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Influence Of Slope Position On Soil Health Properties On Nsugbe College Experimental Field.

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Abstract

Soil characteristic properties vary across the landscape. Topographic position can affect soil physical, chemical, and biological properties in different ways. In this experimental study aggregate stability, bulk density, cation exchange capacity, total nitrogen available phosphorous, soil pH, soil organic carbon and soil organic matter were the indicators used to assess the soil health status of the topographic positions. The selected topographic positions consist of summit, shoulder, backslope and footslope. The design of the study was randomized complete block design. The result concluded that all the slope positions were low in overall soil health as all the positions had scores that range from 42% to 48.4%.Shoulder slope position obtained the highest soil health score and was observed to have the highest aggregate stability and lowest bulk density among the other slope positions. Soil organic matter was also highest in the shoulder slope position.

Keywords: Soil organic carbon, Soil organic matter, Soil health.

Introduction

Ahealthy soil is very important for sustainability of both crop production and healthy living of human and livestock. Farming systems, crop management systems, fertility practices and landscape positions can determine to a large extent the health status of the soil (Saranya 2018). Soil health assessment is a new best practice amongst soil scientists which aims at holistically assessing the soil using chemical, biological and physical properties of the soil as against the old method that uses one or two aspects of the soil for analysis (Andrew et al 2003). Slope position is a topographic parameter, that is; the relative height position along the hill slope has a significant indirect influence on the slope physical, chemical and biological properties by controlling the movement of water and eroded materials in a slope and contributing to the spatial differences on the soil properties (Begum et al.,2010,). Wang et al (2001) regarded topography as the dominant influencing soil properties variation due to its influence in runoff, drainage, and microclimate and soil erosion. Moreover many soil properties including particle size distribution, pH and organic matter content vary substantially with slope position (Mulugeta and Sheleme. 2010. Wang et al 2001). Soil properties vary across the landscape (Cambardella et al., 2004). Topographic position can affect soil physical, chemical, and biological properties in many different ways. Therefore, scientists have shown that variability of soil properties is related to the position on the landscape. One study found soil hydraulic conductivity and bulk density were affected by topographic position (Schimel et al. (1985) showed that more carbon, nitrogen and phosphorus were found in the Ahorizon of the summit position than in the backslope position. They also found an increasing amount of carbon, nitrogen and phosphorus in down slope positions.

In this study, the long-term plots (more than 30 years) of an experimental field behind the college farm buildings were used to study the effect of slope on soil health properties. To make the comparisons, sloppy field of intercropped Cassava maize and vegetables with no fertility input was used. Considering the landscape of the field, plot 1, 2, 3 and 4 were selected to study summit, shoulder, backslope and footslope.

Materials and methods

Plot Selection

The study was conducted in the Teaching and Research farm of Nwafor Orizu College of Education Nsugbe , located in Anambra East LGA of Anambra state, Nigeria. Nsugbe is located in latitude 6°13"0"N and 6°14"0"N and longitude 6°47"0"E and 6°48"20"E. The farm was established in 1982 at the inception of the college. Since the establishment, various plots were planted with various types of crops and maintained for teaching and learning purposes. The cultural practices used for the plots were documented by the farm manager for many years.

To study slope effect on soil health properties, four plots were chosen as experimental units. These are summit plot(1), shoulder plot (2), backslope Plot (3)and footslope plot(4). They include the following:

Plot 1, intercropped Cassava Maize and vegetables with no nutrient input

Plot 2, intercropped Cassava Maize and vegetables with no nutrient input

Plot 3, intercropped Cassava Maize and vegetables with no nutrient input

Plot 4, intercropped Cassava Maize and vegetables with no nutrient input

The total slope gradient of the slope used was 32.8%, which was 18.2 degree of inclination (16 degrees from satellite imagery analysis). The individual plots has the following percentages: - Summit 33% (18.4 degrees), Shoulder 44% (23.7degrees), Backslope 29% (16.2 degrees) and Footslope 25% (14.03 degrees).

