

Sustainability Status of a Solarized Alfisol in Sheda Abuja Nigeria

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Abstract

Original Research Article

Soil fertility potentials are often affected by land use types and intensity. This makes assessing the current sustainability status of our soil imperative. A study was carried out to assess the influence of soil solarization on the sustainability status of soil in Sheda, Abuja Nigeria. To achieve this, A farmland located on an alfisol was selected marked and solarized for a period of eight (8) weeks using transparent polyethelene sheets (TPS). Soil samples were collected using cup auger at depth of 0 – 30 cm before the solarization and after the solarization period. The samples collected were subjected to laboratory analysis following standard laboratory procedures. The sustainability of the health of the soil was determined. Selected soil physical, hydrological and chemical attributes were computed. The critical level for the soil properties was determined by assigning relative weighting factors to the indicators. The result obtained showed that the cumulative weighted factor for the unsolarized soil was 25, thus placing it as “sustainable with high inputs” class. For the solarized fields, electrical conductivity, sodium adsorption ratio and exchangeable aluminium posed no limitation to the soil, while soil pH and bulk density posed only a slight limitation. Soil organic matter and texture had moderate limitation and available water holding capacity posed severe limitation. Only field capacity of the soil posed an extreme limitation on the soils. The overall cumulative index was 21, placing the soils in the sustainable class. It was observed that there is a direct relationship between soil health and sustainable land management. It was concluded that soil solarization improved the fertility potential of the soils by boosting soil organic carbon reserve and minimizing nutrient losses, thus enhancing sustainability status of the cultivated soils.

Keywords: Sustainability, Status, Alfisol, Solarization and Sheda.

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Introduction

The performance of field crops in terms of nutrient uptake by plants is determined by the condition of the rhizosphere (Wolie *et al.*, 2023) among other factors such as genetics (Dong *et al.*, 2023), and agronomic practices (Huang *et al.*, 2024). Covering the soil with things like plastics, agricultural wastes, and manures allows it to absorb solar energy; this process is called soil solarization. Research by Bahadur *et al.* (2015)

and Gill *et al.* (2017) shows that this enhances soil temperature, decreases the weed seed bank, and speeds up the decomposition of organic materials. Soil solarization has not been documented in a comprehensive or exhaustive way in the literature regarding its effects on soil fertility or agricultural economic viability (Rokunuzzaman *et al.*, 2016; Jagtap *et al.*, 2022; Sompouviset *et al.*, 2023), particularly in Abuja. The practice of soil solarization involves covering the soil surface using



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plastic, soil or agricultural wastes materials in an attempt to raise soil temperature over a period of time (Bonanomi *et al.*, 2023). This practice has positive effects on soil fertility activation, weed control and soil borne microbes management as reported by many researchers (Gullino *et al.*, 2022, Scopa *et al.*, 2023 and Huang *et al.*, 2024).

According to Al-Solaimani *et al.* (2015), agricultural areas could benefit substantially from soil solarization in terms of increasing the levels of N, P, K, and Zn. The temporary generation of biotoxins is enhanced by solarization such that more plant nutrients are available and soil's physical, chemical, and biological qualities can be positively altered (Al-Shammary *et al.*, 2020). Soil porosity is improved, roots are able to penetrate more easily, organic matter is broken down and mineralized more quickly, and nutrient availability is increased by almost 25%; all of this leads to increased crop growth and productivity (Safdar *et al.*, 2021). Subsoil organic matter, cation exchange capacity, carbon content, and N, P, and K contents are enhanced by solarization of soil for around 12 weeks in tropical environments (Birthisel *et al.*, 2019; Safdar *et al.*, 2021; Zhang *et al.*, 2023). Soil N-NO₃ and N-NH₄ concentrations are also increased. Some vital plant nutrients become attached to soil particles and inaccessible to crops as soil temperatures drop, a phenomenon known as the chelation effect (Safdar *et al.*, 2021). Hydraulic conductivity and active nutrient transfer could both suffer as a consequence of this. Chemical processes in soil, such as the capacity to exchange cations, are enhanced as soil temperatures rise (Al-Shammary *et al.*, 2020). Hence, the chelated nutrient can be released and made available to plants when soil temperature is increased through solarization (Zhang *et al.*, 2023). Soil chemistry and nutrient availability could both be affected by solarization. In addition to improving soil texture, soil solarization also adds nutrients that plants need for growth and development, such as nitrogen, phosphorus, and potassium (Birthisel *et al.*, 2019). It enhances the cation exchange capacity and helps conserve 5.48 percent of the soil moisture that is available in dryland areas (Abd-Elgawad *et al.*, 2019; Mitidieri *et al.*, 2021). According to Golzardi *et al.* (2015), this process enhances soil structure,

