https://doi.org/10.48047/AFJBS.8.6.2026.43-55

AFJBS

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Soil Quality Under a Cocoa-Based Agroforestry System With Associated Indigenous Tree Species In The Department Of Divo (Cote d'Ivoire)

Assi Evelyne Gevere-Marise*[1], Kotaix Acka Jacques-Alain[1], Koffi Kouakou Stanislas[2]

1 Centre National de Recherche Agronomique (CNRA)
2 Université Lorougnon Guédé de Daloa
Author corresponding : Bp 808 Divo, +225 0758434004, evelyne_assi@yahoo.fr

Volume 8, Issue 6, June 2026
Received: 02 March 2026
Accepted: 14 April 2026
Published: 06 June 2026
doi:10.48047/AFJBS.8.6.2026.43-55

Abstract

Agroforestry, a farming system combining trees with crops and sometimes livestock, is considered a sustainable approach to mitigating climate change. An experiment was conducted at the National Agricultural Research Centre in Divo, combining cocoa trees with *Ricinodendron heudelotii* (Akpi). The aim was to evaluate interactions within this system by analyzing soil physical and chemical properties. Four years after planting, soils under shaded cocoa (with *R. heudelotii*) and cocoa grown in full sun were compared. Parameters analyzed included texture, pH, cation exchange capacity (CEC), organic carbon, total nitrogen, available phosphorus, and trace elements. Results showed that soils in both systems were clayey-siltysandy. However, pH improved in the agroforestry system. The C/N ratio was normal in full sun (8.5) but higher under agroforestry (18). Organic matter content remained below recommended levels in both systems. CEC values were within acceptable ranges for cocoa, with slightly higher values in the agroforestry system. Total phosphorus was also higher under *R. heudelotii*. However, the Mg/K ratio was below recommended levels in both systems. Overall, the presence of R. heudelotii positively influenced several soil fertility parameters compared to full sun cultivation.

Keywords : agroforestry, cocoa, fertility, *Ricinidendron heudolotii*, soil

Introduction

The cultivation of the cacao tree (*Theobroma cacao* L.) was introduced to Côte d'Ivoire during the 19th century and developed mainly in the southern forest zone, where soil and climate conditions were particularly favourable for its growth (Bastide, 2007; Kouakou *et al.*, 2013). Since the late 1970s, Côte d'Ivoire has been the world's leading producer of cocoa beans (ICCO, 2012). Currently, the cocoa industry is a crucial economic and social sector for the country. However, this expansion has been at the expense of natural forest cover. Cocoa farming has been one of the main causes of deforestation in Côte d'Ivoire, leading to the gradual degradation of forests. This massive deforestation has contributed to the exacerbation of the effects of climate change, resulting in particular in longer periods of drought, higher average temperatures, lower rainfall totals and increasingly irregular distribution of precipitation. These climatic disturbances have a significant impact on agricultural productivity, particularly that of cocoa plantations, and result in high failure rates when establishing new plantations (Assi, 2021). In light of this situation, agroforestry appears to be a sustainable alternative for improving the resilience of cocoa systems (Rice & Greenberg, 2000; Sonwa *et al.*, 2007; Adou *et al.*, 2016). This practice involves combining shade trees with cocoa crops (Nair, 1993) in order to restore certain ecological functions of forest ecosystems. In an agroforestry ecosystem, there are interactions between trees and agricultural crops. Trees provide multiple services to crops, including shade, protection from strong winds and pests, nitrogen fixation in the soil, water control, etc. However, many uncertainties remain regarding other interactions between trees and cocoa trees. Indeed, some authors have mentioned that constraints associated with agroforestry methods for cocoa have been observed in various producing countries, notably a decline in cocoa production (Dalliere and Dounias, 1998). It is therefore necessary to determine the origin of these negative interactions for crops, in this case for cocoa trees. To this end, these interactions will be studied on a plot involving a combination of cocoa trees and *R. heudolotii* (akpi) plants, which has been set up at the CNRA research station in Divo.

