International Journal of Agronomy and Agricultural Research
ISSN: 2223-7054 (Print); 2225-3610 (Online) | IJAAR |
Website: https://www.innspub.net
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RESEARCH PAPER
Vol. 28, Issue: 2, 2026

OPEN ACCESS

Diagnosis of soil fertility and market gardening systems in the department of Sinématiali (Lokoli and Pegnankaha), northern Ivory Coast

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DOI: https://dx.doi.org/10.12692/ijaar/28.2.39-50

ARTICLE INFORMATION

RESEARCH PAPER

Vol. 28, Issue: 2, p. 39-50, 2026

Int. J. Agron. Agri. Res.

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ACCEPTED: 23 February, **2026**

PUBLISHED: 28 February, **2026**

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ABSTRACT

Market gardening plays a crucial role in food security, income generation, and livelihood improvement in northern Côte d'Ivoire; however, its sustainability is increasingly threatened by declining soil fertility and inadequate management practices. This study aimed to assess the fertility status of market garden soils and analyze associated production systems in the department of Sinématiali, focusing on two representative sites, Lokoli and Pegnankaha. A combination of socio-economic surveys involving 65 farmers and detailed morpho-pedological and physicochemical soil analyses was conducted. Soil samples from different horizons were analyzed for pH, organic matter, nitrogen, phosphorus, exchangeable bases, cation exchange capacity, and particle size distribution. The results indicate that market gardening is predominantly practiced by young male farmers who widely adopt crop rotation and organo-mineral fertilization. The soils are mainly Ferralsols and Gleysols with clayey textures, moderate cation exchange capacity (14–24 cmol/kg), and satisfactory base saturation. However, they are slightly acidic (pH 5.1–6.7), with low organic matter (0.43–1.15%) and deficient available phosphorus (4.08–7.52 mg/kg), indicating low to moderate fertility. Variations between sites were observed, with deeper and more structured soils in Lokoli and lighter, sandy soils in Pegnankaha. In conclusion, despite the adoption of adaptive farming practices, the strong reliance on chemical inputs and insufficient organic matter replenishment may threaten long-term soil productivity. These findings highlight the need for integrated soil fertility management, including increased organic amendments and balanced nutrient management, to ensure the sustainability of market gardening systems in the region.

Key words: Characterization, Market gardening, Soil, Fertility, Sinématiali, Ivory Coast

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INTRODUCTION

In many developing countries, market gardening remains a cornerstone of the socio-economic fabric, contributing to food security, rural employment, and poverty reduction. Market gardening occupies a unique position, particularly in urban and peri-urban areas, where it meets a growing demand for fresh produce while generating income for many households (FAO, 2022).

In Côte d'Ivoire, this activity is experiencing significant growth, especially in the northern regions, where it is adapting to sometimes unfavorable soil and climate conditions. In addition to providing essential food diversity, market gardening is a source of employment for a significant segment of the population, particularly young people and women (Coulibaly *et al.,* 2020).

However, this positive momentum is accompanied by major constraints, notably the progressive degradation of soils. The intensification of production, often practiced on small plots without crop rotation or regular input of organic matter, leads to a marked loss of fertility. The signs are visible: decreased nutrient content, depletion of organic matter, deterioration of soil structure, and reduced yields. These constraints are all the more concerning given that market gardeners, often with limited resources, have restricted access to inputs and the necessary technical support. The department of Sinématiali, located in northern Côte d'Ivoire, clearly illustrates this situation. Market gardening is booming there, driven mainly by family farmers. However, this expansion is accompanied by increased pressure on the soil, without a clear soil analysis having yet been established. However, a thorough understanding of the physical and chemical properties of cultivated soils is an essential prerequisite for implementing sustainable market gardening practices that can improve and stabilize yields in the long term. It is within this framework that the present study is situated, aiming to characterize the market garden soils of the Sinématiali department and analyze the cultivation practices implemented, in order to better understand the interactions between soil quality and the performance of production systems.

MATERIALS AND METHODS

Location of study sites

The study was conducted in market gardening areas in the Poro Region, specifically in the department of Sinematiali (Fig. 1). The Poro Region, located between 8°26 and 10°27 N and 5°17 and 6°19 W, is bordered by the Tchologo and Mali rivers to the north, the Hambol rivers to the south, the Bagoué and Béré rivers to the west, and again by the Tchologo rivers to the east (Karamoko *et al.,* 2020). It is dominated by a wooded to shrubby savanna, becoming more grassy towards the north, with the main tree species being Kapok, Shea, and Néré.

