weeds of cotton (*Gossypium herbaceum* L.) farms, while Traoré *et al.* (2010) [7] focused on the weeds of palm (*Elaeis guineensis* Jacq.) plantations. Mangara *et al.* (2010) [8] studied the weeds in pineapple (*Ananas comosus* (L.) Merr.) farms when Tano *et al.* (2016) [9] assessed the weeds of banana (*Musa paradisiaca* L.) farms and Traoré *et al.* (2019) [10] on those of the sugarcane (*Saccharum officinarum* L.) farms. The weed flora of rice was inventoried by Kouamé *et al.* (2011) [11], Konan *et al.* (2014) [12] and Touré (2014) [13]. Indeed, many species were harvested from these biotopes by communities for several purposes. Touré *et al.* (2018) [14] have shown that the riparian communities of the Sanaimbo forest reserve, in the south Côte d’Ivoire, knew and maintained the weed species used as traditional medicine, food, house construction and basketry material in their fields. For the cashew (*A. occidentale* L.) few is known about both on the diversity and the use of the associated weed species by farmers. In savannah zones, this crop occupies increasingly large areas (Dugué *et al.* 2003) [15] and its relations with other species in the farms and the importance of these plants for farmers should be understood. Furthermore, it is necessary to know the useful weed species preserved during the maintenance operations in the farms. In order to gather these data, this study was conducted the regions of Gontougo, Bounkani, Marahoué and Kabadougou were cashew is most cultivated. The objective was to show the diversity and the importance of weeds in the cashew orchards of savannah area of Côte d’Ivoire.

2. Methodology

2.1 Study area

The study was carried out in the regions of Bounkani and Gontougo, in Northern-east, of Kabadougou (Northern-west) and Marahoué (Center-west) in Côte d’Ivoire (Figure 1) from July to October 2020. This period corresponds to the vegetative phase of the cashew tree and the weeds inventoried. The regions of Kabadougou and Bounkani are characterized by a Sudanese climate with an average temperature of 30 °C with a Sudanian savannah vegetation

(Monnier 1983) ^[16]. The annual rainfall of these regions ranged from 800 to 1 200 mm (Krogba *et al.*, 2016) ^[17]. The regions of Gontougo and Marahoué are in a forest-savannah mosaic vegetation (Monnier 1983) ^[16] where the climatic regime was similar to the Guinean zone with an average annual rainfall varying between 1.200 and 1.500 mm. The annual average temperature is 28.4 °C (FAO 2005) ^[18].

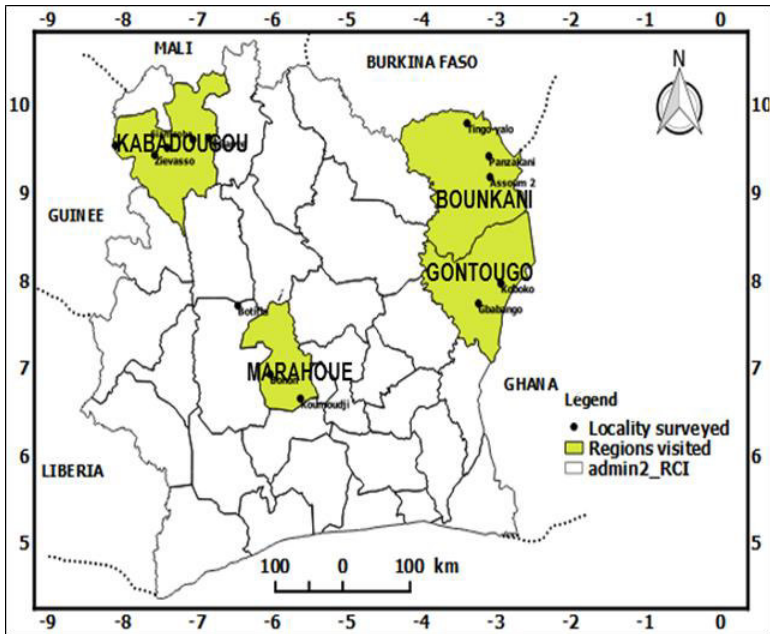


Fig 1: Localization of the studied regions on the map of Côte d'Ivoire

2.2 Data collection

The botanical survey was conducted in 108 cashew farms encompassing three villages in each region of Bounkani and Gontougo and six villages in each region of Kabadougou and Marahoué. In each village six cashew orchards were visited and their owners were retained for the survey (Figure 2). Their weeds flora were inventoried using the surface inventory method (Aman *et al.* 2004, Ipou 2005, Adou *et al.*, 2016) ^[6, 2, 19] and the way walking inventory method (Aké Assi 1984, Kouamé 1998a, 1998b, 2016, Malan 2008) ^[20, 21, 22, 23, 24]. A semi-direct questionnaire (Appendix 1) was used to interview the owner of each visited farm (Figure 3). Thus, 108 farmers were interviewed using the questionnaire proposed by Touré *et al.* (2018) ^[14] on the weeds species uses and origins (introduced or spontaneous).



A). Collective selection



B). Selection of a parent

Fig 2: Farmer selection



A). Designation of a species in the orchard



B). Species utility interview

Fig 3: Semi-structured interview

2.3 Specimens identification

The collected weeds were identified in the field using the West African weed guide of Akobundu and Agyakwa (1989) ^[25], Le Bourgeois and Merlier (1995) ^[26] and Arbonnier (2009) ^[27] or at the herbarium of the Centre Suisse of scientific researches in Côte d'Ivoire. The nomenclature of Cronquist (1981) ^[28] updated by APG (2016) ^[29] was followed in this work.

2.4 Data analysis

The diversity index of the weeds in the farms was calculated using the ratio of the species number on the genera number (Aké Assi 1984, Aman *et al.* 2004) ^[20, 6]. The relative importance of the categories of the weeds uses and of the organs used were analyzed by a simple descriptive statistical method as the percentage.

3. Results

3.1 Weed flora richness and diversity in the cashew farms

A total of 73 weeds useful for the farmers were assessed in the cashew farms of the four visited regions. These useful weeds species belong to 63 genera and 34 families (Table 1) of which the most represented were Malvaceae (26.47%), Fabaceae (17.64%) and Dioscoreaceae (11.76). The figure 4 shows a photo of a cashew orchard.

The Gontougo region, with only 18 questioned farmers, showed the highest number of useful species while the lowest number of useful weeds was recorded in the Kabadougou region, with 36 questioned farmers (Table 2). Six commonest species were cited by the farmers in all regions (Table 1). *Azadirachta indica*, *Hibiscus asper* and *Saba senegalensis* were cited only in Bounkani Region while *Dioscorea bulbifera*, *Adenia cissampeloides*, *Alchornea cordifolia*, *Anthocleista djalonensis* and *Cnestis ferruginea* were cited only in Gontougo Region. *Annona senegalensis*, *Arachis hypogaea*, *Daniellia oliveri* and *Sarcocephalus latifolius* were cited only in Kabadougou region. The species cited only in Marahoué region were *Borassus aethiopum*, *Carica papaya*, *Cocos nucifera*, *Coffea canephora*, *Griffonia simplicifolia*, *Hevea brasiliensis*, *Newbouldia laevis* and *Theobroma cacao*.

The Gontougo region showed the highest percentage of cultivated weeds and lowest percentage of spontaneous weeds (Table 3) while the lowest percentage of cultivated weeds was found in the Kabadougou Region. The number of useful weeds differs between regions due to the level of knowledge and also to the access of the species outside the orchard.

Table 1: List of the uses of the cashew farms weeds in the studied regions

Origins, Cul: cultivated, Spo: spontaneous; *uses categories*, Foo: food, Med: medicinal, Cra: crafts, Fol: Fodder, Oth: other, *used organs*, Fru: fruits, Lea: leaves, Roo: roots, Rod: rods; *regions*, Bou: Bounkani, Gon: Gontougo, Kab: Kabadougou, Mar: Marahoué.

