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EFFECTS OF AGROCHEMICALS AND THEIR IMPACT ON SOIL QUALITY IN PART OF SUDAN SAVANNAH ZONE OF NORTHWESTERN NIGERIA

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ABSTRACT

The use of agrochemicals causes a number of environmental issues, including harm to human health, contamination of groundwater and other aquatic habitats, and soil degradation that lowers soil quality and turns many formerly productive agricultural lands into unproductive ones. This study assessed the effect of agrochemicals on soil quality in the area. A survey was conducted among 331 farmers from seven villages in Bunkure Local Government Area Kano State. Soil samples were also collected and analyzed to determine various soil parameters (OC, P, N, CEC, Ca^{2+}, Na^{2+}, Mg^{2+} and K^{2+}). Questionnaire was used to obtain information on the farmers' knowledge and perception regarding agrochemical application and impact to soil quality. The results revealed that a majority (78%) of the farmers had been using agrochemicals for more than four years, with most (76%) applying those more than twice per year. Furthermore, a significant proportion (61%) indicated awareness of the impact of agrochemicals on soil quality. In addition, findings indicated that 94% of the respondents believed that the use of agrochemicals affected soil quality. Among them, 83% reported a positive effect on soil quality, while 10% observed a negative effect. Only 4% perceived no effect of agrochemicals on soil quality. The amount of Organic Carbon, Phosphate, Nitrogen, and Cation Exchange Capacity (CEC) were found to be within the permissible limits set by the World Health Organization (WHO) with exception of phosphate. Additionally, the cation distribution in the soil profile followed the order: $Ca^{2+} > Na^{2+} > Mg^{2+} > K^{2+}$. The average concentrations of these cations were also within the ≤100 ppm WHO recommended range. These suggest that the current agrochemical practices had not significantly deteriorated the soil quality in the area.

Keywords: Soil quality, Agrochemicals application, Farmers knowledge, Kano state

INTRODUCTION

Soil, often referred to as the "skin of the Earth," is an extremely dynamic and intricate natural resource that is essential to the continuation of life on Earth. It is a critical component of ecosystems, providing the physical, chemical, and biological foundation for plant growth and a habitat for a myriad of organisms. Soil also serves as a vital reservoir of water and nutrients, influencing the quality of air and water, climate regulation, and even human civilization's development (Kumar *et al.,* 2012).

Besides the quality of the air and water, soil is one of the three elements that make up environmental quality (Abdullahi *et al*., 2021; Andrews *et al.,* 2022). According to Carter et al. (2017), the primary criterion for defining the quality of water and air is the level of pollution that directly affects the health and consumption of humans and animals as well as natural ecosystems. On the other hand, soil quality is typically characterized much more broadly as something that goes beyond the level of soil pollution. According to Doran and Parkin (2016) and (2018), soil quality refers to "the capacity of a soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health."

Agricultural modernization has increased output, frequently at the expense of environmental quality. According to Zhang *et al.* (2019), the overuse and prolonged use of synthetic fertilizers that contain nitrogen, phosphorus, and potassium in combination with organic fertilizer has a significant negative impact on soil, its native microflora, soil texture and productivity, soil-enzymatic activity, ecosystems, and human health.

Agrochemicals are a major issue of current agricultural systems around the globe. Consequently, utilization of agrochemicals such as pesticides and fertilizers remained a major practice in most tropical countries. Major stakeholders have prevented the adoption of some pesticides in the environment in most developing nations as a result of their persistence, but yet they are still in use in developing nations, including Nigeria, due to their low cost, ease of synthesis, or being obtained from developed nations (Abdullahi *et al*., 2023).