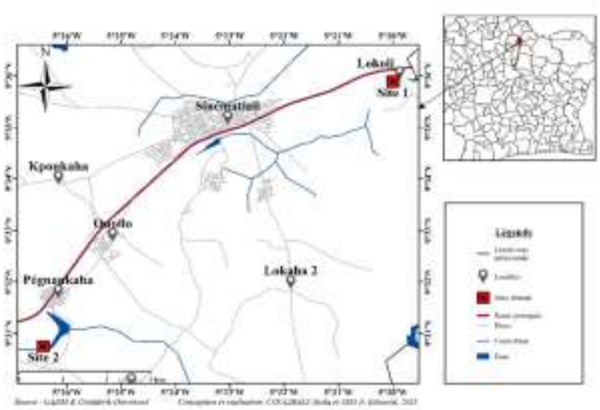

Fig. 1. Presentation of the study sites

The climate is Sudano-Guinean, highly variable from year to year, with an average annual rainfall of approximately 1,343 mm (N'guessan *et al.,* 2019). Average temperatures range from 24°C to 33°C.

The terrain consists of hills, plains, and a plateau reaching elevations of 300 to 400 m, interspersed with tabular hills. Valleys are wider on granite bedrock and narrower in schist areas, reflecting a direct geological influence (Karamoko *et al.,* 2020).

The hydrographic network is dominated by the Bandama and Bagoué rivers, supplemented by numerous intermittent streams (Koné, 2017). The soils, predominantly tropical ferruginous and rich in iron oxides (Jones *et al.,* 1975), are often shallow, locally compacted, and have low water retention capacity, necessitating appropriate management to support agricultural production.

Socio-economic characteristics of market gardeners

Two representative sites were selected: Lokoli and Pegnankaha. Structured surveys were conducted with sixty-five market gardeners to collect data on the producers and their farming practices.

Physico-chemical characteristics of the soils

Six 1.20 m deep soil pits were dug to describe the soil profiles and collect 17 soil samples from different horizons. The samples were dried in the shade at room temperature and sieved using a 2 mm square sieve before being sent to the laboratory for analysis.

Physicochemical analyses focused on soil fertility parameters. The following parameters (pH, carbon, nitrogen, phosphorus, calcium, magnesium, potassium, sodium) and particle size (clay, silt, sand) were determined by infrared spectrometry. The structural stability index was proposed by Pieri (1989).

Statistical analysis

The data collected during the investigations were preprocessed and then classified using Excel software. They were then statistically analyzed using STATISTICA software. The chi-square (χ^2) test was used to characterize the parameters and variables of each site before comparing the sites to highlight the differences between the production systems of each site. In addition, the physico-chemical parameters of the two sites (Lokoli, Pegnankaha) were subjected to an analysis of variance (ANOVA), followed by a post-Anova test (Tukey's HSD test).

RESULTS

Social profile of market gardeners

The socio-demographic characteristics of market gardeners in Lokoli and Pegnankaha are presented in Table 1. The activity is predominantly practiced by men, who represent 61.43% of the total respondents, while women account for 38.57%. However, a significant difference was observed between the two sites (χ^2 = 9.285; p = 0.0023), with a higher proportion of men in Lokoli (80%) compared to Pegnankaha, where women are relatively more represented (57.14%).

Most of the producers are married (90.52%), with only 9.48% being single. This parameter did not show a significant difference between the two sites (χ^2 = 0.975; p = 0.3232), indicating a similar marital structure among respondents.

Regarding age distribution, the majority of farmers fall within the 25–34 years age group (64.53%), followed by those aged 35–44 years (27.85%) and 45–52 years (7.62%). No significant difference was observed between the sites (χ^2 = 0.197; p = 0.905), suggesting that market gardening is largely dominated by young and economically active individuals in both areas.

Household size is mainly between 1–4 members (58.34%), followed by 5–9 members (34.28%) and 10–14 members (7.38%). This variable also showed no significant difference between the sites (χ^2 = 2.03; p = 0.36).

In terms of educational level, the majority of producers are not formally educated (67.15%), while 21.66% have primary education and only 11.19% have secondary education. No significant difference was observed between Lokoli and Pegnankaha (χ^2 = 2.369; p = 0.365).

The results indicate that market gardening in the study area is primarily carried out by young, married, and predominantly male farmers with low levels of formal education, with limited socio-demographic variation between the two sites except for gender distribution.

Farming practices

The characteristics of the cropping systems practiced in Lokoli and Pegnankaha are presented in Table 2. The results reveal variations in certain agricultural practices between the two sites.

In terms of cultivation method, all producers in Lokoli (100%) use the billon system, whereas in Pegnankaha, 82.86% adopt billons and 17.14% use planks. This difference is statistically significant (χ^2 = 5.66; p = 0.017), indicating a variation in land preparation practices between the two sites.