N°	Family	Species	Origins		Uses categories					Used organs				Regions			
			Cul	Spo	Foo	Med	Cra	Fod	Oth	Fru	Roo	Lea	Rod	Bou	Gon	Kab	Mar
1	Malvaceae	<i>Adansonia digitata</i> L.		X	X	X				X		X		X		X	
2	Passifloraceae	<i>Adenia cissampeloides</i> Harms		X	X					X					X		
3	Zingiberaceae	<i>Aframomum alboviolaceum</i> K. Schum.		X	X	X				X	X			X		X	
4	Fabaceae	<i>Albizia adianthifolia</i> W.F. Wight		X				X				X		X	X		
5	Fabaceae	<i>Albizia zygia</i> (DC.) J.F. Macbr.		X		X						X			X		X
6	Euphorbiaceae	<i>Alchornea cordifolia</i> Müll. Arg.		X		X						X			X		
7	Sapindaceae	<i>Allophylus africanus</i> P. Beauv.		X		X						X		X	X		
8	Bromeliaceae	<i>Ananas comosus</i> (L.) Merr.		X	X					X				X	X	X	X
9	Araceae	<i>Anchomanes difformis</i> (Blume) Engl.		X		X						X			X		
10	Annonaceae	<i>Annona senegalensis</i> Pers.		X	X					X						X	
11	Combretaceae	<i>Anogeissus leiocarpa</i> Guill. & Perr.		X		X			X		X		X	X			X
12	Gentianaceae	<i>Anthocleista djalonensis</i> A. Chev.		X		X	X				X		X		X		
13	Moraceae	<i>Antiaris to Xicaria</i> Loes.		X				X				X		X			X
14	Fabaceae	<i>Arachis hypogaea</i> L.	X		X					X						X	
15	Meliaceae	<i>Azadirachta indica</i> A. Juss.	X			X						X		X			
16	Sapindaceae	<i>Blighia sapida</i> K.D. Koenig		X		X						X			X		
17	Malvaceae	<i>Bomba X costatum</i> Pellegr.		X	X						X				X	X	X
18	Arecaceae	<i>Borassus aethiopum</i> Mart.		X	X	X	X			X		X	X				X

19	Caricaceae	<i>Carica papaya</i> L.	X		X	X				X		X					X
20	Malvaceae	<i>Ceiba pentandra</i> (L.) Gaertn.		X	X		X					X		X	X		
21	Compositae	<i>Chromoleana odorata</i> R. King & H. Rob.		X					X			X		X		X	
22	Rutaceae	<i>Citrus limon</i> (L.) Osbeck	X		X	X				X	X	X		X	X	X	X
23	Rutaceae	<i>Citrus ma Xima</i> (Burm.) Merr.	X		X	X				X	X	X		X	X	X	X
24	Rutaceae	<i>Citrus reticulata</i> Blanco	X		X	X				X		X				X	X
25	Connaraceae	<i>Cnestis ferruginea</i> VahleX DC.		X		X				X		X			X		
26	Arecaceae	<i>Cocos nucifera</i> L.	X		X	X				X							X
27	Rubiaceae	<i>Coffea canephora</i> Pierre	X		X					X							X
28	Rubiaceae	<i>Coffea arabica</i> L.	X		X					X				X			X
29	Malvaceae	<i>Cola nitida</i> (Vent.) Schott & Endl.	X		X				X	X					X		X
30	Malvaceae	<i>Corchorus tridens</i> L.		X	X					X		X		X	X		
31	Fabaceae	<i>Daniellia oliveri</i> (Rolfe) Hutch. & Dalz.		X					X				X			X	
32	Sapindaceae	<i>Deinbollia pinnata</i> Schum. & Thonn.		X		X						X		X	X		
33	Fabaceae	<i>Dialium guineense</i> Willd.		X	X					X					X	X	
34	Dioscoreaceae	<i>Dioscorea alata</i> L.	X		X					X				X	X		X
35	Dioscoreaceae	<i>Dioscorea bulbifera</i> L.		X	X					X					X		X
36	Dioscoreaceae	<i>Dioscorea cayennensis</i> Lam.	X		X					X				X	X		X
37	Dioscoreaceae	<i>Dioscorea odoratissima</i> PaX		X	X					X				X	X		X
38	Ebenaceae	<i>Diospyros mespiliformis</i> Hochst.		X	X	X	X			X	X	X	X	X	X		X
39	Arecaceae	<i>Elaeis guineensis</i> L.	X		X	X				X				X	X	X	X
40	Moraceae	<i>Ficus eXasperata</i> Vahl		X				X				X	X	X			X
41	Moraceae	<i>Ficus sur</i> Forssk.		X			X					X		X			X
42	Malvaceae	<i>Griffonia simplicifolia</i> (Vahl) Baill.		X		X	X					X	X				X
43	Euphorbiaceae	<i>Hevea brasiliensis</i> (Willd.) Müll.Arg.	X				X	X					X				X

44	Malvaceae	<i>Hibiscus asper</i> Hook.f.		X	X					X		X			
45	Malvaceae	<i>Hibiscus esculentus</i> (L.) Moench.	X		X					X			X	X	X
46	Meliaceae	<i>Khaya senegalensis</i> (Desv.) A.Juss.		X					X			X			X
47	Verbenaceae	<i>Lippia multiflora</i> Moldenke		X	X	X				X	X		X		X
48	Euphorbiaceae	<i>Mallotus oppositifolius</i> Müll.Arg.		X		X						X			X
49	Anacardiaceae	<i>Mangifera indica</i> L.	X		X	X			X	X	X	X		X	X
50	Euphorbiaceae	<i>Manihot esculenta</i> Crantz	X		X					X		X		X	X
51	Moraceae	<i>Milicia eXcelsa</i> (Welw.) Berg		X			X					X		X	X
52	Apocynaceae	<i>Motandra guineensis</i> (Thonn.) A.DC.		X		X						X		X	X
53	Musaceae	<i>Musa paradisiaca</i> L.	X		X					X				X	X
54	Musaceae	<i>Musa sapientum</i> L.	X		X					X				X	X
55	Bignoniaceae	<i>Newbouldia laevis</i> (P. Beauv.) Seem.		X			X					X	X		X
56	Fabaceae	<i>Parkia biglobosa</i> (Jacq.) R.Br.		X	X				X	X				X	X
57	Poaceae	<i>Paullinia pinnata</i> L.		X		X						X		X	X
58	Phyllanthaceae	<i>Phyllanthus amarus</i> Schum. & Thonn.		X		X						X	X	X	X
59	Fabaceae	<i>Piliostigma thonningii</i> Milne-Redh.		X		X						X		X	X
60	Myrtaceae	<i>Psidium guajava</i> L.	X		X					X				X	
61	Apocynaceae	<i>Rauwolfia vomitoria</i> Afzel.		X		X						X		X	X
62	Apocynaceae	<i>Saba senegalensis</i> (A.DC.) Pichon		X	X					X				X	
63	Celastraceae	<i>Salacia baumannii</i> Loes.		X		X						X			X
64	Rubiaceae	<i>Sarcocephalus esculentus</i> (Sm.) Afzel.		X		X						X			
65	Anacardiaceae	<i>Spondias mombin</i> L.		X	X					X				X	
66	Malvaceae	<i>Theobroma cacao</i> L.	X		X				X	X					X
67	Balanophoraceae	<i>Thonningia sanguinea</i> Vahl		X		X						X	X		X
68	Annonaceae	<i>Uvaria chamae</i> P. Beauv.		X	X					X				X	

69	Compositae	<i>Vernonia amygdalina</i> Delile		X		X					X			X		X
70	Sapotaceae	<i>Vitellaria paradoxa</i> C.F. Gaertn.		X	X	X				X		X		X		X
71	Lamiaceae	<i>Vite X doniana</i> Sweet		X	X					X				X	X	X
72	Poaceae	<i>Zea mays</i> L.	X		X					X				X		X
73	Zingiberaceae	<i>Zingiber officinale</i> Roscoe.	X		X	X				X	X			X		X

Table 2: Richness and generical diversity index of useful weeds in cashew orchards of the investigated regions

Regions	Families	Genera	Species	Generical diversity index
Boukani	24	31	36	1.16
Gontougo	26	36	42	1.16
Kabadougou	18	24	26	1.08
Marahoué	23	31	40	1.29

Table 3: Origins of the useful weeds recorded in the cashew farms in each region

Regions	Cultivated weeds		Spontaneous weeds	
	Number	Percentage	Number	Percentage
Boukani	13	36.12	23	63.88
Gontougo	18	42.85	24	57.15
Kabadougou	10	38.46	16	61.54
Marahoué	15	37.50	25	62.50

In terms of morphological types, all regions showed 23 weeds trees, 28 weeds shrubs, 14 weeds lianas and 8 herbaceous weeds (Figure 2). The Gontougo region showed the highest number of both useful weeds trees and lianas species while the Marahoué region experienced the poorest useful weeds trees species (Table 4). The highest number of useful weeds shrubs was found in the Marahoué region and the lowest number of both useful weeds lianas and shrubs was recorded in the Kabadougou region of (Table 4). The herbaceous useful weeds were higher in Kabadougou region and poorer in Marahoué region (Table 4).

3.2 Uses categories

The uses of weed species could be encompassed into the categories of food, of medicine, of crafts, of fodders and of other (Figure 5). The farmers used more the weeds for food and health care in the study area. The Marahoué region showed the highest number of weeds used in the farmers' diets while the lowest number was obtained in the Kabadougou region (Table 5). Similar number of weeds were recognized in both Marahoué and Gontougo regions as medicinal plants while fewer species were experienced in Kabadougou region (Table 5). In all regions, few weeds were used as fodders, handicrafts and others (Table 5).