Table .1: Cropping Systems, Plot Size and Management History of Selected Treatments from Nsugbe College Teaching and Research Farm.

Cropping System	Years	Size of plot	Management / Practice
Inter CMV	1995Present	9x60	Cleared and conventionally tilled with tradit hoes. Cassava intercropped with maize and vegetables. Received no nutrient input. Sam and treatments repeated every year.
Inter CMV	1995Present	18.2x60	Cleared and conventionally tilled with tradit hoes. Cassava intercropped with maize and vegetables. Received no nutrient input. Sam and treatments repeated every year.
Inter CMV	1995Present	13.7x60	Cleared and conventionally tilled with tradit hoes. Cassava intercropped with maize and vegetables. Received no nutrient input. Sam and treatments repeated every year.
Inter CMV	1995Present	20.1x60	Cleared and conventionally tilled with tradition hoes. Cassava intercropped with maize and vegetables. Received no nutrient input. Sam and treatments repeated every year.

Legend: Inter = Intercrop, CMV = Cassava, Maize, Vegetable

Field Sampling

Four replicates were collected on each of these four dates;(7th June,27th December 2021,5th June, 29th December 2022) from the four plots resulting in a total of 64 samples. The dimension of each plot is shown on (Table 1). For this study four composite auger samples were taken in from the plot to obtain a representative sample of the plot. Sampled plots were chosen within the plots with distance away from the boarder. Core sampler was used to collect samples for bulk density during the selected sampling time each year. The auger and core sampler were drilled and driven into the soil at the depth of 0-15 cm. The soil samples collected were placed in a labeled plastic bag and taken to the laboratory for preparation and subsequent analysis.

Laboratory Analysis

After due preparation, the samples were packaged and taken to the University of Nigeria soil science laboratory for analysis of the following soil properties. Aggregate stability, Bulk density, cation exchange capacity, total Nitrogen, Available Phosphorous, Soil pH, Soil organic carbon and Soil organic matter. Aggregate stability was determined by the wet-sieving method by (Kemper and Rosenau 1986) Total Nitrogen was analyzed using the macro Kjedali method (Bremner and Mulvaney(1982). Available phosphorous was analyzed using Bray11 method by (Olesen and Sommers (1982). Soil organic carbon (SOC) was analyzed by Walkley/Black procedure (Nelson and Sommers (1982). Soil pH in water was measured by glass electrode pH meter (Mclean 1982). The cation exchange capacity was analyzed by the method described by Thomas (1982). Bulk density was determined by the core method (Grossman and Reinsch 2002)

Table 2. Summary of soil health laboratory analysis including physical, chemical and biological properties and their analytical methods

Property	Indicators	Abrev.	Method	Reference
Physical	Bulk density	BD	Core Wet-sieving method	Grossman and
properties	Aggregate stability	AS		Reinsch (2002)
Chemical	Cation exchange capacity	CEC		Thomas(1982).
Properties	Available Phospho rous			
	Total Nitrogen	P	Bray 2	Olesen and
				Summer (1982)
	Potential of Hydrogen	N	Macro Kjeldahi	Bremner and
				Mulvaney (1982)
		pH	Glass electrode pH meter	McLean (1982)
Biological	Soil organic	SOC	Walkley/Black	Nelson and
properties	Carbon			Summer (1982)
	Soil organic matter	SOM	Walkley/Black	Nelson and
				Summer (1982)

Statistical Analysis

After all results were collected from the laboratory the data generated were painstakingly arranged according to the different classes (Physical, chemical and biological) properties and arranged in a Randomized Complete Block Design (RCBD) and then ANOVA was used to statistically test for differences among the treatments, using Genstat statistical package. The means were separated by least significant difference to see if the differences seen among the treatments were statistically different.