Study site

Our study was conducted in the department of Divo, specifically at the research station of the National Centre for Agricultural Research (CNRA). The capital of the Lôh-Djiboua region, Divo, is bordered to the east and south by the department of Tiassalé, to the west by the department of Lakota, to the south by the department of Guitry and to the north by the department of Oumé. The Divo department is characterised by a sub-equatorial, bimodal climate. Average humidity of 85% varies greatly between seasons, with the lowest levels occurring between November and March and average annual rainfall of 1,200 mm. The department of Divo has an undulating terrain with altitudes ranging from 101 to 200 metres. The vegetation, once consisting of dense semi-deciduous forest, has been reduced to a mosaic of forest remnants due to agricultural activities and logging.

Materials and methods

Plant material

The plant material used in our work consists of cocoa trees from a mixture of several cocoa varieties, combined in the same plot with *Ricinodendron heudelotii* (Akpi) plants.

MethodExperimental

Setup and planting

The experimental plot is completely randomised. After preparing the site, including cleaning and marking out the future cocoa trees, *Ricinodendron heudolotii* (Akpi) seedlings were marked out and planted in 2018 at a density of 18 trees/hectare, forming a plot measuring 48.7 m x 23.5 m. The agroforestry trees were maintained for two years before the cocoa trees were planted. Then, in October 2020, the banana trees were staked and planted. Finally, in May 2021, the cocoa trees were planted at a density of 1,333 trees per hectare, with a spacing of 3 metres by 2.5 metres.

Assessment of the physical and chemical quality of soil in a cropping system combining cocoa and *Ricinodendron heudolotii* (Akpi)

Assessment of soil physical quality

The texture was characterised *in situ* using the tactile method or the sausage method. For the 20 cm horizon, fine soil was sampled and soaked in water. This soil sample is kneaded between the fingers to form a roll. The texture of the soil is determined based on the following results: (i) whether or not a roll is formed, (ii) if a roll is formed, whether it breaks into 1, 2, or 3 pieces or forms a ring (Yoro, 2004). This operation was carried out on soil samples taken from the base of cocoa trees under direct shade from *R. heudolotii* and from the base of cocoa trees without shade from *R. heudolotii.*

Assessment of soil chemical quality in systems combining cocoa trees and *Ricinodendron heudolotii* (Akpi)

Soil sampling

Soil samples were taken from the plot four years after the experimental plot was fully established, i.e. after the cocoa trees had been planted, for analysis to determine the chemical fertility of the soil. Soil samples were taken from the 0-20 cm layer from the soil surface and 1 m from the cocoa tree using a cylindrical sampling tube. This operation was carried out on the four cocoa trees located around each *R. heudolotii* plant. Another soil sample was taken from the control plot where cocoa trees were planted without shade trees (full sun). This sample constitutes the control sample. The soil samples collected were dried by category at ambient temperature for 5 days before being sieved using a square mesh sieve with a mesh size of 2 mm. The two composite samples, packaged in plastic bags, were sent to the laboratory for analysis.

Soil chemical parameters assessed

-grain size

-water pH, in a soil/solution ratio of 1/2.5 using a pH meter; -exchangeable

bases, cation exchange capacity (CEC):

-organic carbon (C) using the Walkley and Black method, 1934;
-total nitrogen (total N) using the Kjeldahl method;

-assimilable phosphorus (P ass), using the Olsen method modified by Dabin (1967).

From these parameters, the following were deduced:
-organic matter (OM), using the equation: OM = 1.724 x C;

- carbon to nitrogen ratio (C/N);
-the sum of exchangeable bases (Ca^{2+}, K^{+}, Na^{+} and Mg^{2+}) referred to as (S);

-the saturation rate of the adsorbent complex (V %) using the following formula: (S/CEC) x 100;

-cation balances for optimal mineral nutrition and production in cocoa trees (Snoeck, 2006). To assess the chemical balances of the various nutritional elements in cocoa trees, the "soil diagnostic" method established by Hornus and Snoeck (2010) was adopted. Total nitrogen content should be compared with the sum of exchangeable bases, according to the following formula:

-N (%) = [(K+Ca+Mg) + 6.15] /8.9.