Fig 4: A cashew orchard from the edge

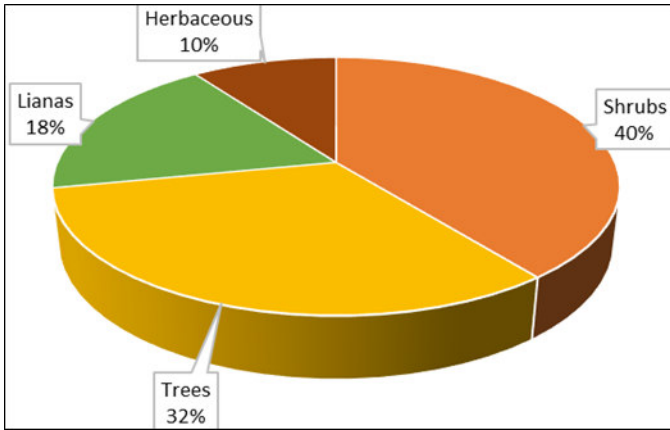


Fig 5: Proportions of the morphological types of the useful weeds in the study area

Table 4: Morphological types of useful weeds recorded in each region

Regions	Trees		Shrubs		Lianas		Herbaceous	
	Number	%	Number	%	Number	%	Number	%
Boukani	9	24.32	15	40.54	7	18.91	6	16.21
Gontougo	11	26.82	15	36.58	9	21.95	6	14.34
Kabadougou	8	33.33	9	37.50	0	0.00	7	29.16
Marahoué	7	17.94	23	58.97	5	12.82	4	10.25

Table 5: Number of weeds species per use-categories in the different regions

Regions	Food	Medicine	Crafts	Fodders	Others
Boukani	22	18	3	2	4
Gontougo	25	21	6	3	4
Kabadougou	13	16	3	2	2
Marahoué	26	21	3	3	4

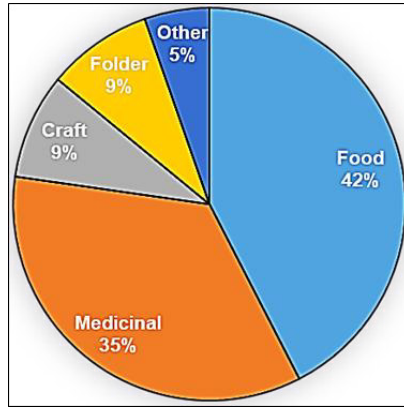


Fig 5: Representativeness of the weeds uses categories

3.3 Weeds used organs

All the weeds organs were used except the flowers (Figure 6). The fruits and the leaves were the most used organs with a proportion of 39% each while the stems and the roots were the least used with respectively 14% and 8% of uses (Figure 6). The figure 7 shows a picture of some species with consumed fruits.

3.4 Weeds in feeding

Forty-four (44) edible species were encountered (Table 1). The organs generally consumed were the fruits, the tubers and the leaves. In all regions, the fruits of *Mangifera indica*, *Citrus limon* and *Citrus maxima* were directly consumed in the field and sometimes at home. The tubers of *Dioscorea alata*, *Dioscorea cayennensis* and *Dioscorea odoratissima* were cooked in water and eaten boiled or crushed. The fruits of *Parkia biglobosa* and *Vitellaria paradoxa*, and the leaves of *Adansonia digitata*, *Bombax costatum* and *Ceiba pentendra* were cooked and eaten.

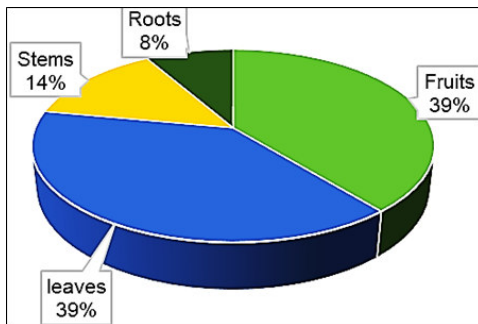


Fig 6: Distribution spectrum of weed organs used by cashew farmers



A) *Mangifera indica* L.

B) *Citrus lemon* L.

Fig 7: Cultivated species with consumed fruits in orchards

In sauce in the regions of Bounkani, Gontougo and Kabadougou. The leaves of *Lippia multiflora* were boiled and consumed as morning tea in Bounkani and Kabadougou regions.

3.5 Weeds in traditional medicine

Thirty-five (35) weeds have been recognized by farmers as plants with therapeutic virtues for human health. The organ parts used were the fruits, the leaves, the roots and the stems. Thus, the useful species could be classified into three groups.

The first group gathers 29 weeds species whose the leaves only were used. In the Marahoué region, the leaves of *Albyzia zygia*, *Antiaris toxicaria*, *Blighia sapida*, *Diospyros mespiliformis*, *Griffonia simplicifolia* and *Vernonia amygdalina* were used by farmers to heal themselves. In both the Kabadougou and Bounkani regions, the leafy branches of *Annona senegalensis*, *Parkia biglobosa*, *Piliostigma thonningii*, *Sarcocephalus latifolius*, *Vitellaria paradoxa* and *Vitex doniana* were used to heal several diseases. In the Gontougo region, farmers used the leaves of *Alchornea cordifolia*, *Deinbollia pinnata*, *Mallotus oppositifolius*, *Motandra guineensis* and *Paullinia pinnata* to heal themselves.

The second group of *Diospyros mespiliformis*, *Mangifera indica*, *Lippia multiflora*, *Alchornea cordifolia* and *Sarcocephalus latifolius* whose both the roots and leaves were used simultaneously to heal the diseases all the studied area.

The third and smallest group encompasses *Anchomanes difformis*, *Phyllanthus amarus*, and *Thonningia sanguinea* whose the entire plants were used against diseases.

3.6 Minor uses of weeds

Twenty-two (22) weeds species were used as foddors, in the crafts, as resting place for men, as source of income and as spiritual significance in the visited regions.

The leaves of *Albizia adianthifolia*, *Albyzia zygia*, *Antiaris toxicaria*, *Ficus exasperata* and *Ficus sur* were used as foddors for domestic animals. The stems of *Anthocleista djalonenis*, *Borassus aethiopum*, *Ceiba pentendra*, *Diospyros mespiliformis*, *Griffonia simplicifolia*, *Hevea brasiliensis* and *Milicia excelsa* were used in construction, in carpentry, to make furnitures (chairs and stools) and as kitchen equipments (pestle). The fruits of *Arachis hypogaea*, *Coffea canephora*, *Coffea arabica*, *Theobroma cacao* and *Zea mays* are a significant source of income for the cashew farmers. *Daniellia oliveri* and *Khaya senegalensis* were supposed to be spiritually protection plants the orchards in all the study area. Their presence keeps away evil spirits.

4. Discussion

The higher number of useful weeds species (36-42 species) in Bounkani and Gontougo both regions with 18 questioned farmers each than those in Kabadougo region (26 species) with a twice number of questioned farmers shows the lack of the interviewed farmers number's impact on the knowledge of the weeds uses in the study area. The higher representatives of the spontaneous weeds (57-63%) than those of the cultivated species in all regions shows that the cashews orchards in the study are more colonized by local natural pioneer species which germinate or resprout in these areas despite the human local activities. But the proportion between 36% and 42% of the introduced useful species by the farmers in their orchards experience also the high contribution of the cashew farmers to the flora of their farms. The lower representatives of both Lianas (0-21.95%) and herbaceous (10.25-29.16%) to the useful weeds flora in all regions reveals the higher contribution of both trees and shrubs to the useful weeds dominated by the food (13-26 species) and the medicinal (16-28 species) uses in the study area.

Many ethnobotanical studies have been carried out in the Sudanian zone (Kouamé *et al.* 2008, Kouamé and Gnahoua 2009, Dro *et al.* 2013, Sibirina *et al.* 2014) [31, 31, 32, 33] and in the Guinean zone (Tra Bi 1997, Ambé 2001) [35, 36] of Côte d'Ivoire but none was on the cashew orchards. The 73 species of useful

weeds found the in-cashew orchards of the four regions is close to the 75 species of useful plant species obtained by Ambé (2001) ^[35] in the natural vegetation of the northern-western Côte d'Ivoire. And this richness is also very similar to those of the 72 food plants species found by Kouamé *et al.* (2008) ^[30] in the natural vegetation of the central-western Côte d'Ivoire.

The presence of both spontaneous weeds species and introduced weeds species in all assessed farms shows that the cashew orchards in Côte d'Ivoire are not single crop farms as a part of local and native flora is preserved in these orchards. Tiebré *et al.* (2016a, 2016b) ^[36, 37] showed that utilitarian species are scarcely available in savannah and degraded opened forests. However, these authors argued that the cultivated areas, the fallows and the opened forests are the reservoirs of utilitarian plants in northern Côte d'Ivoire. This study showed similar results in the Marahoué region in the central-western Côte d'Ivoire where 40 weeds species were preserved in cashew orchards.