Table 1. Sociodemographic characteristics of respondents at the two sites (Lokoli and Pegnankaha)

Characteristics	Parameters	Lokoli (%) (n= 30)	Pegnankaha (%) (n= 35)	Total (%) (n= 65)
Gender	Female	20	57,14	38,57
	Male	80	42,86	61,43
	Total (%)	100	100	100
	X^2		9,285	
	P		0,0023	
Marital status	Single	6,67	12,29	09,48
	Married	93,33	87,71	90,52
	Total (%)	100	100	100
	X^2		0 ,975	
	P		0,3232	
Age	[25-34]	63,33	65,72	64,53
	[35-44]	30	25,71	27,85
	[45-52]	6,67	8,57	7,62
	Total (%)	100	100	100
	X^2		0 ,197	
	P		0,905	
Household size	[1-4]	56,67	60	58,34
	[5-9]	40	28,57	34,28
	[10-14]	3,33	11,43	7,38
	Total (%)	100	100	100
	X^2		2,03	
	P		0,36	
Education level	No formal education	60	74,29	67,15
	Primary	23,33	20	21,66
	Secondary	16,67	5,71	11,19
	Total (%)	100	100	100
	X^2		2,369	
	P		0,365	

Table 2. Characteristics of the cropping systems observed at the sites

Agricultural practices	Parameters	Lokoli (%)	Pegnankaha (%)	Total (%)
Cultivation method	Billon	100	82.86	91.33
	Plank	0	17.14	8.57
	Total (%)	100	100	100
	X^2	5.66		
	P	0.017		
Rotation	Yes	100	100	100
	No	0	0	0
	Total (%)	100	100	100
	X^2	31.9624		
	P	0.000017		
Fertilization	Yes	100	94.29	97.15
	No	0	5.71	2.85
	Total (%)	100	100	100
	X^2	1.768		
	P	0.183		
Pesticides	Yes	100	94.29	97.15
	No	0	5.71	2.85
	Total (%)	100	100	100
	X^2	1.768		
	P	0.183		
Water source	Dam	100	0	50
	River	0	100	50
	Total (%)	100	100	100
	X^2	65		
	P	0.0000		
Irrigation system	Motorized system	100	82.86	91.43
	Manual system	0	17.14	8.57
	Total (%)	100	100	100
	X^2	5.665		
	P	0.0173		

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Crop rotation is universally practiced by all producers (100%) in both Lokoli and Pegnankaha, showing a highly significant result ($\chi^2 = 31.9624$; $p < 0.001$). This reflects the widespread adoption of rotation as a key strategy in market gardening systems.

Fertilization practices show that all producers in Lokoli (100%) and the majority in Pegnankaha (94.29%) apply fertilizers, combining mineral inputs (urea, NPK) with organic amendments. However, this difference is not statistically significant ($\chi^2 = 1.768$; $p = 0.183$).

Similarly, pesticide use is very high in both sites, with 100% of producers in Lokoli and 94.29% in Pegnankaha reporting pesticide application. This practice does not show a significant difference between the sites ($\chi^2 = 1.768$; $p = 0.183$).

Regarding water sources, a clear contrast exists between the two sites. In Lokoli, irrigation relies entirely on dam water (100%), whereas in Pegnankaha, all producers depend on river water (100%). This difference is highly significant ($\chi^2 = 65$; $p < 0.001$), reflecting site-specific water availability.

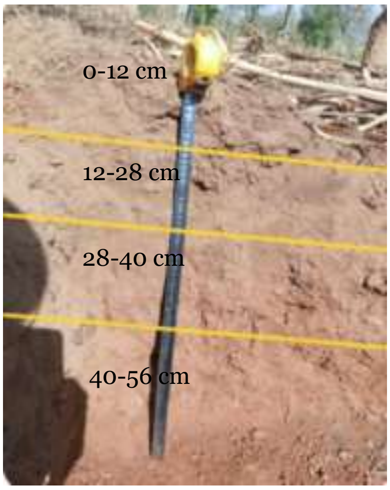
Finally, irrigation systems differ between the sites. All producers in Lokoli (100%) use motorized irrigation, while in Pegnankaha, 82.86% use motorized systems and 17.14% rely on manual irrigation. This difference is statistically significant ($\chi^2 = 5.665$; $p = 0.0173$).

The results indicate that while crop rotation and input use are widely adopted across both sites, significant differences exist in cultivation methods, water sources, and irrigation systems, reflecting variations in resource availability and production strategies.

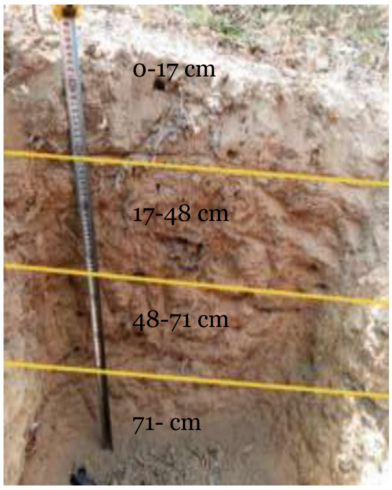
Morpho-pedological characterization of the soils

The morpho-pedological characteristics of soils in Lokoli and Pegnankaha, illustrated in Figs 2 and 3, reveal distinct structural and morphological features between the two sites.