makes more plant nutrients available, improves nutrient absorption, and decreases soil acidity. Solarization raises the soil's soluble electrical conductivity index (EC) because organic matter is quickly converted and soluble chemicals are released into the soil at higher temperatures (Golzardi *et al.*, 2015; Sofi *et al.*, 2014). A vast number of soil pathogens are killed and converted into organic fertilizer through soil solarization. This improves plant growth while decreasing the amount of fertilizer needed (Hamooh, 2014). The mineralization of organic matter and the subsequent increase of soil organic carbon by approximately 2 kg m² can also reduce the negative impacts of soil biochemical activities. Because of this, chemical fertilizers may not be needed as often, which could increase soil health and fertility (Di Mola *et al.*, 2021). Soil solarization is a promising method for increasing crop yields by increasing the availability of key nutrients and soil fertility.

Soil sustainability assessment is aimed at evaluating the potential of a soil under a current land use or practice without depleting its potential for future use (Barnabas *et al.*, 2025). Over the years, the need for optimum production of food to meet the demand for human consumption, animal feed production and other industrial uses of food materials as raw materials has become imperative. This has put significant pressure on the soils of sub Saharan Africa, Nigeria inclusive (FAO ITPS, 2015). Consequently, this has resulted in the adoption of cropping systems and technologies that have exploited the soils and degraded its quality, resulting in declining yields and threat of impending food shortages and insecurity. At the base of all other forms of insecurity, lies food insecurity. This explains why the Sustainable Development Goals numbers 1 and 2 emphasized the concept of food security for all, covering availability and accessibility for nutritious food and poverty eradication. But for these goals to be attainable, the soil resource has to be conserved and properly managed.

According to the revised World Soil Charter (FAO, 2015) soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced

without significantly impairing the soil functions that enable those services or biodiversity. The Status of the World's Soil Resources Report identified ten threats that hamper the achievement of sustainable soil management (SSM). These threats are: soil erosion by water and wind, soil organic carbon loss, soil nutrient imbalance, soil salinization, soil contamination, acidification, loss of soil biodiversity, soil sealing, soil compaction and waterlogging (Soil Survey Staff, 2022). These different threats vary in terms of intensity and trend depending on geographical contexts, though they all need to be addressed in order to achieve sustainable soil management (FAO and ITPS, 2015). It is believed that soil solarization could be a viable option in enhancing the sustainability status of agricultural soils in the tropical sub-saharan Africa (FAO, 2015). In a bid to assess the sustainability status of agricultural soils for better productivity, this study aims to evaluate the effect of soil solarization on some soil properties and the sustainability status of soils in a farm land in Sheda Abuja Nigeria.

Materials and methods

The study was conducted at the research field of the National Agricultural Seed Council (NASC) in Sheda, Abuja, Nigeria. (8°50'N 7°30'E) within the Southern Guinea Savanna Zone of Nigeria, which is bounded by longitudes 6° 20'E and 7° 33'E and

latitudes 8° 30'N and 9° 20'N. Hot humid tropical (AW) is the Coppens climatic classification that best describes the Federal Capital Territory (FCT) (FCDA, 2019). A farmland located on an alfisol was selected marked and solarized for a period of eight (8) weeks using transparent polyethelene sheets (TPS). Soil samples were collected using cup auger at depth of 0 – 30 cm before the solarization and after the solarization period. The samples collected were subjected to laboratory analysis following standard laboratory procedures of IITA 2015.