Among the four identified ecosystems services described by Brauman *et al.*, (2007) ^[38], only the provisioning services and a lesser extent cultural services seemed to drive farmer's decision to conserve or not weeds species in their orchards. In fact, the weeds kept preserved in the cashew orchards are used most often for food (42.39%), traditional medicine (34.78%) and minor uses. Touré *et al.* (2018) ^[14] found similar results in central-eastern Côte d'Ivoire. More awareness among the cashew farmers about other services provided by plants could lead to the maintenance of more biodiversity in cashew orchards. Tra Bi (1997) ^[34] indicated that the people of the Central-western Côte d'Ivoire consumed the fruits of *Deinbollia pinnata* and the leaves of *Triplochiton scleroxylon*. The consumption of *Deinbollia pinnata*'s fruit is confirmed in the studied area but the edibility of *Triplochiton scleroxylon* was not cited by farmers during this survey. Kouamé and Gnahoua (2008³²) found that the young leaves of *Sterculia tragacantha* and *Triplochiton scleroxylon* were consumed by the populations of central-western Côte d'Ivoire. Tiebre *et al.* (2016b) ^[37] showed that *Adansonia digitata* and *Vitellaria paradoxa* were widely consumed in the Sudanian zone of Côte d'Ivoire. Guinko and Pasgo (1992) ^[39] noted that the availability and consumption of the wild fruits constitute a considerable contribution to household diets. Cunningham (1993) ^[40] Ngalamulume *et al.* (1995) ^[41], Kasuku *et al.* (1999) ^[42] and Dounias *et al.* (2000) ^[43] advocated that the traditional use of medicinal plants forms was the basis of curative medicine for low-income populations. Ambé (2001) ^[35], Soro *et al.* (2012) ^[44], Dro *et al.* (2013) ^[32] and Olivier *et al.* (2013) ^[45] demonstrated the empirical know-how of the use of therapeutic plants by rural populations. The other uses of

some weeds in the study area are not similar to those other areas. Thus, Tra Bi (1997) ^[34] and Touré *et al.* (2018) ^[14] mentioned that the trunk of *Nesogordonia papaverifera* was used for making pestle and mortar, and as a framework among the populations of central-western and western Côte d'Ivoire.

Conclusion

This study shows that cashew orchards in the four regions studied in Côte d'Ivoire are rich in useful weeds for farmers. With 73 species inventoried including trees, shrubs, lianas and herbs, it can be stated that these farms hold a significant level of biodiversity. The species inventoried can be cultivated by the farmer or spontaneous in the orchards. But the maintenance of weed species is rather driven by provisioning services (food, medicine, craft and fodder). This means that in the event of improvement of basic social services and modernization (dispensary, urbanization), these practices could be considerably reduced. Therefore, the conservation of useful weed species in cashew orchards show that this culture also allows the establishment of an agroforestry system.

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Chapter - 3

Richness and Diversity of Weeds in the Cashew Orchards in Côte D'ivoire

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Chapter - 3

Richness and Diversity of Weeds in the Cashew Orchards in Côte D'ivoire

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Abstract

The present chapter aims to contribute to the knowledge of the floristic composition and diversity of weeds in the cashew orchards of Côte d'Ivoire savannah area. In each of the 261 cashew orchards visited, a single or couple of 100 sqm plots were established and assessed for weeds according to the heterogeneous crowns of cashew trees (closed and juxtaposed or separated) or the homogeneous crowns (closed or juxtaposed or separated). In all these 261 assessed orchards, 438 weed species belonging to 276 genera and 73 families were found. The Fabaceae family (18.49%), Poaceae family (9.13%), Rubiaceae and Compositae families (6.39% each), Malvaceae family (4%), Lamiaceae family (3.88%), Combretaceae family (3.42%), Cyperaceae and Apocynaceae families (3.19%) and Euphorbiaceae and Phyllanthaceae families (2.73% each) were the most represented. Total annual rainfall, average daily temperature, the geographical coordinates and soil type did not influenced the richness of weeds. However, the crown cover status influenced the nature and cover of weeds.

Keywords: Cashew, savanna, weeds, species, diversity

1. Introduction

Cashew (*Anacardium occidentale* L.) is a small tree of the Anacardiaceae family, cultivated in the tropics for the production of cashew nuts (Figure 1A), which are indehiscent kidney-shaped drupes, and cashew apples (Figure 1B&C), which are pseudo-fruits resulting from the development of the stalk and floral receptacle at the base of the drupe (Fournet 2002) ^[1]. Native to tropical America, from Mexico and the Caribbean to northeastern Brazil and Peru (Fournet 2002) ^[1], the cashew tree was domesticated longtime before the conquest of America by Europeans (Mitchell and Mori 1987 Clement *et al.* 2015) ^[2,3]. From its origin in northeastern Brazil, cashew cultivation is thought

to have spread to Central America around 900-400 BC (Lentz 2000) ^[4]. In the 16th century, cashew was transplanted by the Portuguese to Mozambique and India and from there it spread to Southeast Asia and became widely naturalized in tropical areas, especially in coastal regions (Piperno 2011) ^[5].

Today, widely cultivated in the tropics, it is found in Africa, the Caribbean, Northeast Brazil, Southeast Asia, China and India (Piperno 2011) ^[5]. Cashew plantations occupy about 7.5 million hectares worldwide and are distributed in 32 countries (Fao 2002) ^[6]. Cashew trees help solve environmental and socio-economic problems in the countries where they are grown (Tandjiékpon *et al.* 2003, Dwomoh *et al.* 2008, Hammed *et al.* 2008, Yabi *et al.* 2013) ^[7,8,9,10]. Indeed, cashew trees are used to fight against erosion and also allow for the rapid reconstitution of agricultural areas degraded by the extensive cultivation of other agricultural crops (Aïvodji and Anassidé 2009) ^[11]. The cashew nut sector is an important sector for the African continent, which accounts for more than 55% of global cashew nut production. Between 2000 and 2016, cashew production in Africa increased by a factor of 4.5, from about 400,000 tons to over 1,800,000 tons in 2016 (Aca 2017) ^[12].

Introduced in Côte d'Ivoire in 1951, it was only between 1959 and 1960 that cashew forest plantation programmes were carried out and extended to the entire ecologically favourable zone, notably the Sudano-Guinean savannas (Goujon *et al.* 1973) ^[13]. Since then, cashew orchards have continued to expand over the northern half of the country and became one of the main agricultural exports from Côte d'Ivoire. As a result, Côte d'Ivoire has become the leading African producer and exporter of raw



A): Mature cashew nut; B): Mature cashew apples in red colour and C): Mature cashew apples in yellow colour

Fig 1: Different types of cashew fruit

cashew nuts (Djaha *et al.*, 2010, Piperno, 2011, Minagri, 2016) ^[14, 5, 15], with an estimated production of 500,000 tons in 2013 and 700,000 tons in 2015. However, cashew cultivation is subject to numerous biotic like pests, weeds and abiotic constraints like climate change, which contribute to the decline in yields. With regard to biotic factors, productivity losses in cashew-

based perennial systems are due to the use of unimproved plant material and still traditional production techniques (Viana *et al.* 2007) ^[16], in addition to diseases such as bacterial blight, rust, anthracnose and pests (Silué *et al.* 2017, N'Depo *et al.* 2017) ^[17, 18].

1.1 Problematic

The impact of the weeds on the cashew productivity is still unknown in Côte d'Ivoire because studies on the composition of the weed flora and its evolution, which are prerequisites for improving control techniques, are non-existent.

1.2 Objectives

The general objective of this chapter is to remedy this deficiency by characterizing the weed flora of cashew orchards in the savannah zone of Côte d'Ivoire. More specifically, the aim was to draw up and comment on the list of weeds assessed in the cashew orchards. Then, the ecological factors determining their distribution were explained. Given the size of the cashew production area and the variability of vegetation in the agro-ecological zones of cashew production in Côte d'Ivoire, we hypothesise the existence of several weed groups in the cashew studied orchards. This hypothesis was tested through a multi-variate analysis integrating all floristic lists from all cashew orchards.

2. Materials and Methods

2.1 Material

The biological material of the study consisted of weeds observed in cashew orchards in the 19 regions cashew production sites in Côte d'Ivoire (Table 1). The technical equipment consisted of the classic tools of botanists to which were added a soil map of the study area, a GPS and computer equipment with various software. The identification of inventoried species was done on site with the help of the West African weed guide (Akobundu and Agyakwa 1989) ^[19] and confirmed with the herbarium materials of the Centre Suisse de Recherches Scientifiques in Côte d'Ivoire.

2.2 Study area

Côte d'Ivoire is divided into three major agro-ecological zones (FAO, 2005) ^[20] comprising the Guinean zone, the Sudano-Guinean zone and the Sudanian zone. The field work was carried out in the 19 cashew-producing regions of Côte d'Ivoire (Table 1, Figure 2), located in the Sudano-Guinean and Sudanian zones.

The Sudano-Guinean zone is a transition zone between the forest zone and the northern savannah. It is characterised by four seasons which are the long dry season (November to February), the long rainy season (March to June), the short dry season (July to August) and the short rainy season (September to October). Rainfall varies between 1,200 and 1,500 mm. It is the most difficult area for agriculture in Côte d'Ivoire because of drought and flooding. The average annual temperature is 28.4 °C. The Sudanian zone, covering about 31% of the country, is located further north. It is a savannah region with a tropical Sudanese-Guinean climate and a single rainy season. Rainfall, between 900 and 1,200 mm, generally allows for rain-fed agriculture. Soils with acceptable agricultural potential represent less than 50% of the area.