In Lokoli (Fig. 2), the soils are generally moderately deep (up to about 56–96 cm) and exhibit predominantly clayey to silty-clay textures with well-developed subangular polyhedral structures. The surface horizons (A11 and A12) are yellowish-brown, low in humus, and moderately porous, with the presence of fine roots and good structural organization. With increasing depth, the horizons (B) become more clayey, compact, and display red to bright red coloration (5YR hues), reflecting iron accumulation and advanced weathering typical of tropical ferruginous soils. The gradual transition between horizons and the presence of hydromorphic features in some profiles indicate periodic water influence. These soils are classified as Clayic Ferritic Ferralsols, with some profiles showing characteristics of Clayic Stagnic Gleysols, indicating localized drainage constraints.



Soil type: Clayic Ferritic Ferralsols



Soil type: Clayic Stagnic Gleysols

Fig. 2. View of the soil profiles of the Lokoli site

Soil type: Clayic Ferritic Ferralsols

0-12 cm: Dry yellowish-brown horizon 7.5YR 4/3, low humus content, silty texture, subangular polyhedral structure, cohesive, moderately porous, a few millimeter-sized roots with a subhorizontal orientation, drainage class 1.5, abrupt transition, regular boundary. Horizon A11

12–28 cm: Dry yellowish-brown horizon 7.5YR 5/4, low humus content, silty texture, subangular polyhedral structure, cohesive, moderately porous, a few millimeter-sized roots with a subhorizontal orientation, drainage class 1.5, gradual transition, regular boundary. Horizon A12

28–40 cm: Dry, light red horizon 5YR 6/6, non-humus-rich, clayey texture, polyhedral structure, slightly porous, a few millimeter-sized roots with a subhorizontal orientation, drainage class 2. Horizon B

40–56 cm: Dry, bright red horizon 5YR 6/8, non-humus-rich, clayey texture, polyhedral structure, slightly porous, a few millimeter-sized roots with a subhorizontal orientation, drainage class 2.5. Horizon B

Soil type: Clayic Stagnic Gleysols

0–17 cm: Dry yellowish-brown horizon 7.5YR 5/4, humic, clayey texture, polyhedral structure tending towards granular, cohesive, porous, numerous millimeter-sized roots with a subhorizontal orientation, drainage class 1.5, good biological activity, gradual transition, regular boundary. Horizon A3

17–48 cm: Dry yellowish-brown horizon 10YR 6/8, patch 7.5YR 5/8, slightly humic, clayey texture, polyhedral structure tending towards granular, cohesive, slightly porous, a few millimeter-sized roots with a subhorizontal orientation, drainage class 2.5, low biological activity, clear transition, regular boundary. Horizon B1

48–71 cm: Dry yellowish-brown horizon 2.5YR 7/4, patch 5YR 4/8, non-humic, clayey texture, polyhedral structure tending towards granular, cohesive, slightly porous, a few millimeter-sized roots with a subhorizontal orientation, drainage class 2.5, poor biological activity, sharp transition, regular boundary. Horizon B12

71 cm: Dry yellowish-brown horizon 2.5YR 7/4, patch 5YR 5/8, non-humic, clayey texture, polyhedral structure tending towards granular, cohesive, slightly porous, few millimeter-sized roots with a subhorizontal orientation, drainage class 2.5, poor biological activity. Horizon B22/G

In contrast, the soils of Pegnankaha (Fig. 3) are generally lighter, sandy to sandy-clay in texture, and rich in coarse elements. The surface horizons are brown to yellowish-brown, with loose to crumbly or subangular granular structures, reflecting weaker aggregation compared to Lokoli soils. Organic matter content is relatively higher at the surface but decreases rapidly with depth. Subsurface horizons (AB and B) show mottling (rust-ochre colors), reduced porosity, and very low biological activity, indicating poor drainage conditions and periodic water saturation. Some profiles also exhibit compact and poorly structured layers, limiting root penetration. These soils are mainly classified as Arenic Skeletic Ferralsols, Novic Skeletic Ferralsols, and Clayic Histic Gleysols, reflecting their sandy nature, coarse fragments, and hydromorphic conditions.