Soil Health Assessment

To obtain the relative soil health assessment the plots in Nsugbe College farm, the Cornell Comprehensive Assessment of Soil Health (CASH) (Moebius-Clune et al 2016) was utilized. Before calculating the soil health index for all physical, chemical and biological properties. The first step was to create the cumulative normal distribution (CND) functions and curve of each indicator in order to obtain the soil health score index by using the mean data from laboratory analysis result. The soil health score ranged from 0 to 100 (with 100 the best), which was divided into five even intervals; scores 0−20, 20−40, 40−60, 60−80, and80−100. 0-20 very low, 20-40 low 40-60 medium,60-80 high and 80- 100 very high.

Three scoring types were used in the procedure of the soil health assessment.

1) More is better

In this case, if the mean value of each measured indicator is large, the score will be large as well. The indicators in this category were comprised of water-stable aggregates, total nitrogen, soil organic carbon, cation exchange capacity and soil organic matter.

2) Less is better

Only bulk density fell into this scoring type. Additionally, less is better means that the smaller the measured value, the larger the score observed.

3) Optimum Curve

Optimum curve will be applied with both pH and available phosphorus. Subsequently, an overall soil health score is calculated by summing soil health scores from the cumulative normal distribution function of each indicator and dividingthe sum by number of the indicators. In addition, the overall score also used the soil health score range from 0 to 100 as well as the ratings terms of soil health scores.

Results and Discussion

Physical properties

Table 3 reports the means of soil physical indicators including aggregate stability and bulk density in different slope positions; Summit(SU), Shoulder(SH), Backslope(BS) and Footslope(FS). Results shows that slope position only had a significant difference in aggregate stability between shoulder which scored the highest mean value of 33.2% and summit with 24.8%. Backslope had the same aggregate stability of 26.7% which was not significantly different from the other treatments.

The bulk density values were quite close and not significantly different from each other, but it was noted that that the shoulder plot which had the highest aggregate stability in the study had the lowest bulk density of 1.302g/cm-3.

Table 3: Effects of Slope Positions on Physical Soil Health Indicators

Plot No	Slope Position	AS (%)	BD (gcm-3)
1	Summit	24.8	1.312
2	Shoulder	33.2	1.302
3	Backslope	26.7	1.329
4	Footslope	26.7	1.322
LSD (p>0.05)		**8.30**	**0.1029**

AS=Aggregate stability, BD=Bulk density

Chemical Properties

Cation exchange capacity, total nitrogen, available phosphorous and soil pH were presented in table 4. Cation exchange capacity (CEC) ranges from 9.67 to 11.07mg/100g, but they were not significantly different from each other. The footslope had the highest CEC than the rest of the slope position, which could be caused by the influences of leaching and water movement of movement of clay and organic matter from a higher position to a lower position (Donald et at, 1993). It was observed that as the land became sloppy the CEC increases because the summit was the lowest in CEC.

For total nitrogen, footslope had the highest mean value of 0.1379% but it was significantly different from the other values obtained by other slope positions. Backslope had the lowest value of 0.1211%. Summit and shoulder had 0.125% and 0.1248% respectively but the %N values were not significantly different from each other.

The available P values were low and range from 6.14cmol/kg 9.67cmol/kg. The summit plot had the highest P value of 9.67cmol/kg which was significantly different from the other treatments. Backslope with available P of 6.14 was also significantly different from footslope with 7.85 cmol/kg.