Rainfed crops dominate (maize, rice, groundnuts) and are often combined. About 40% of the farms in the region produce cotton. Perennial crops (mango, shea, cashew) and livestock are also important sources of income. Temperatures vary between 24 and 32 °C.

Table 1: Agro-ecological zones and cashew production regions covered by the study

Type of vegetation: F for forest and S for savanna. Soil type: A-Sab for sandy clay, Ar for red clay, S-Arg for sandy clay, Sab for sandy and Lim for silty ^[1]. From <https://fr.climate-data.org/afrique/cote-d-ivoire>, ^[2] from Monnier (1983) ^[21] from Perraud ^[3] (1971) ^[22].

Agro-ecological zones	Visited regions	Number of orchard	Annual precipitation (mm) ^[1]	Mean temperature (°C) ^[1]	Hygrometry (%) ^[1]	Vegetations types ^[2]	Soil nature
Sudanese-Guinean	Béliér	9	1118	28.0	87.0	FS	A-Sab
	Gbêkê	13	1139	27.0	68.5	FS	A-Sab
	Iffou	8	1118	28.0	87.0	FS	Ar
	Moronou	3	1179	28.0	87.0	FS	Ar
	N'zi	4	1179	28.0	87.0	FS	Ar
	Marahoué	32	1224	26.5	80.6	FS	Ar
Sudanian	Béré	27	1221	26.0	64.0	S	S-Arg
	Haut-Sassandra	14	1317	26.5	80.6	S	Ar
	Worodougou	17	1268	26.0	64.0	S	Sab
	Bafing	6	1183	26.0	64.0	S	S-Arg
	Folon	9	1479	26.0	64.0	S	S-Arg
	Kabadougou	13	1479	26.0	64.0	S	S-Arg
	Gontougo	24	1129	24.3	67.5	S	S-Arg
	Indénié-Djuablin	5	1300	27.2	67.5	S	Ar
	Tchologo	19	1274	27.0	57.5	S	S-A-Lim
Poro	16	1286	27.0	57.5	S	S-Arg	

	Bagoué	19	1441	27.0	57.5	S	S-A-Lim
	Boukani	20	1098	24.3	67.5	S	A-Sab
	Hambol	10	1139	27.0	68.5	S	S-Arg

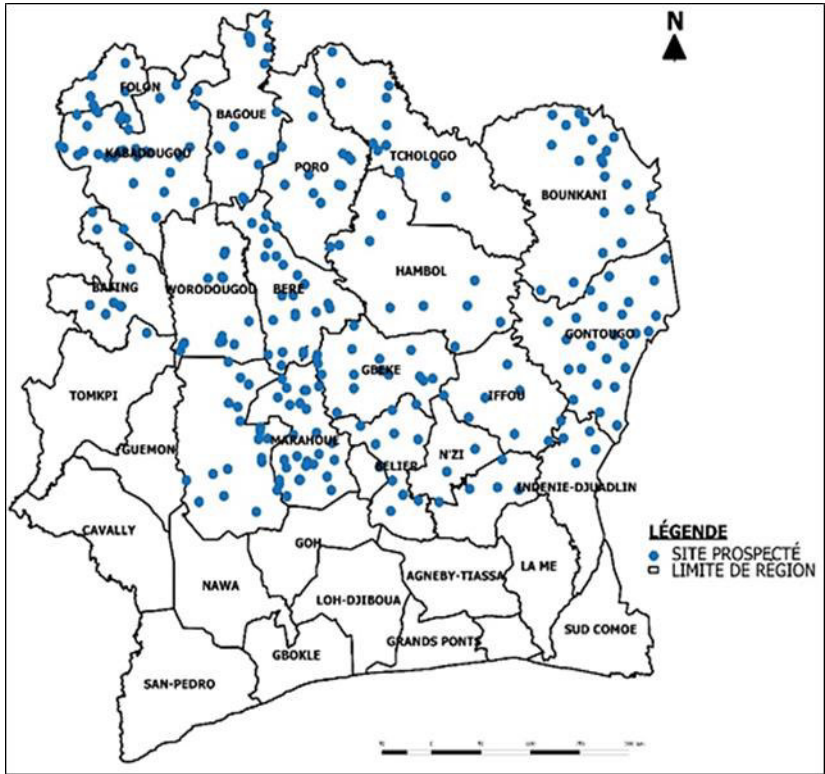


Fig 2: Localization of the assessed cashew orchards on the administrative regions map of Côte d'Ivoire

2.3 Data collection method

Weeds were assessed in 216 plots of 10m x 10m each flowing Ipou (2005)^[23], Adou *et al.* (2016)^[24] and Aman *et al.* (2004)^[25] in the surveyed cashew orchards. The crowns of the cashew trees have been stratified into three layers (Figure 3). When the crowns of the cashew trees never touch each other, they are called separate crowns (Figure 3A), when they barely touch each other, they are called juxtaposed crowns (Figure 3B) and when they all overlap, they are called closed crowns (Figure 3C). In the plantations with homogeneous crowns consisting of closed or juxtaposed or separated crowns, a single 100 m² plot was installed and surveyed. But, in the plantations with heterogeneous crowns (closed and juxtaposed or separated crowns) two 100 m² plots were installed, one under the closed or juxtaposed crowns and the other under the separated crowns. Weed cover, on a scale of 1 to 5 (Table 2), was then determined in each plot.



A) Separated crowns

B) Juxtaposed crowns

C) Closed crowns

Fig 3: Different crowns of the cashew trees

Table 2: Weeds' recoveries according to Braun-Blanquet's scale

Steps	Corresponding recoveries
1	Very Rare, rare or fairly abundant individuals, but low coverage.
2	Very abundant individuals or coverage greater than 1/20 of the area.
3	Individuals covering ¼ to ½ of the area, any abundance.
4	Individuals covering ½ to ¾ of the area, any abundance.
5	Individuals covering more than ¾ of the area, any abundance.

2.4 Analysis of the data

2.4.1 Floristic composition and richness

The analysed parameters were the numbers of families, genera and species recorded in all the orchards surveyed. The number of species recorded in each of the plots was also analysed.

2.4.2 Frequencies

The absolute frequency (F_a) of a given weed species corresponds to the number of plots where this species was recorded (Gounot, 1961, 1969) ^[26, 27]. The relative frequency of a given weed species is the ratio of its absolute frequency (F_a) to the total number (N) of plots. It is calculated by the following formula. $Fr (\%) = \left(\frac{F_a}{N}\right) \times 100$. Raunkiaer's (1905) ^[28] histogram was built using the species relative frequencies within 4 classes (Table 3).

Table 3: Relative frequency classes of taxa according to Raunkiaer (1905) ^[28]

Frequency classes	Corresponding relative frequencies (%)
Class I	1 – 20
Class II	21 – 40
Class III	41 – 60
Class IV	61 – 80
Class V	81 – 100

2.4.3 Generical diversity

The generical diversity index is the ratio between the number of species and genera in a given area. It gives an idea of the degree of floristic diversity of a studied area (Aké Assi 1984, Aman *et al.* 2004) [29, 25]. Its formula is as follow

$$Id = \frac{\text{number of species}}{\text{Number of genres}}$$

2.4.4 Coefficient of similarity

The coefficient of similarity leads to check the floristical link between two compared sites. In this chapter it's determined according to the formula of Sørensen (1948) [30] below

$$Cs = \frac{2c}{a+b}$$

With a and b representing the number of species recorded respectively in two compared sampling sites A and B, C the number of common species to both sites. Cs varies from 0 to 100%. If Cs is greater than or equal to 50%, this means that the two compared sites are floristically similar (homogeneous).

2.4.5 Linear regression

This linear regression analysis is used to determine the strength of a linear relationship between two quantitative variables of relationship which only one is measured. This method was used to evaluate the evolution of species richness as a function of geographical coordinates and ecological factors. A linear relationship is negative for $R < 0$, positive for $R > 0$ and very strong for $R = 1$ or -1 .

2.4.6 Multi-variate analysis

A Principal Component Analysis was performed with the R software in order to highlight the interactions between ecological factors that could influence the distribution of weeds in the surveyed orchards.

3. Results

3.1 Floristical composition and richness

The total richness of weeds in the 261 plots of the assessed cashew orchards was about 438 species belonging to 276 genera and 73 families (Table 4) of which the main were Fabaceae family (18.49%), Poaceae family (9.13%), Rubiaceae and Compositae families (6.39% each), Malvaceae family (4%), Lamiaceae family (3.88%), Combretaceae family (3.42%), Cyperaceae and Apocynaceae families (3.19% each), Euphorbiaceae and Phyllanthaceae

families (2.73% each). The Dicotyledonous Angiosperms were the most representative (Figure 4) with 363 species (82.87%) followed by the Monocotyledonous Angiosperms with 73 species (16.66%).