The sustainability of the health of the soil was determined after Lal (1994) guide. Selected soil physical, hydrological and chemical attributes were computed. The critical level for the properties were determined according to Lal (1994) by assigning relative weighting factors to the indicators. The limitation ranges with relative weighting factors of 1 to 5 as presented in Table 1.

Tables 2 and 3 show the indicators, the critical level, limitation and relative weighting factor that was used. The critical level data was combined into a cumulative rating index

The sustainability rating adopted with the 'less is better' system (Lal, 1994) was followed. Table 4 shows the sustainability rating of land use in relation to the cumulative rating index which was followed.

Table 1: Limitation rates for sustainability assessment after Lal 1994

factor	Class	Limitation	Remarks
1	0	No limitation	the negative effect of the indicator on sustainability of land use is nil
2	1	Slight limitation	the negative effect of the indicator on the sustainability of land use is slight
3	2	Moderate limitation	the negative effect of the indicator on sustainability of land use is moderate
4	3	Severe limitation	the negative effect of the indicator on sustainability of land use is severe
5	4	Extreme limitation	the negative effect of the indicator on sustainability of land use is extreme

Source: Lal (1994)

Table 2: Critical levels and relative weighting factors for soil properties used in the cumulative rating

Limitation	RWF	BD kgm ⁻³	AWHC %	SOC %	CEC C mol/kg	SHC (cm h ⁻¹)	Texture
None	1	<1.3	> 30	5 - 10	< 5	2	L
Slight	2	1.3-1.4	20 – 30	3 – 5	5 – 10	0.2-2	SiL, S, SiCL
Moderate	3	1.4-1.5	8 – 20	1 – 3	10 – 15	0.02-0.2	Cl, SL
Severe	4	1.5-1.6	2 – 8	0.5 – 1	15 – 20	0.002-0.02	SiC , LS
Extreme	5	>1.6	< 2	,< 0.5	> 20	>0.002	C, S

Note; RWF = relative weighting factor, texture; SiL = silt loam Si = silt, SiCL = silt clay loam; Cl = clay loam, SL = sandy loam, SiC= silt clay, LS = loamy sand, C = clay, S = sand, BD = bulk density, AWHC = available water holding capacity, SOC = soil organic carbon

Source Lal (1994)

Table 3.: Chemical indicators, limitation and relative weighting factors.

Limitation	Relative weighting factors	pH H ₂ O 1:1	Al(% CEC)	EC (d S m ⁻¹)	Organic carbon (surface horizon %)
None	1	6-7	<20	<3	5-10
Slight	2	5.8-6	20-35	3-5	3-5
Moderate	3	5.4-5.8	35-40	5-7	1-3
Severe	4	5.0-5.4	40-50	7-10	0.5-1
Extreme	5	<5	>50	>10	<0.5

Source: Lal (1994)

Table 4: Sustainability rating

Sustainability Rating	Cumulative rating Index
Highly sustainable	<20

Sustainable	20-25
Sustainable with high input	25-30
Sustainable with another land use	30-40
Unsustainable	>40

Sources: Lal (1994)

Results and discussion

Table 5 gives the sustainability of the soil under the two agricultural practices of soil solarization and usual farmers Practice of not solarizing the soils of their farms. For the unsolarized soils, electrical conductivity, sodium adsorption ratio and aluminium percentage contained in CEC posed no limitations to the soils. Soil pH and texture of the soil had moderate limitation. Whereas available water holding capacity, bulk density and soil organic carbon capacity had severe and extreme limitations on the soil. The cumulative weighted

factor was 25. This indicated that the unsolarized cultivated field fall under the “sustainable with high inputs” class. For the solarized fields, electrical conductivity, sodium adsorption ratio and exchangeable aluminium posed no limitation to the soil, while soil pH and bulk density posed only a slight limitation. Soil organic matter and texture had moderate limitation and available water holding capacity posed severe limitation. Only field capacity of the soil posed an extreme limitation on the soils. The overall cumulative index was 21, placing the soils in the sustainable class.