The balances between exchangeable bases must comply with the following ratios:

-K (%) = 8 (K+Ca+Mg); Ca (%) = 68 (K+Ca+Mg); Mg (%) = 24 (K+Ca+Mg).

Results and discussion

Results Assessment of the physical quality of soil in situ in a cropping system combining cocoa and *Ricinodendron heudolotii* (Akpi)

In situ characterisation of the texture revealed that the soil is sandy loam under cocoa trees in direct shade from *R. heudolotii* and under cocoa trees that do not benefit from their shade (Table 1).

Table 1. In situ characterisation of texture

Types de parcelle	Soil texture
Cocoa trees shaded by *R. heudolotii*	Sandy loam
Cocoa trees in full sun (Control)	Sandy loam

Laboratory assessment of soil physical quality in a cropping system combining cocoa and *Ricinodendron heudolotii*

The results highlighted the presence of silt in the soil compared to the *in situ* characterisation. However, the results showed that the soils are clay-silt-loam with a higher proportion of silt in the soil of cocoa trees that do not benefit from direct shade from *R. heudolotii* plants (Table 2).

Table 2. Contents of the different grain size fractions

Contents of the different particle size fractions (%)				**Texture**
Treatment	**Clay**	**Sand**	Loam	
Cocoa trees shaded by *R. heudolotii*	66.77±0.20a	18.48±0.48a	14.80±0.43b	Clayey-Sandy Loam
Cocoa trees in full sun (Control)	65.21±0.44b	13.28±0.31b	21.52±0.60a	Clay-Loam Sandblaster
Average	65.99	15.88	18.21	
CV	1.03	3.15	5.07	

Pr > F	<0.0001	<0.0001	0.0002

Averages with the same letter in the same column are not significantly different at the 5% level.

Chemical characteristics of the soil in the intercropping system combining cocoa and *Ricinodendron heudolotii* (Akpi)

Organic matter content and mineralisation

Compared to the control, the cocoa- *R. heudolotii* treatment has higher values for the C/N ratio (18) compared to a lower value in the control (8.5). For soil organic matter (SOM) (27.8 g/kg) compared to a lower value in the control group (20.4 g/kg) and for Soil organic carbon (SOC) (1.62 cmol/kg) compared to a lower value in the control group (1.19 cmol/kg). In contrast, total nitrogen (Nt) values were statistically similar between treatments, with an average of 0.11 cmol/kg (Table 3).

Table 3. Organic matter and its mineralisation according to treatments

Treatments	**C/N**	**SOM (gkg^{-1})**	**Nt ($cmolkg^{-1}$)**	**SOC ($cmolkg^{-1}$)**
Cocoa trees shaded by *R. heudolotii* (Akpi)	18±0.57a	27.8 ± 0.10a	0.09 ± 0.00a	1.62 ± 0.06a
Cocoa trees in full sun (Control)	8.5±0.20b	20.4±0.04b	0.14±0.01a	1.19±0.02b
Pr > F	<0.0001	<0.0001	0.072	<0.0001
Average	11.25	24.1	0.11	1.40
CV	5.41	56.2	20.32	5.68

Averages with the same letter in the same column are not significantly different at the 5% threshold. SOM: soil organic matter; C/N: carbon to nitrogen ratio; Nt: total nitrogen; COS: soil organic carbon

Adsorbent complex and soil acidity

The results of the chemical analysis showed that statistical differences were observed with the following parameters: CEC, SBE, pH and Al. For CEC and SBE, the highest values were determined with the control; they were 31.97 cmol/kg and 86.01 cmol/kg, respectively. Regarding pH, the highest value was recorded with the cocoa-*R.heudolotii* treatment at 5.97. However, for the base saturation rate (V%), the values were statistically similar between treatments, with an average value of 56.52 % (Table 4).