The plot richness in these 261 cashew orchard plots varied between 1 and 49 species per 100 m² (Figure 5). The distribution of cashew orchards according to their floristic richness followed Gaussian curve histogram (Figure 4) with an optimum of 11 species per 100 m². The proportion of cashew orchards with a floristic richness between one and 17 species per 100 m² was evaluated at 84.29%, 82.75% of which had their floristic richness between five and 17 species per 100 m² (Figure 5). The floristic richness for which there were more than ten cashew orchards each, ranged from six to 15 species per 100 m² and concerned 73.56% of the orchards (Figure 5).

Table 4: Genera and species numbers of the most represented families

Families	Number of genres	Number of species	Generical diversity Index
Fabaceae	44	81	1.84
Poaceae	20	40	2.00
Compositae	20	28	1.40
Rubiaceae	16	28	1.75
Apocynaceae	11	14	1.27
Malvaceae	11	17	1.54
Euphorbiaceae	9	12	1.33
Lamiaceae	9	17	1.88
Cyperaceae	8	14	1.75
Phyllanthaceae	5	12	2.40
Combretaceae	3	15	5.00
Others (65)	120	160	1.33
Total	276	438	1.59

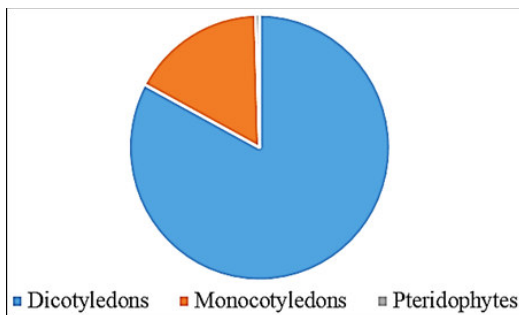


Fig 4: Distribution of the cashew orchard weed flora within large groups of vascular plants

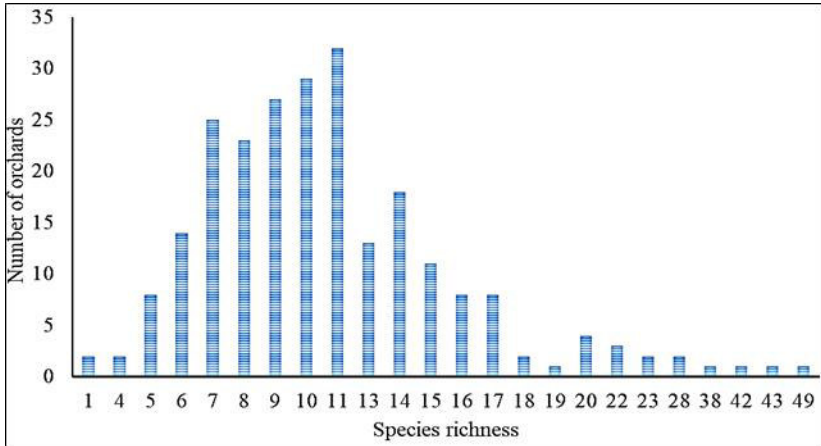


Fig 5: Distribution of cashew orchards according to their plot weed richness

3.2 Biological types, morphological types and chorologies

In terms of biological types, the weed flora was dominated by microphanerophytes and nanophanerophytes weeds with 34.25% and 24.20% of the species respectively (Table 5). Therophytes were well represented with 18.03% of species. Geophytes and megaphanerophytes weeds were the least represented with 2.97% and 2.28% of species respectively (Table 5).

In terms of morphological types, shrubs and herbaceous weeds were the most represented with 36.30% and 30.60% of species respectively (Table 5). The lianas weeds, represented by 22.60% of the species, are more than double the number of tree weeds species in the cashew orchards (Table 5).

The chorological affinities of weeds in the cashew orchards were dominated by species belonging to the transition zone between the Guineo-Congolian and Sudano-Zambezi regions, on the one hand and to the Guineo-Congolian zone, on the other hand, with respectively 46.58% and 42.01% of species (Table 4). The Sudanian savannas region typical species with 7.99% and the West African forest block typical species with 3.42% were the least abundant in these orchards (Table 5).

3.3 Floristical homogeneity

The distribution of species according to the frequency histogram (Figure 6) showed that the vegetation of all the orchards studied was floristically homogeneous. Indeed, the representation of the species according to their frequency class follows a unimodal inverted "J" pattern (Figure 6). The histograms were characterised by a strong presence of species with the lowest relative frequencies belonging to class I whatever the type of crown. The

coefficient of similarity between the types of crowns: closed, juxtaposed and separated indicates that the sub-crowns of cashew orchards are floristically identical (homogeneous).

Indeed, this coefficient is respectively 52% between juxtaposed and closed crowns, 51% between separated and closed crowns and 66% between separated and juxtaposed crowns (Table 6). These coefficients show that the pairs of cashew tree crown types are floristically homogeneous.

3.4 Floristical diversity

The overall generical diversity index value obtained from the orchards' weeds flora was 1.59 showing that the orchards are floristically diverse. This index for the 11 most represented families (Table 4) varied from 1.27 for the Apocynaceae family to 5 for the Combretaceae family showing that this weed flora included both plant families with low diversity (Combretaceae) and those with a high degree of floristical diversity (Apocynaceae, Euphrobiaceae).

Table 5: Distribution of inventoried species within biological types, morphological types and chorologies

Biological types: Ch: chamephyte (perennial plant $0 \text{ m} \leq \text{height} \leq 0.25 \text{ m}$), G: geophyte, H: hemicytrophite, mP: mesophanerophyte ($8 \text{ m} \leq \text{height} < 32 \text{ m}$), mp: microphanerophyte ($2 \text{ m} \leq \text{height} < 8 \text{ m}$), MP: megaphanerophyte ($\text{height} \geq 32 \text{ m}$), np: nanophanerophyte ($0.25 \text{ m} \leq \text{height} < 2 \text{ m}$), Th: therophyte. *Lifeform types:* B: shrubs, H: herbaceous, L: lianas, A: trees. *Chorologies:* GC: taxon of the Guineo-Congolian region, GCW: taxon endemic to the forest block west of Togo including Ghana, Côte d'Ivoire, Liberia, Sierra Leone, Guinea, Guinea Bissau, The Gambia and Senegal, GC-SZ: taxon common to both the Guineo-Congolian and Soudano-Zambezi regions, SZ: taxon from the Sudano-Zambezi region.

Biological Types	Richness (Species)	Percentage (%)	Lifeform types	Richness (Species)	Percentage (%)	Chorologies	Richness (Species)	Percentage (%)
Ch	25	5.71	B	159	36.30	CG-SZ	204	46.58
G	13	2.97	H	134	30.60	GC	184	42.01
H	21	4.80	L	99	22.60	SZ	35	7.99
mP	34	7.76	A	46	10.50	GCW	15	3.42
Mp	150	34.25						
MP	10	2.28						
Np	106	24.20						
Th	79	18.03						

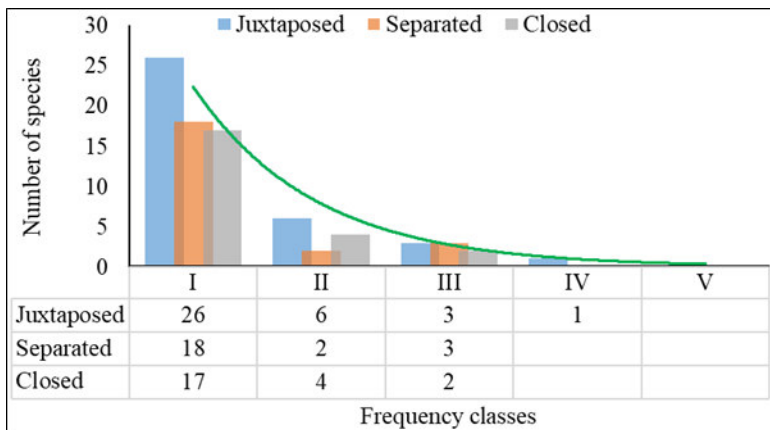


Fig 6: Distribution of the weeds within the frequency classes according to the types of crowns in the cashew orchards

Table 6: Coefficient of the flora similarity between the cashew tree crown types

Crown types of cashew trees in (%)	Closed crowns	Juxtaposed crowns	Separated crowns
Closed crowns	-	52	51
Juxtaposed crowns	-	-	66
Separated crowns	-	-	-

3.5 Impacts of the orchard's location and ecological factors

3.5.1 Location of orchards

The geographical coordinates were not related to weed richness in the cashew orchards (Figure 7). Indeed, although the highest values of weed richness were obtained between latitudes 6° and 8° N (Figure 7A), many orchards at the same latitudes had the same weed richness as those at higher latitudes. Related to the longitudes, high values of weed richness were spread over a wider range from 4° to 7° W longitude (Figure 7B) and low weed richness was observed at all longitudes.