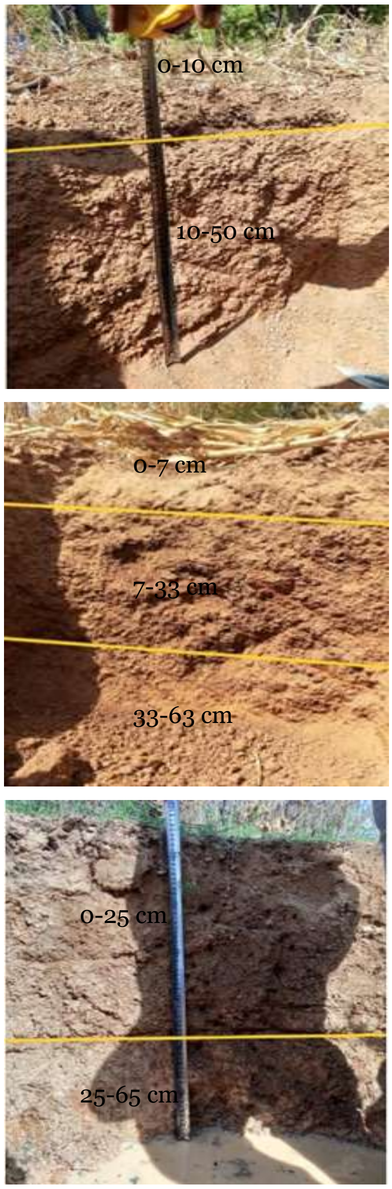


Fig. 3. View of the soil profiles of the Pegnankaha site

Soil type: Arenic Skeletic ferralsols

0–10 cm: Mottled yellowish-brown horizon 7.5YR 5/4, dry and low in humus, sandy texture, crumbly to loose structure, cohesive, porous, a few millimeter-sized roots with a subhorizontal orientation, low biological activity, drainage class 1.5, clear transition, regular boundary. Horizon A11

10–50 cm: Mottled rust-brown horizon 7.5YR 5/4, dry, low in humus, sandy texture, crumbly structure induced by coarse elements, cohesive, low porosity, a few millimeter-sized roots with a subhorizontal orientation, very low biological activity, drainage class 3, gradual transition, regular boundary. Horizon A12

Soil type: Novic Skeletic Ferralsols

0–7 cm: Brown horizon 10YR 6/3, dry, humus-rich, sandy texture, subangular granular structure, loosely cohesive, porous, a few millimeter-sized roots with a subhorizontal orientation, medium biological activity, drainage class 1.5, gradual transition, regular boundary. Horizon A1

7–33 cm: Golden-yellow horizon 10YR 4/4, dry, slightly humus-rich, sandy-clay texture, subangular granular structure, loosely cohesive, porous, few millimeter-sized roots with a subhorizontal orientation, very low biological activity, drainage class 2.5, distinct transition, regular boundary. Horizon AB

33–63 cm: Rust-ochre horizon 5YR 6/6, mottled, dry, slightly humus-rich, sandy-clay texture, subangular polyhedral structure, loose, slightly porous, no roots, very low biological activity, drainage class 3. Horizon B

Soil type: Clayic Histic Gleysols

0–25 cm: Brown horizon 10YR 6/3, moist and humus-rich, clayey texture, subangular polyhedral structure, loose, porous, a few millimeter-sized roots with a subhorizontal orientation, medium biological activity, drainage class 1.5, gradual transition, regular boundary. Horizon A

25–65 cm: Mottled rust-ochre horizon 7.5YR 4/6, moist, slightly humus-rich, clayey texture, subangular polyhedral structure, cohesive, slightly porous, a few millimeter-sized roots with a subhorizontal orientation, very low biological activity, poor drainage. Horizon A12

The morpho-pedological observations indicate that Lokoli soils are deeper, more structured, and clay-rich with better water and nutrient retention capacity, whereas Pegnankaha soils are lighter, sandier, and more affected by coarse elements and drainage limitations. These differences play a key role in influencing soil fertility and agricultural productivity across the two sites.

Physico-chemical characteristics of the soils

The physico-chemical properties of soils from Lokoli and Pegnankaha are presented in Tables 3 to 7 and reveal significant variations in certain parameters between sites and horizons.

The particle size distribution (Table 3) shows that the soils are predominantly clayey at both sites, with clay content ranging from 50.82% to 72.31%. The clay fraction is generally higher in the deep horizons (HP) compared to the surface horizons (HS), particularly in Pegnankaha. Silt and sand contents are comparatively lower. Statistical analysis indicates significant differences for clay ($p = 0.005$), silt ($p = 0.04$), and sand ($p = 0.002$), confirming textural variability between horizons and sites.

Soil acidity and structural stability index (Table 4) show that the soils are slightly acidic to near neutral, with pH values ranging from 5.1 to 6.7. Lokoli soils exhibit slightly higher pH values compared to Pegnankaha. The structural stability index (ST) values are generally low (0.49–1.47) and remain below 2 for all samples, indicating structurally fragile soils. However, no significant differences were observed between sites or horizons for pH ($p = 0.52$) and ST ($p = 0.42$).

The analysis of soil organic matter and nitrogen (Table 5) indicates generally low levels of organic carbon (0.25–0.67%) and organic matter (0.43–1.15%) across both sites. Total nitrogen content ranges from 0.08% to 0.11%, with higher values in surface horizons. Among these parameters, only nitrogen shows a significant variation between samples ($p = 0.01$), while carbon, organic matter, and C/N ratio do not differ significantly ($p > 0.05$). The low C/N ratio suggests rapid mineralization of organic matter.