Table 4. Adsorption complex and soil acidity

Treatments	**CEC (cmolkg^{-1})**	**SBE (cmol.kg^{-1})**	**pH**	**V (%)**
Cocoa trees shaded by *R. heudolotii* (Akpi)	26.08±0.21b	68.47±0.43b	5.97±0.24a	58.76±1.53a
Cocoa trees in full sun (Control)	31.97±0.58a	86.01±1.49a	5.19±0.03b	56.20±1.05a
Pr > F	<0.0001	<0.0001	0.0009	0.08352
Average	29.02	77.24	5.58	57.48
Cv	2.73	0.23	4.21	6.81

Averages with the same letter in the same column are not significantly different at the 5% threshold. pH: hydrogen potential; CEC: cation exchange capacity; SBE: sum of exchangeable bases, V: saturation rate, Al: aluminium

Soil nutrients under cocoa-*Ricinodendron heudolotii* (Akpi) intercropping

Significant differences were observed between treatments for all elements analysed. For iron, phosphorus, calcium and magnesium, the highest values were determined in the control sample. they were 12.90 mg/kg, 12.90 mg/kg, 39.48 mg/kg and 31.06 mg/kg, respectively. For potassium, the highest value was also observed in this same treatment, at 15.45 mg/kg.

With regard to trace elements, the highest zinc (3.7 mg/kg) and copper (2.8 ± 0.03 mg/kg) contents were observed in the control (Table 5).

Table 5. Nutritional elements in soils under cocoa-*Ricinodendron heudolotii* (Akpi) intercropping

Treatments	**Fe (mg/kg)**	**P (mg/kg)**	**K (mg/kg)**	**Ca^{2+} (mg/kg)**	**Mg^{2+}(mg /kg)**	**Zn (mg/kg)**	**Cu (mg/kg)**
Cocoa trees shaded by *R. heudolotii* (Akpi)	11,65±0,68b	11.65±0.68b	13.78±0.69b	35.31±0.68b	19.37±0.60b	2.6±0.01b	2.7±0.00b
Cocoa trees in full sun (Control)	12,90±0,20a	12.90±0.20a	15.45±0.26a	39.48±1.59a	31.06±0.90a	3.7±0.12a	0 .1±0.01c
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Moyenne	12.27	12.27	14.40	37.39	25.21	3.15	1.4
Cv	0.74	0.74	0.81	0.48	0.53	4.07	1.83

Averages with the same letter in the same column are not significantly different at the 5% level. N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; Fe: iron; Zn: zinc

Chemical balances of soil nutrients in the cropping system combining cocoa and *Ricinodendron heudoloti* (Akpi)

The data recorded in Table 5 show significant differences between treatments for the ratios (Ca + Mg)/K, K/SBE, (SBE + 6.15)/N, Mg/K, and Ca/Mg. For the ratios (Ca + Mg)/K, Mg/K and (SBE + 6.15)/N, the highest values were determined with the control; they were 4.56, 2.00 and 12.4, respectively (Table 6).

Table 6. Chemical balances of nutritional elements in a cocoa-*Ricinidendron heudolotii* (Akpi) system

Treatments	**(Ca + Mg) / K**	**(SBE+6. 15)/N**	**Mg/K**
Cocoa trees shaded by *R. heudolotii*	3.96±0.02b	8.04±0.31b	1.40±0.00 b
Cocoa trees in full sun (Control)	4.56±0.00a	12.4±0.24a	2±0.00a
P	<0.0001	<0.0001	<0.0001
Average	3.90	10.22	1.40
Cv	0.90	4.21	0.97