3.5.2 Climatic factors

Total annual rainfall, mean monthly temperature and mean monthly humidity had no statistically established influence on weed richness in cashew orchards (Figure 8). However, a weak tendency towards an increase in weed richness in the orchards was observed with increasing rainfall (Figure 8A) and decreasing mean monthly temperature (Figure 8B). The same trend of increase is also observed with the increase of the average monthly humidity (Figure 8C).

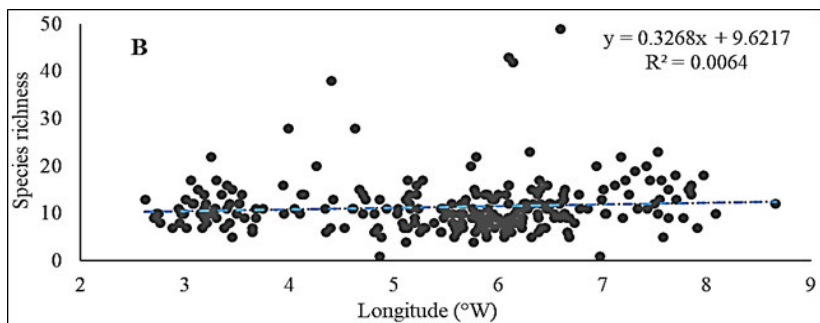
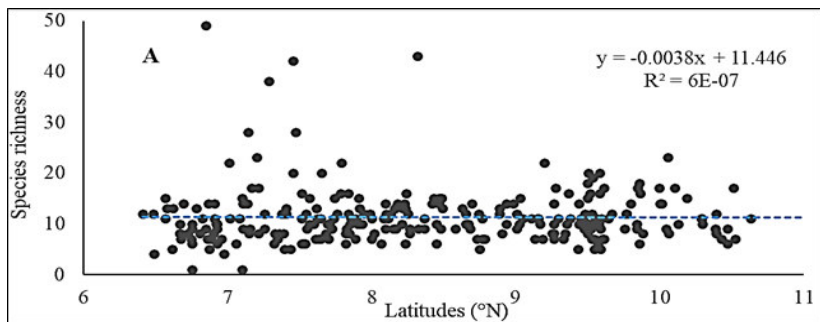
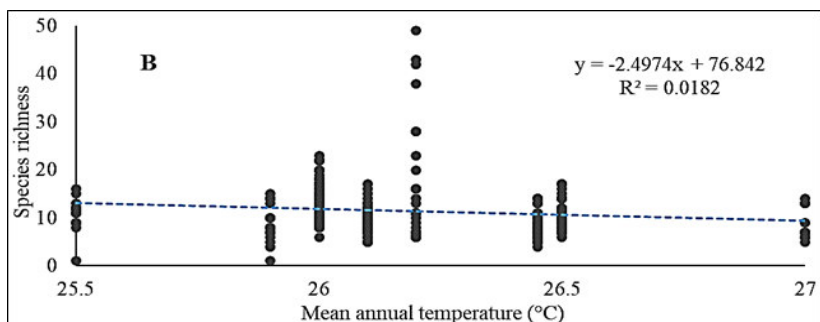
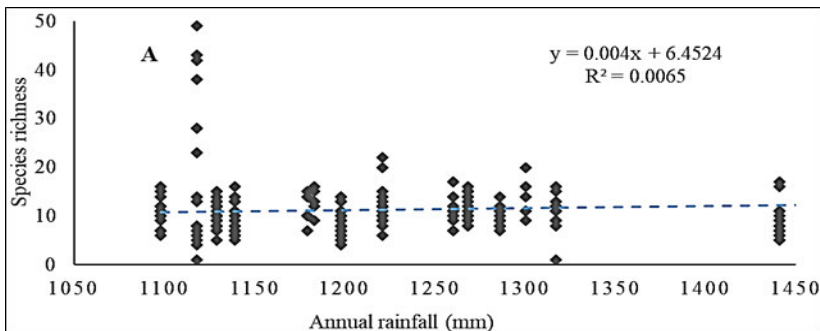


Fig 7: Evolution of the flora richness according to the geographic coordinates of the cashew orchards



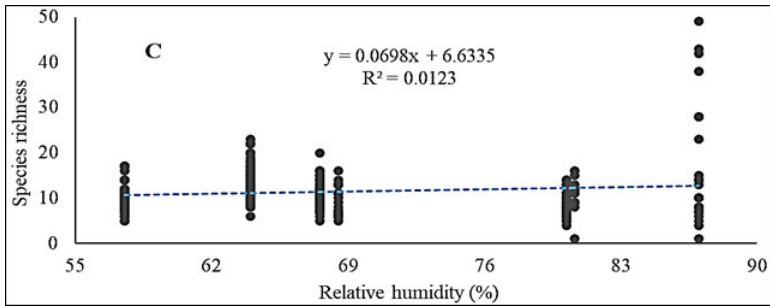


Fig 8: Evolution of the flora richness according to the climatic factors of the cashew orchards

3.5.3 Soil type

Soil type in cashew orchards showed no impact on weed richness (Figure 9). However, the highest values of weed richness were obtained on red clay and sandy clay soils (Figure 9). All four soil types (Table 1) had weed richness values below 10 species per 100 m² (Figure 9).

3.5.4 Cashew tree crown types

The state of closure or opening in the cashew tree crown did not show any statistical influence on the floristic richness of weeds in the orchards (Figure 10). However, weed richness never reached 10 species per 100 m² in the open crown orchards, whereas it exceeded 20 species per 100 m² in the side-by-side crown orchards and 30 species per 100 m² in the closed crown orchards (Figure 10). Low values of floristic richness were observed under all three crown types in the cashew orchards.

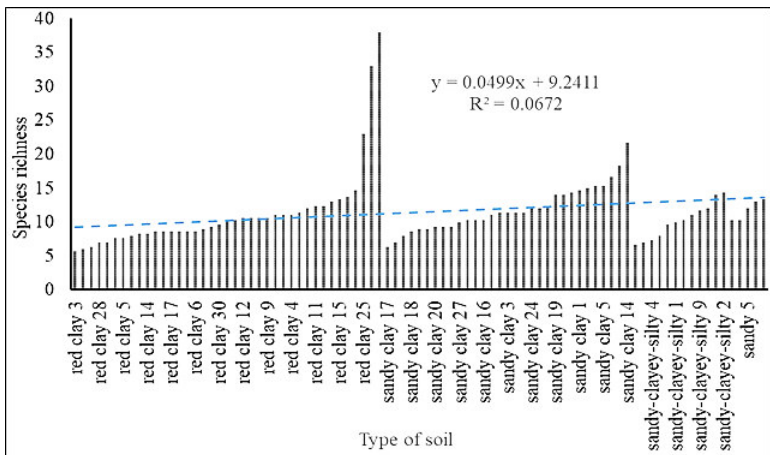


Fig 9: Evolution of the moving average of the weed flora richness according to the type of soil in the cashew orchards

Since it was impossible to represent all the orchards the moving average per group of 3 orchards was used.

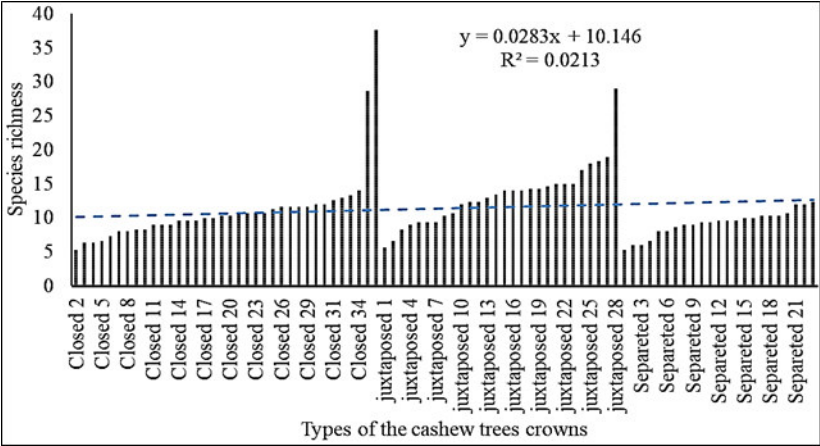


Fig 10: Evolution of the moving average of the flora richness according to the degree of closure of cashew wreaths

Since it was impossible to represent all the orchards the moving average per group of 3 orchards was used.