Soil pH of the slope position range from 6.219 to 6.637. Footslope had the highest pH value of 6.637 classified as neutral, while the other slop positions; summit, shoulder and backslope obtained values of 6.219, 6.512, 6.387 which are all classified as slightly acidic. The pH value of 6.637 obtained by footslope was statistically different from values for summit and backslope

Table 4: Effects Slope Positions on Chemical Soil Health Indicators

Plot No	Slope Position	CEC (meq/100g)	TN (%)	AV.P (cmol/kg-)	pH
1	Summit	9.67	0.125	9.67	6.219
2	Shoulder	9.78	0.124	6.26	6.512
3	Backslope	10.59	0.121	6.14	6.387
4	Footslope	11.09	0.138	7.85	6.637
LSD(p>0.05)		**2.167**	**0.0175**	**1.604**	**0.1609**

+CEC-Cation exchange capacity, TN - Total nitrogen, AV.P - Available Phosphorous, pH- Soil pH

Biological Properties

Soil biological properties including soil organic carbon(SOC) and soil organic matter (SOM) are shown in table 5. The shoulder had the highest SOC value of 1.277% which was significantly different from summit and footslope values of 0.890 and 1.004% respectively. Backslope with the value of 1.182% was significantly different from the value obtained by summit position. Soil organic matter maintained a similar trend with SOC. Shoulder slope position had the highest SOM value of 2.208% which was significantly different with that if summit plot with 1.526%SOM but did not significantly differ from backslope and footslope positions which had 9.72% and 1.735% SOM respectively.

Table 5: Effects Slope Positions on Biological Soil Health Indicators

Plot No	Slope Position	SOC (%)	SOM (%)
1	Summit	0.890	1.526
2	Shoulder	1.277	2.208
3	Backslope	1.182	1.972
4	Footslope	1.004	1.935
LSD(p>0.05)		0.251	0.488

+ SOC-Soil organic carbon, SOM- Soil organic matter

Soil Health Assessment

Table 5 shows the compilation of the overall soil health of slope positions. The four plots used for the experiment three (plot 1, 2, 3 and 4)) were assessed for their soil health status by using mean values of the indicators (Aggregate stability, Bulk density, cation exchange capacity, Total nitrogen, Available phosphorous, Soil pH and Soil organic matter) as scoring functions that enables the values of a specific indicator to be converted to a rating in the assessment. A score of 100 was the best (highest) while a score of 0 was the lowest (poorest). The three scoring curves of the CASH soil health assessment were followed thus: (a) More is better for (Aggregate stability, cation exchange capacity, Total nitrogen, Soil pH and Soil organic matter). (b) Less is better for bulk density. (c) Optimum curve for Soil pH and Available phosphorous.

The overall soil quality score was computed by summing the average of the individual indicator scores and was expressed on a percentage scale. The overall classification of the soil health based on the percentage score were given as:

1. >85% Very high
2. 70% - 85% High
3. 55% - 70% Medium
4. 40% - 55% Low
5. >40% Very low

(Cornwell comprehensive soil health score classification 2017)

Table 6: Comprehensive Assessment of soil health for slope positions

Plot No	Tret.	Agg.stab.	B.D	CEC	%N	Ave.P	pH	SOM	Total	Mean
1	Summit	26	65	45	24	0	90	44	294	42
2	Shoulder	34	68	48	23	0	98	68	339	48.4
3	Backslope	25	64	70	21	0	95	59	334	47
4	Footslope	25	68	84	32	0	60	50	317	45.3