Averages with the same letter in the same column are not significantly different at the 5% threshold. Ca: calcium; Mg: magnesium; K: potassium; SBE: Sum of Exchangeable Bases; N: nitrogen

Discussion

The results relating to the physical characterisation of the soil of cocoa trees associated with *R. heudoloti*i showed that the texture of the soil was not altered by the presence of the trees. Indeed, soil samples taken from cocoa trees under direct shade from *R. heudolotii* and from cocoa trees without shade from *R. heudoltii* were of a sandy-clay texture. Ultimately, the physical fertility study showed that seven years after the association was established, physical fertility still remains within the norms required by cocoa trees, indicating that the presence of the trees has not degraded this fertility. After assessing the physical fertility of the soil, its chemical fertility was also evaluated. Indeed, the study of the two agroforestry systems (cocoa trees and *R.*

Heudolotii (Akpi)) showed a significant impact on the chemical fertility of the soil. The cocoaR. Heudolotii (Akpi) agroforestry system resulted in a greater accumulation of organic matter (27.8 $g.kg^{-1}$) than the full sun system, which was 20.4 $g.kg^{-1}$. However, these organic matter values remain below the threshold recommended to ensure good soil stability for cocoa cultivation (Kimetu *et al.*, 2009). According to the authors, cocoa trees require soils rich in organic matter, with a minimum content of 30 $g.kg^{-1}$ or 3 %. These results could indicate low microbial activity in the soil. The C/N ratio, an indicator of the degree of decomposition of organic matter, i.e. its ability to decompose more or less rapidly in the soil, was 8.5 for the control. This value remains slightly below the optimal standards for cocoa trees, which are generally between 9 and 12. Indeed, a C/N ratio of less than 9 promotes rapid mineralisation of organic matter, while a ratio of more than 12 leads to nitrogen immobilisation. The optimal threshold ($9 < C/N < 12$) ensures a balance between mineralisation and immobilisation, which is beneficial for the nutrition of cocoa trees (Kimetu *et al.*, 2009). This result indicates a good balance between the organic carbon and total nitrogen content of the organic matter present in the soil. This ratio indicates that organic matter decomposition occurs at a moderate rate, allowing for gradual mineralisation of nutrients. Indeed, work carried out by Tossah *et al.* (2006) has shown that the mineralisation process is more or less normal when C/N is between 8 and 15. The C/N ratio of 18 observed in the cocoa-*R. Heudolotii* (akpi) agroforestry system, which is higher than the recommended standard for cocoa (9-15), suggests that the organic matter is relatively low in nitrogen and rich in carbon. This result could be explained by the immobilisation of nitrogen by soil microorganisms, temporarily limiting its availability to plants. Furthermore, a ratio higher than 15 could indicate a slow degradation of organic matter, reducing the rate of nutrient release, which can negatively affect soil fertility and, consequently, the growth of cocoa trees. Indeed, a total loss of leaves from *R. heudolotii* (Akpi) plants during the dry season (Mapongmetsem, 1998) has been observed.

The pH, the second most important property of soil after texture, provides information about nutrients and toxicity risks. Soil biological activity, like the availability of most nutrients, depends on pH. The different pH values obtained during our work comply with the thresholds for good cocoa tree development. This is corroborated by Appiah *et al.* (2006) and Tossah e*t al.* (2006), who concluded that slightly acidic soil pH is not a constraint for cocoa trees because, even though the optimum pH for the best soils under cocoa trees is 7, This plant can grow in soils with an acidic pH (4.5–6) or slightly alkaline pH (pH 6.7–7.5). Across all systems, the pH values obtained fall within the recommended range. The pH results also show an improvement in soil pH through the cocoa-*R. heudolotii* agroforestry system. With regard to the V saturation rate, it appears that all systems recorded overall saturation rates of less than 60%. This situation is a constraint because a saturation rate of less than 60% is a factor in nutritional imbalance for cocoa trees. This phenomenon is thought to be due to a low exchangeable cation saturation rate of the absorbent complex and significant leaching of exchangeable cations caused by the type of clay present, which is unable to retain large quantities of cations on its surface. Indeed, ferralsols generally have a low saturation level of between 46% and 70% according to N'guessan (2017).