3.5.5 Combined impacts of factors

The synchronisation of the two axes of the PCA of the studied factors (Figure 11) allowed the orchards to be gathered into three groups according to their relationship to crown types, relative humidity, annual temperature and soil type (Figure 12). The first group G1 (in black) is characterised by plots with species distribution according to relative humidity and canopy type. Group G2 (in green) is characterised by plots where species are influenced by rainfall and soil type. Group G3 (in red) is characterised by plots where species are controlled by temperature. Of all the parameters studied, the state of closure of the cashew tree crowns was the most important factor that separated all the orchards within the three previous groups (Figure 11). In the end, it was found that the nature and cover of the species varied, depending on the state of closure of the cashew tree crowns. Thus, 122 weed species were recorded only under closed cashew tree crowns with coverages sometimes reaching three on Braun-Blanquet’ scale (Table 2). Sixty-three (63) weed species were recorded only under the juxtapedosed cashew tree crowns with overlaps sometimes of four. On the other hand, only 18 weed species were recorded under the separate cashew tree crowns with overlaps varying from one to five. In all the orchards studied, the most common weeds are, in decreasing order, *Chromolaena odorata* (L.) R. King & H. Robyns. (60%), *Ageratum*

conyzoides L. (48%), *Croton hiruts* L'Hér. (37%), *Daniellia oliveri* (Rolfe) Hutch. & Dalziel (28%), *Hyptis suaveolens* (L.) Poit. (26%), *Imperata cylindrica* (L.) Raeusch. (25%) and *Euphorbia heterophylla* L. (23%). Individuals of these species have the highest cover under the juxtaposed or separated crowns of cashew trees.

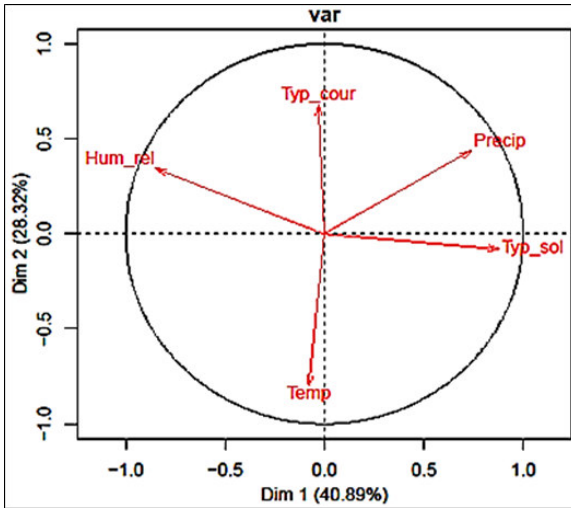


Fig 11: Distribution of ecological factors of the orchards through a Principal Component Analysis

The first two axes (Dim 1 & Dim 2) restore 69.21% of the information (inertia) of the relationships between the floristic characteristics of the plots and the environmental parameters of the plots. Axis 1 has a strong positive correlation with precipitation and soil type, and a strong negative correlation with relative humidity. Ultimately, this axis expresses the water available for weeds. Axis 2 has a strong positive correlation with the type of cashew crowns and a strong negative correlation with temperature. Therefore, the axis expresses the solar illumination for weeds.

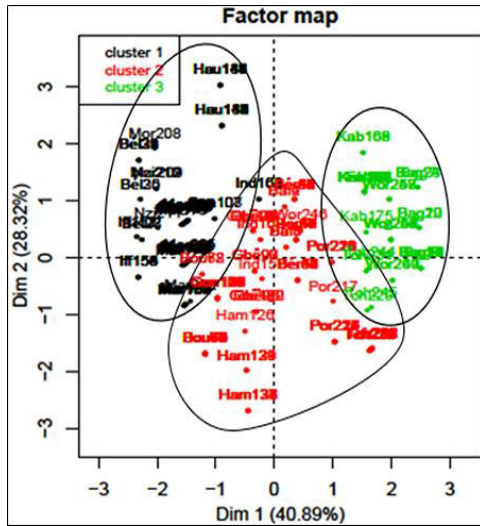


Fig 12: Distribution of orchards through a Principal Component Analysis

4. Discussion

4.1 Floristic composition and diversity

The floristic richness in cashew orchards, estimated at 438 species, distributed among 73 families and 276 genera (Table 4), is higher than that obtained in pineapple cultivation in the localities of Bonoua and N'Douci, in Lower Côte d'Ivoire, by Mangara *et al.* (2010) [31] and estimated at 239 species and 62 families. Similarly, it is higher than that obtained by Tano *et al.* (2016) [32] in two plantain production areas in southern Côte d'Ivoire, estimated at 161 species and 129 genera in 51 families. This higher floristic richness obtained in cashew orchards (Table 4) compared to the results of Mangara *et al.* (2010) [31] and those of Tano *et al.* (2016) [32] may be mainly due to the difference in area covered in the different studies. Indeed, the cashew orchards surveyed in this study cover more than half of Côte d'Ivoire (Figure 2) and consequently, encompass several ecosystems with different floristic assemblages, some of which will persist in the orchards and add to the species that occur in disturbed environments. The predominance of the weed flora of cashew orchards by microphanerophytes and nanophanerophytes is contrary to the results of different authors (Aman 1973, 1978, Maillet 1981, Miderho *et al.* 2017) [33, 34, 35, 36] who found that therophytes and hemicryptophytes were in the majority in anthropogenic environments. This value is also comparable to the value between 1.40 and 1.54 obtained by Aman *et al.* (2004) [25] in cotton plantations.

4.2 Homogeneity of the flora

The distribution of species in the frequency histogram, which follows a unimodal inverted "J" pattern, demonstrates the homogeneity of the flora of cashew orchards. These results are similar to those obtained by Kouadio (2010) [37], in industrial banana cultivation in Dabou, who showed that 73% of weeds were very poorly represented in terms of relative frequency. Traoré *et al.* (2010) [38] also found a high presence of species with very low relative frequencies, i.e. less than 80% in a palm grove in Dabou.

4.3 Factors in the distribution of the flora

The distribution of cashew orchards according to their floristic richness showed that the number of weed species varies between five and 17 per 100 m², with an optimum of 11 species. However, depending on local ecological conditions, this number can go down to one species or increase to 49 species. The most important ecological factor found in this study, which governs the distribution of weeds, is the degree of closure of cashew tree crowns, which regulates the sunlight available to weeds in the cashew understory. Thus, the values of Sørensen's (1948) [30] coefficient of similarity between the three groups of cashew orchards, according to the state of crown closure, ranged from 51 to 66%, lower than the 75% recorded by Aman *et al.* (2004) [30] in cotton plantations and demonstrate a low floristic homogeneity between these groups of orchards. This low floristic homogeneity translates into groups of weed species that live preferentially in each of these three groups of orchards. The closed crown orchards are favourable to a greater number of weed species that develop there with low to medium cover. Thus, the 122 weed species found in this group of orchards are mainly forest species that can withstand the shade of cashew trees. The low floristic richness observed in this group of orchards is attributable to the excessive shading of certain regularly cleaned orchards, which only allows species that can withstand very low intensities of refracted solar light to develop (Alexandre 1982, Poorter 1999) [39, 40]. Generally speaking, cashew orchards in this group host between five and 17 weed species. This richness increases rapidly when the orchards are abandoned for several years. In split-crown orchards, the total availability of light for weeds will only be favourable to the heliophilic pioneer species that can withstand the high intensity and long daily duration of sunlight (Alexandre 1982, Poorter 1999) [39, 40] that develop there. The low number of 18 weed species in this group of orchards, compared to 122 species in the group of closed crown orchards, shows that the flora in this group of orchards is very low in diversity. Several monospecific plots were even encountered, where a single species completely covers the space between the cashew trees. The

richness in cashew orchards with juxtaposed crowns where the intensity and duration of sunlight are intermediate, compared to the two previous groups of orchards, is ultimately a result of those of the latter groups. The 63 species found in these orchards are far less numerous than those of the closed-crown orchards and far more numerous than those of the separate-crown orchards. Although climate has not been reviewed as a determining factor in the floristic richness of cashew orchards, other studies on weeds of cereal crops (Traoré 1991) ^[41], cotton (Le Bourgeois 1993) ^[42] and oil palm (Traoré 2007) ^[43] have demonstrated the preponderance of rainfall over other factors for the distribution of species.

5. Conclusion

The inventory of the weed flora in 261 plots of 100 m² in cashew orchards, in the savannah zone of Côte d'Ivoire, allowed the identification of 438 weed species divided into 73 families and 276 genera. This flora, made up almost exclusively of Angiosperms, is dominated by Dicotyledons on the one hand, and shrubs and herbaceous plants on the other. Micro- and nanophanerophytes from the transition between the Guinean-Congolian and Sudanese-Zambezi regions on the one hand and the Guinean-Congolian region on the other, dominate these weeds. Total annual rainfall, mean monthly temperature, geographical coordinates, soil type and the state of closure of cashew tree crowns do not influence weed richness. However, the state of closure of cashew tree crowns influences the nature and cover of weeds. Thus, cashew orchards with closed crowns have several mainly forest species with low or medium cover each; those with separated crowns have a few pioneer species with high local abundance each. The orchards with juxtaposed crowns host weeds with moderate light intensity and duration requirements, with local abundances varying from low to high. The hypothesis of finding groups of weeds in the cashew orchards studied in this work is thus confirmed. Ultimately, the spacing between trees and the width of the cashew tree crowns, which determine the state of closure of the cashew tree crowns, were found to be determinant in controlling the nature and abundance of weeds.

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