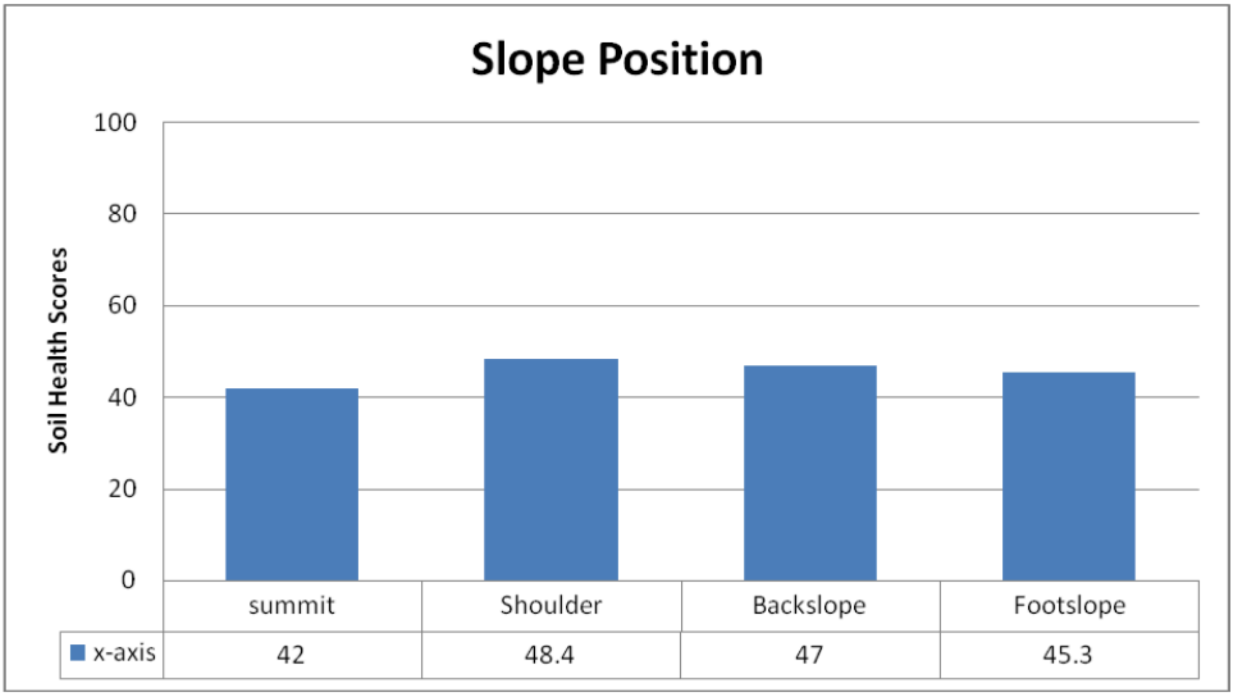
Soil Health Assessment Scores

The overall soil health scores for slope position were presented in fig 1. Slope position affected the soil health of the soil studied as all obtained soil health score classified as low. Shoulder slope position nevertheless had the highest soil score of 48.4%, followed by backslope position with 47%. While footslope and summit had 45.3% and 42% soil health score respectively.

These very low scores obtained are not unexpected as the slope received no nutrient input. but are cropped every year with intercrop cassava maize vegetables. The plot rely solely on inherent soil fertility are gradually becoming marginal soils.

The lack of statistical differences observed among the treatments in physical properties and some chemical soil properties are similar to the work of Ogban (2021) who reported that slope positions were generally similar on the effect on the soil physical quality attributes. Wezel et al (2002) reported 10 – 22% lower organic N and P content at lower slopes and attributed it to the enhanced mineralization, frequent cropping in lower slope rather than erosion. This in consonance with result obtained from this study, as shoulder slope obtained slightly higher soil health score than footslope (a lower slope).

Fig 1: Overall Soil Health Scores for Slope Position



Summary and Conclusion

This study examined the effect of slope position on soil health properties of long-term experimental field of Nsugbe college farm. The selected topographic positions consist of summit, shoulder, backslope and footslope. The result concluded that all the slope positions were low in overall soil health as all the positions had scores that range from 42% to 48.4%.

Shoulder slope position obtained the highest soil health score and was observed to have the highest aggregate stability and lowest bulk density among the other slope positions. Soil organic matter was also highest in the shoulder slope position.

This study provides the findings of effects of topographic landscape which can contribute to knowledge and better understanding of long- term agriculture landscape effects, and result may be used as database for future soil health assessment work in this area that researchers can use in future.

References

Andrews, S.S., C.B. Flora, J.P. Mitchell, and D.L. Karlen.(2003). Growers' perceptions and acceptance of soil quality indices. Geoderma. 114(3–4):187–213.