Table 3. Particle size distribution

	Horizons	Cly (%)	Silt (%)	Sand (%)
Lokoli	HS	50,82 ± 2,63 b	22,34 ± 1,099 a	26,83 ± 2,37 a
	HP	66,11 ± 2,58 a	15,76 ± 1,608 a	18,11 ± 1,14 a
Pegnankaha	HS	67,56 ± 3,74 a	15,20 ± 2,071 a	17,23 ± 1,67 a
	HP	72,31 ± 5,59 a	14,26 ±2,956 b	13,41 ± 1,67 b
F		6,62	3,50	8,43
P		0,005	0,04	0,002
Significance		Yes	Yes	Yes

HS: surface horizon; HP: deep horizon

Table 4. Acidity and structural stability index of soils

	Horizons	pH (%)	ST (%)
Lokoli	HS	6,4 ± 0,5 a	1,47 ± 1,08 a
	HP	6,7 ± 0,4 a	1,04 ± 0,53 a
Pegnankaha	HS	5,3 ± 0,1 a	1,39 ± 1,10 a
	HP	5,1 ± 0,2 a	0,49 ± 0,27 a
F		3,34	0,99
P		0,52	0,42
Significance		No	No

HS: surface horizon; HP: deep horizon

Table 5. Soil organic matter and nitrogen

	Horizons	C (%)	N (%)	MO (%)	C/N
Lokoli	HS	0,64 ± 0,26 a	0,11 ± 0,010 b	1,10 ± 0,89 a	5,47 ± 3,25 a
	HP	0,49 ± 0,09 a	0,08 ± 0,003 ab	0,84 ± 0,42 a	6,14 ± 3,18 a
Pegnankaha	HS	0,67 ± 0,25 a	0,11 ± 0,008 a	1,15 ± 0,89 a	6,00 ± 4,83 a
	HP	0,25 ± 0,08 a	0,10 ± 0,005 a	0,43 ± 0,24 a	2,45 ± 1,34 a
F		0,83	5,72	0,83	0,85
P		0,49	0,01	0,49	0,48
Significance		No	Yes	No	No

HS: surface horizon; HP: deep horizon

Table 6. Exchangeable bases of soils

	Horizons	Ca^{2+} (cmol.kg^{-1})	Mg^{2+} (cmol.kg^{-1})	Na^{+} (cmol.kg^{-1})	K^{+} (cmol.kg^{-1})
Lokoli	HS	6,49 ± 0,53 b	3,16 ± 0,36 a	1,53 ± 0,14 a	0,37 ± 0,03 a
	HP	6,80 ± 0,19 a	5,88 ± 0,71 ab	1,99 ± 0,19 a	0,38 ± 0,00 a
Pegnankaha	HS	5,94 ± 0,13 a	7,82 ± 1,98 a	1,03 ± 0,25 a	0,36 ± 0,02 a
	HP	5,94 ± 0,13 a	8,54 ± 1,44 a	1,32 ± 0,84 a	0,36 ± 0,02 a
F		10,09	3,66	1,59	0,29
P		0,001	0,04	0,23	0,82
Significance		Yes	Yes	No	No

HS: surface horizon; HP: deep horizon

Table 7. Cation exchange capacity (CEC), saturation level (V), sum of exchangeable bases (S), and phosphorus

	Horizons	CEC	V (%)	S (cmol/Kg)	P (mg.kg-1)
Lokoli	HS	14,12 ± 1,38 a	83,09 ± 5,91 a	11,56 ± 0,78 a	7,52 ± 0,26 b
	HP	24,10 ± 3,39 a	68,19 ± 8,36 a	15,07 ± 0,69 a	5,65 ± 0,36 ab
Pegnankaha	HS	20,05 ± 4,70 a	82,15 ± 10,48 a	15,16± 2,08 a	4,54 ± 0,50 a
	HP	22,42 ± 7,80 a	72,54 ± 13,00 a	14,49 ± 2,41 a	4,08 ± 0,88 a
F		1,09	0,67	1,44	8,88
P		0,38	0,55	0,27	0,001
Significance		No	No	No	Yes

HS: surface horizon; HP: deep horizon

Regarding exchangeable bases (Table 6), calcium (Ca^{2+}) and magnesium (Mg^{2+}) exhibit significant differences between sites ($p = 0.001$ and $p = 0.04$, respectively), while sodium (Na^{+}) and potassium (K^{+}) do not show significant variation ($p > 0.05$). Calcium levels are relatively stable across horizons, whereas magnesium tends to increase in deeper horizons, particularly in Pegnankaha soils.

The cation exchange capacity (CEC), base saturation (V), and sum of exchangeable bases (S) (Table 7) do not show significant differences between sites or horizons ($p > 0.05$). CEC values range from 14 to 24 cmol/kg, indicating moderate nutrient retention capacity, while base saturation values remain relatively high (>68%), reflecting a satisfactory mineral reserve. However, available phosphorus shows a significant difference ($p = 0.001$) and remains low across all samples (4.08–7.52 mg/kg), indicating a major limiting nutrient for plant growth.

The soils of both sites are characterized by clayey textures, moderate cation exchange capacity, low organic matter content, and limited available phosphorus, reflecting low to moderate fertility status.