Table 4.8. Sustainability status of unsolarized and solarized fields planted to maize, cowpea and groundnut mixture in Sheda, Abuja

Field treatment	Soil indicators (0 - 30 cm)	Soil indicator values	Weighted factor	Limitation
Unsolarized agricultural field	Electrical conductivity (dS/m)	0.16	1	None
	pH (H ₂ O)	5.47	3	Moderate
	SOC (mg/ha)	7.07	5	Extreme
	Sodium Adsorption Ratio	2.02	1	None
	Texture	sl	3	Moderate
	AWHCy (cm ³ cm ³)	0.08	4	Severe
	Bulk density (kg/m ³)	1.57	4	Severe
	Aluminium (% of CEC)	2.93	1	None
	CEC (C mol/kg)	8.27	2	slightly
	SHC (cm/hr)	4.46	1	None
Cumulative index			25	Sustainable with high inputs

Solarized agricultural field	Electrical conductivity (dS/m)	0.25	1	None
	pH (H ₂ O)	6.36	2	Slight
	SOC (Mg/ha)	15	3	Moderate
	Sodium Adsorption Ratio	2.5	1	None
	Texture	sl	3	Moderate
	AWHC (cm ³ cm ⁻³)	0.08	4	Severe
	Bulk density (kg/m ³)	1.33	2	Slight
	Aluminium (% of CEC)	1.78	1	None
	CEC C mol/kg	12.72	2	Slightly
SHC (cm/hr)	4.01	1	None	
Cumulative index			21	Sustainable

AWHC = available water holding capacity, SHC = saturated hydraulic conductivity

Soil solarization could be considered as a sustainable land management practice in the study. The solarized soil was classified as “sustainable” (based on the rating index). Some critical soil properties contribute to structural build-up within the soil may not be functioning at optimal capacity. The soil under the traditional or usual farmers’ practices with little or not adequate external input and sound soil management practice will continue to deteriorate or degrade to unsustainable status. The soil solarized is rated as “sustainable” has a soil sustainability rating of $> 20 \leq 25$. Being just sustainable implies that some properties still constitute limitations to the productivity of the soil. The unsolarized soil is in the class of “sustainable with high inputs” with a sustainability rating of $> 26 \leq 30$. This indicates that if the sustainable management system or technology is not introduced in no distant future, the soil is likely to enter a state of “no return to a non-productive life”.

Bulk density is one property that adds up to reducing the sustainability of the soil. This implies restriction to root growth, restriction to the transmission of water within the soil (Larson and Pierce, 1994; Aki *et al.*, 2016, and Oku *et al.*, 2020). Water stable aggregate (WSA) and the size distribution of aggregates responsible for aggregation constituted limitations that ranged from severe to extreme. The limitations in WSA and MWD combines with unfavourable bulk density

will render the soil prone to degradation and reduction in the sustainability of the soil. The soil organic carbon (SOC) levels in all fields is a major concern and one major factor combining with other soil properties to imposed severe limitations and reduced the ability of the soil to continue to support crop production and other agronomic activities. Soil organic carbon is a property that serves as the “blood” of productive soil (Oku, *et al.*, 2020; Idowu *et al.*, 2009). The availability of nutrients in the soil to enhance crop productivity and enhance the environmental quality of the soil is linked to the level of SOC (Harris *et al.*, 1996). The levels of SOC in the fields are low from the study of the fertility of the fields. Hence crop productivity in the field is also expected to be low.

Sustainability of soil with the prediction “with high input” needs specialized expert-recommended soil management practices and inputs for the fields. The inputs must be incorporated with high-quality green materials and inorganic materials. The high bulk density needs to be improved upon by introducing tillage. The SOC must be improved with organic amendments. With the improvement in SOC, the water-stable aggregate will increase and reduce or eliminate the limitations imposed by MWD on the soil. From this study and some previous studies, there is a direct relationship between soil health and sustainable land management (Gregorich *et al.*, 1995). This Agrees with Karlen *et al.*, (1998) and

Doran and Zeiss (2000). The critical component of sustainable agriculture and a farming system can only be sustainable when soil quality is maintained or improved (Larson and Pierce 1991). When soil become degraded, more resources in terms of time, money, energy, and chemicals will be needed to produce less-abundant crops of lower quality.

Conclusion and recommendations

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