Begum, F., Bajracharya, R.M., Sharma, S., Sitaula, B.K., 2010. Influence of slope aspect on soil physico-chemical and biological properties in the mid hills of central Nepal. *Int. J. Sustain. Dev. World, 17, 438–443*

Cambardella, C.A., T.B. Moorman, S.S. Andrews, and D.L. Karlen. (2004). Watershedscale assessment of soil quality in the loess hills of southwest Iowa. Soil Tillage Res. 78(2):237–247. Celik, I., I. Ortas, and S. Kilic. (2004). Effects of compost, mycorrhiza, manure and fertilizer on some physical properties of a Chromoxerert soil. *Soil Tillage Res. 78(1):59–67.Chahal, I., and Van Eerd, L. L. (2019). Quantifying soil quality in a horticultural-cover cropping system. Geoderma 352, 38-48.*

Grossman, R.B. and Reinsch, T.G.(2002). Bulk density and linear extensibility. 201–228. JH Dane and GC Topp (ed.) Methods of soil analysis. Part 4. Physical methods. SSSA Book Ser. 5. SSSA, Madison, WI. Bulk density and linear extensibility. 201–228. In JH Dane and GC Topp (ed.) Methods of soil analysis. Part 4. Physical methods. SSSA Book Ser. 5. SSSA, Madison, WI.

Kemper, W.D., and R.C. Rosenau. 1986. Aggregate stability and size distribution. In: A.Klute, editor, Methods of soil analysis. Part 1. 2nd ed. ASA and SSSA, Madison,WI.. 425–442.

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M. Kurtz, D.W. Wolfe, and G.S. Abawi.(2016). Comprehensive Assessment of Soil Health – The Cornell Framework. 3.2 ed. Cornell University, Geneva, NY. National Research Council. 1993. Soil and water quality: an agenda for agriculture. National Academy Press, Washington, DC.

Mulugeta, D., Sheleme, B., 2010. Characterization and Classification of soil along toposequence of Kyndo Koye Wetershed in Southern Ethiopia. *East African Journal of Sciences, 4, 2, 65–77.*

Nelson, D.W. and Sommers, (1982). *Total Carbon, Organic Carbon and Organic matter. In: methods of soil analysis.* Part 2: chemical and microbiological properties, Wiscosin, A.L. (ed). 2nd edn., Asa and SSSA; Madison, W.I., 539 -579

Ogban, P.I.,(2021). Influence of slope aspect and position on soil physical quality and management implication of Uyo teaching and research farm in Akwa-ibom state Nigeria. *Agro-science journal of tropical agriculture, food, environment and extension.20 (3) 37-43.*

Olsen, R.S. and Sommer, L.E. (1982). *Phosporus. In: methods of soil analysis, part 2: chemical and microbiological properties*, pages A.L, R.H. Miller and D.R. Keeney (Eds) 2nd Edn., AsA and SSSA; Madison, W.I., USA, 403 -430.

Saranya, N. (2018) Soil Health Assessment of the Sanboarn Field, long- term experimental study. *A PhD dissertation presented to the faculty of the graduate school at the University of Missouri Columbia.*

Schimel, D., M.A. Stillwell, and R.G. Woodmansee. (1985). Biogeochemistry of C, N, and P in a soil catena of the shortgrass steppe. Ecology. 66(1):276–282.

Thomas, G.W. (1982). Methods of soil analysis. Chemical methods of soil analysis. *Amer Soil Sci. Soc. 5(2): 52 -85.*

Wang, J., Fu, B., Qiu, Y., Chen, L., 2001. Soil nutrients in relation to land use and landscape position in semi-arid small catchment of the loess plateau in China. J. *Arid Environ., 48, 537–550.*

Wezel,a., Stinuller, N., Fnederichsen, J.R., (2002). Slope position effects on soil fertility and crop productivity and implications for soil conservation in Upland north west Vietnam. Agriculture ecosystem and environment 91 113-126.