DISCUSSION

Market gardening in Sinématiali is predominantly practiced by men (over 61%), a result consistent with Ouattara's observations (2020) and attributed to the physically demanding nature of the activity as well as the low level of education among producers. The activity is mainly carried out by young people aged 25 to 34 (64.53%), attracted by the economic opportunities it offers, which aligns with the conclusions of Assouma *et al.* (2008) regarding the role of market gardening as a source of supplementary income.

Market gardeners use crop rotation due to land reduction linked to urbanization. This land pressure fosters a strong dependence on chemical inputs: 97.15% use fertilizers and pesticides. Despite pesticide residues below MRLs (EU, 2018), this uncontrolled practice carries risks, as highlighted by Coulibaly *et al.* (2018).

Irrigation relies on dams and tributaries of the Bandama River, with a marked difference between the sites: Pegnankaha depends on river water, while Lokoli uses dam water, a diversity essential for climate resilience (ANADER, 2022). Motorized irrigation predominates in Lokoli, while Pegnankaha still partially uses manual irrigation, reflecting a higher level of equipment in Lokoli, an advantage for managing the agricultural calendar (Kouamé *et al.,* 2020).

The soils of both sites are Ferralsols with a high clay content, with deeper horizons being more clayey than the surface horizons, reflecting the leaching typical of tropical soils (Zoungrana *et al.,* 2018). This accumulation improves water and nutrient retention, while the low proportion of silt confirms a granular structure characteristic of Sudanian zones (Zoungrana *et al.,* 2019).

pH levels vary little between horizons, with slightly more acidic soils at depth in Lokoli and the opposite in Pegnankaha, reflecting leaching (Koné *et al.,* 2021). The slightly acidic to neutral soils of Lokoli remain suitable for market gardening (N'Guessan, 2015).

Total nitrogen is more concentrated at the surface due to the abundant organic matter (Yao *et al.,* 2017). Carbon, organic matter, and the C/N ratio decrease with depth, and the low C/N ratio indicates rapid decomposition of organic matter, favored by heat and high microbial activity (Ouattara *et al.,* 2020).

Phosphorus is low at both sites, typical of ferruginous soils where it is immobilized by iron and aluminum oxides (Yao *et al.,* 2017; Diatta *et al.,* 2019). Its low variability between horizons results from slow mineralization of organic matter, the absence of differentiated fertilization, and continuous extraction by crops (Ouattara *et al.,* 2022), which limits root development and plant growth.

Exchangeable cations vary between sites: at Lokoli, magnesium increases with depth while calcium remains stable, whereas at Pegnankaha, calcium is more abundant at the surface, reflecting tropical leaching (Traoré *et al.,* 2016). Sodium, potassium, CEC, total base, and base saturation levels change little between horizons. High CEC increases with depth due to clay and limited weathering (Adjei-Gyapong *et al.,* 2018), and a saturation rate >70% indicates good mineral reserve despite low organic matter (Akinbola and Adediran, 2020).

CONCLUSION

This study provides a comprehensive assessment of soil fertility and market gardening systems in the Sinématiali department, revealing a clear interaction between soil characteristics and agricultural practices. The soils across both Lokoli and Pegnankaha sites are predominantly ferruginous tropical soils (Ferralsols and Gleysols), characterized by high clay content, moderate cation exchange capacity, and satisfactory base saturation, but constrained by low organic matter and limited available phosphorus. These physicochemical conditions, combined with slightly acidic to near-neutral pH, indicate soils of low to medium fertility status.

The morpho-pedological analysis further highlights structural variability between sites, with Lokoli soils showing greater depth and clay accumulation, while Pegnankaha soils are lighter, sandy, and influenced by coarse elements, affecting water retention and nutrient dynamics. Despite these limitations, current farming systems demonstrate adaptive strategies such as universal crop rotation and widespread use of organo-mineral inputs. However, the heavy reliance on chemical fertilizers and pesticides, coupled with low organic matter replenishment, raises concerns about long-term soil sustainability.

RECOMMENDATIONS

Based on the results obtained, several strategic and practical measures are proposed to enhance soil fertility and ensure the long-term sustainability of market gardening systems in the Sinématiali department.

First, increasing organic matter inputs should be prioritized. The regular application of compost, farmyard manure, and crop residues is essential to improve soil structure, enhance microbial activity, and increase nutrient availability, particularly in soils with low organic carbon content.

Second, the adoption of integrated soil fertility management (ISFM) practices is strongly recommended. This includes the combined use of organic amendments and mineral fertilizers in balanced proportions to optimize nutrient efficiency while minimizing environmental risks.

Third, given the observed low phosphorus availability, targeted phosphorus management strategies should be implemented. These may include the application of phosphate fertilizers in appropriate doses, the use of locally available rock phosphate, and practices that enhance phosphorus mobilization, such as incorporating organic matter.

Fourth, the introduction of legume-based crop rotations and cover crops should be encouraged to improve nitrogen availability, reduce soil degradation, and enhance overall soil fertility. These practices also contribute to better soil cover and erosion control.