CEC is a fundamental property of soil that depends, on the one hand, on the clay content and organic matter and, on the other hand, on the type of clay present in the soil. Indeed, the CEC values obtained during our work comply with the CEC thresholds (12 <CEC<30 Cmol.kg-1) for cocoa soils defined by Snoeck *et al.* (2015). Similarly, it has been reported that the minimum recommended cation exchange capacity (CEC) for soils cultivated with cocoa trees is approximately 12 $cmol.kg^{-1}$, thus ensuring good soil fertility. The values obtained in each of the cocoa-*R. heudolotii* agroforestry system and full sun system are favourable for good mineral nutrition of the cocoa tree. These results demonstrate the presence of a type of clay with a large specific surface area.

Assimilable phosphorus, which after nitrogen is the second most common deficiency in ferralsols, was greater than 10 mg/kg (determined using the Olsen-Dabin or modified Olsen methods) in both systems studied. This value is the recommended threshold for good nutrition in cocoa trees (Snoeck *et al.,* 2016)

The results showed an imbalance between Mg and K based on the value of this ratio in all the systems studied. According to Jadin and Snoeck (1985), this ratio has an optimum value of 3. Regarding the ratio (SBE + 6.15)/N, which is used to determine nitrogen or exchangeable base requirements in cocoa soil under full sun (control), it was higher than 8.9, so in the cacao-*R. heudolotii* (Akpi) system, it is close to the threshold. According to Jadin and Snoeck (1985), this observation indicates that nitrogen is probably not essential, either because the soil is poor in exchangeable bases (in which case, the cacao trees will respond to an increase in exchangeable base levels), or nitrogen is present in sufficient quantities (in which case, additional nitrogen may even prove toxic to the cacao trees). With regard to Ca-Mg-K balances, the values collected in each system for magnesium and potassium were practically below the threshold established by Snoeck *et al.* (2006). Indeed, this author recommends 68% calcium, 24% magnesium and 8 % potassium as the optimum Ca-Mg-K balance in soils under cocoa trees.

Conclusion

This work was carried out in a cocoa production context marked by numerous constraints, particularly climatic disturbances. To address these, agroforestry was recommended as a sustainable solution. In this context, a trial combining cocoa trees with *Ricinodendron heudolotii* trees was set up at the CNRA station in Divo to determine the effect of the presence of trees on the physical and chemical parameters of the soil under this combination. The results highlighted the varying effects of this combination on the soil. Regarding the effect of the cocoa-*R. heudolotii* (apki) combination on the physical and chemical parameters of the soil, the results showed that, in physical terms, the soil texture remained clayey-silty-sandy for both systems studied. With regard to chemical fertility, a good pH level was observed in the cocoa*R. heudolotii* (Akpi) agroforestry systems (5.97), showing that agroforestry systems could improve soil pH. The C/N ratio, which defines the speed at which organic matter is mineralised, was higher than the norm for cocoa trees in the *R. heudolotii* cocoa tree system, indicating slow mineralisation. Similarly, the CEC of the full sun and cocoa tree-*R. heudolotii* system remained within the standards for cocoa trees (12≤CEC≤30). Phosphorus levels were also within the recommended thresholds for good cocoa tree nutrition.

Acknowledgements : The authors would like to thank Coffee and Cocoa Council (CCC) to fund the works and the National Centre for Agricultural Research (CNRA) where the work took place.