Fifth, there is a need to promote the rational use of pesticides and chemical inputs through farmer training and awareness programs. This will help reduce potential environmental and health risks while maintaining crop productivity.

Sixth, improving water management and irrigation efficiency is essential, particularly in areas with variable water sources. The adoption of efficient irrigation techniques and better water resource management will support sustainable production under changing climatic conditions.

Finally, strengthening capacity building and extension services is crucial. Providing farmers with training on sustainable agricultural practices, soil fertility management, and input optimization will enhance their ability to make informed decisions and improve productivity.

REFERENCES

Adjei-Gyapong T, Asiamah RD. 2018. The genesis and classification of soils in the forest-savanna transition zone of Ghana. Ghana Journal of Agricultural Science **53**(1), 35–45.

Akinbola GE, Adediran JA. 2020. Cation exchange capacity and soil fertility in West African soils. West African Journal of Applied Ecology **28**(1), 60–74.

ANADER. 2022. Annual report 2022–2023 on irrigation systems and access to water in the northern zone. National Agency for Rural Development Support (ANADER), Abidjan, Côte d'Ivoire, 75 p.

Assouma Y, Allah F, Djidji AH, Fondio L, Mahyao A, Kouamé C. 2008. Survey on the production and marketing of traditional vegetables in urban and peri-urban areas of Côte d'Ivoire. CNRA/IndigenoVeg Project Report, CNRA, Bouaké, 16 p.

Coulibaly K, Koné Y, Traoré M. 2020. Role of women in family farming in northern Côte d'Ivoire. Revue Ivoirienne des Sciences Sociales **6**(2), 45–58.

Coulibaly Y, Koné M, Diarra S, Yao K. 2018. Effects of agricultural practices on soil quality and health in northern Côte d'Ivoire. European Scientific Journal **14**(15), 272–287.

Diatta S, Khouma M, Diop T. 2019. Available and dynamic phosphorus in tropical ferruginous soils of the Sahel. African Journal of Environment and Agriculture **3**(1), 45–56.

European Union. 2018. Pesticides database. https://ec.europa.eu/food/plant/pesticides

FAO. 2022. Voluntary guidelines for soil description. Food and Agriculture Organization of the United Nations. https://www.fao.org/documents/card/en/c/cc2274

Jones MJ, Wild A. 1975. Soils of the West African savanna. Commonwealth Agricultural Bureaux, UK, 246 p.

Karamoko K, Adjobi EAS, Kambiré SH, Kouamé A. 2020. Feasibility study for agro-industrial hub development project in northern Côte d'Ivoire, 55 p.

Kone B, Diomandé T, Coulibaly L. 2021. Variability of physico-chemical properties of soils in the Sudanian zone of Côte d'Ivoire. African Agronomy **33**(1), 15–28.

Koné K. 2017. Study of the availability and management of water resources in the Poro region. Félix Houphouët-Boigny University, Abidjan, 45–49.

Kouamé S, Kouassi K, Kpan K. 2020. Modernization of irrigation and agricultural productivity in Côte d'Ivoire. Ivorian Journal of Rural Studies **5**(2), 91–104.

N'Guessan D, Kouadio KE, Yao KA, Kouamé AK. 2019. Deforestation and its impacts in West Africa. African Journal of the Environment **15**(2), 67–75.

N'Guessan K. 2015. Sustainable soil management for market garden crops in Côte d'Ivoire. Journal of Agronomic Sciences **9**(2), 45–53.

Ouattara A, Yao KM, Traoré S. 2020. Soil organic matter quality according to land use in Ivorian savannah zones. Tropicultura **38**(3), 153–160.

Ouattara A, Zombré PN, Yao KM. 2022. Evaluation of crop response to phosphorus in ferruginous tropical soils of northern Côte d'Ivoire. Tropicultura **40**(1), 11–20.

Pieri C. 1989. Fertility of savannah lands: review of thirty years of agricultural research in sub-Saharan Africa. CIRAD IRAT, Paris, 444 p.

Traoré S, Coulibaly Y, Ouattara A. 2016. Dynamics of exchangeable cations in tropical soils under agricultural practices in Côte d'Ivoire. African Journal of Environmental Science and Technology **10**(4), 125–134.

Yao KA, Kouadio KE, Dosso K. 2017. Assessment of agricultural land degradation and farmers' adaptation strategies in Côte d'Ivoire. European Scientific Journal **14**(36), 241–259.

Zoungrana BJB, Sédogo PM, Thiombiano L. 2018. Characterization of tropical ferruginous soils in relation to natural vegetation in Burkina Faso. International Journal of Applied Botany and Horticulture **8**(2), 27–40.

Zoungrana BJB, Sédogo PM, Thiombiano L. 2019. Evolution of the structure and texture of tropical soils under different plant covers. International Journal of Biological and Chemical Sciences **13**(5), 2329–2342.