Reference

Adou, Yao Y.C., Kpangui, K.B., Vroh, B.T.A. and Ouattara, D. (2016). Cultural Practices, Use Values and Farmers' Perception of Cocoa Companion Species in Traditional Agroforests in Central Côte d'Ivoire. *Revue d'Ethnoécologie*, 9 : 1-17. https://doi.org/10.4000/ethnoecologie.2474

Assi, E.G.M. (2021). Optimisation de l'itinéraire technique de production du cacaoyer (*Theobroma cacao* L, Malvaceae) dans le département de Divo (Côte d'Ivoire). Thèse de Doctorat, Université Nangui Abrogoua, Abidjan, Côte d'Ivoire. 174p.

Bastide, J. (2007). Le cacaoyer, base d'un bon chocolat. Découverte (352-353): 23-29. https://agritrop.cirad.fr/542280/

Dabin, B., (1967). Sur une méthode d'analyse du phosphore des sols tropicaux - Colloque sur la fertilité des sols tropicaux, Tananarive, 19-25 novembre 1967, 1, p. 99-115.

Dalliere, C. and Dounias, E. (1998). Agroforêts caféières et cacaoyères des Tikar (Cameroun central) structures, dynamiques et alternatives de développement. Séminaire silvaFORAFRI Session 3, Produits de la forêt. Libreville. 26 pp.

ICCO. (2012). Rapport Annuel 2010/2011. ICCO. Londres WC1A. Royaumes Unis : 13-26.

Jadin, P. and Snoeck, D. (1985). La méthode du diagnostic sol pour calculer les besoins en engrais des cacaoyers. Café, Cacao, Thé, 29 (4): 255-272. https://agritrop.cirad.fr/462882/

Kouakou, B., Irie, B., Dick, E., Nemlin, G. and Bomisso, L. (2013). Caractérisation des techniques de séchage du cacao dans les principales zones de production en Côte d'Ivoire et détermination de leur influence sur la qualité des fèves commercialisées. *Journal of Applied Biosciences*, 64 : 4797-4812. DOI:10.4314/jab.v64i1.88469

Mapongmetsem, M.P., Duguma, B., Nkongeneck, B.A., and Puig, H. (1998). Déterminisme de la défeuillaison chez quelques essences forestières tropicales du Cameroun. *Revue d'écologie* (La Terre et La Vie), 53(3) : 193-210. https://hal.science/hal-03529014v1

N'guessan, K. (2017). Fertilité des sols en Côte d'Ivoire : caractéristiques et gestion durable. Éditions Universitaires Européennes : pp 72.

Nair, P.K.R. (1993). An Introduction to Agroforestry. Edition illustrée, Springer Science & Business Media, pp 4-5.

Rice, R.A. and Greenberg, R. (2000). Cocoa Cultivation and the Conservation of Biological Diversity. AMBIO A Journal of the Human Environment 29(3):167-173. DOI:10.1639/0044-7447(2000)029[0167:CCATCO]2.0.CO;2

Snoeck ,D., Abekoe, M. K., Afrifa, A. A. and Appiah, M. R. K. (2006). The soil diagnostic method to compute fertilizer requirements in cocoa plantations. Proc. Int. Conf. on Soil Science. Accra, Ghana, 16 - 21 July 2006. 10 p

Sonwa, D.J., Bernard A., Nkongmeneck, A., Weise, F., Tchatat, M., Akin A.A. and Janssens M.J.J. (2007). Diversity of plants in cocoa agroforests in the humid forest zone of Southern

Cameroon. *Biodiversity and Conservation*, 16 : 2385-2400. DOI 10.1007/s10531-007-9187-1

Tossah, B.K., Koudjega T. and Snoeck D. (2006). Amélioration de la gestion de la fertilité des sols dans les plantations de cacaoyers au Togo. Rapport final scientifique et technique du FSP Régional Cacao. ITRA/CRAF, Togo. 43p.

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1):29–38. **DOI:**10.1097/00010694-193401000-00003

Yoro, G.R. (2004). Formation à la reconnaissance des sols à cacaoyers et aux techniques de régénération cacaoyère. Atelier de formation des techniciens supérieurs, projet STCP. CNRA, Côte d'Ivoire. 5 p.