Agrochemicals serve several critical functions in contemporary agriculture. Fertilizers provide essential nutrients to crops, compensating for nutrient deficiencies in soils and promoting healthy plant growth. Pesticides and herbicides help safeguard crops against the destructive impact of pests, diseases, and invasive weeds, which can otherwise devastate entire harvests. Growth regulators and other specialized agrochemicals offer targeted solutions to improve crop quality, control growth patterns, and optimize harvests. In essence, agrochemicals have become integral to the modern agricultural toolkit, enabling farmers to manage and mitigate the inherent challenges and uncertainties of food production (Singh *et al.,* 2020).

Chemical formulations known as agrochemicals are typically employed to feed nutrients to the soil and control infections and pests. The application of agrochemicals, such as fertilizers, insecticides, and growth regulators, has improved crop growth and yield, stabilizing agricultural output (Jacoby *et al.,* 2017). According to Ficci (2019), the world's current population of 7.2 billion is predicted to grow to 9.3 billion by 2050, increasing the need for food to survive on the planet's finite supply of arable land. Despite the problems of shrinking farm areas and environmental issues, a sustainable approach is necessary to supply the demand for food to a larger extent. According to estimates, disease, pests, and weeds currently account for around 25% of global crop production losses. Conventional or readily accessible agrochemicals are crucial in the fight against pests and diseases (Boxall *et al*., 2018).

These agrochemicals have been widely employed in recent decades, and their widespread usage may have contributed to soil degradation, one of the most serious effects of contemporary agriculture. Agricultural operations were relatively environmentally friendly prior to the Industrial Revolution. In order to maintain soil nutrients, biological pest management, and a buffer zone at the farm's margins, the crop production was mostly dependent on internal resources, such as crop rotation and organic matter recycling. These farming practices preserve the organic equilibrium between the environment and agriculture. As a result, signs of environmental deterioration were few. Agriculture's modernity has weakened the environment-farming balance, which has often been upset due to a lack of understanding of ecological principles (Jayaraj *et al*., 2016).

Similar to air or water, soil quality has a significant impact on the productivity and well-being of an ecosystem and the surrounding ecosystems. However, soil quality has been challenging to define and measure, in contrast to air or water, for which we have quality standards. Depending on personal goals regarding soil function, different people have different ideas about what makes a good soil (Manisalidis *et al.*, 2020). Unbalanced agrochemical use, however, degrades the environment and presents several problems for soil health and agricultural ecosystems. Microorganisms actively participate in nutrient cycling and are important for basic soil activities that improve soil health and crop productivity (Jacoby *et al.*, 2017). Global food security and soil health sustainability have been jeopardized by soil deterioration brought on by excessive pesticide usage (Jie *et al*., 2022).

The use of agrochemicals in modern agriculture has become increasingly prevalent in Nigeria, with the aim of enhancing crop productivity and food security. While these agrochemicals offer short-term benefits, their long-term impact on soil quality in this region remains inadequately understood. Therefore, this research aimed at assessing the effects of agrochemical usage on soil quality within the specific context of Bunkure LGA, Kano State, Nigeria.

MATERIALS AND METHODS

Study area

The location of Bunkure LGA is between Latitude 110 34' 02"N and Latitude 110 46' 05"N of the Equator, and between Longitude 80 26' 36"E and Longitude 80 46' 43"E of the Prime Meridian (Figure 1). It borders Kura and Dawakin Kudu LGAs to the north, Wudil and Garko LGA to the east, and Kibiya to the southwest of the study area (Maryam *et al.*, 2014). The region has a mostly Sudanese kind of tropical wet-dry season climate, with an average annual rainfall of 792 mm. This climate is characterized by 4-5 months of rainfall (from June to October) and 6-7 months of dry season. At around 25.7±20C, the average annual temperature is warm to hot.

The region's vegetation is primarily savanna, which is climatically classified as Sudan savanna and northern Guinea savanna. According to Tukur (2013), the vegetation is characterized by a small number of trees and shrubs. Crop production (farming system), animal husbandry (livestock raising), forestry, and fisheries are the main agricultural activities in the research area (Lynch *et al.*, 2015).

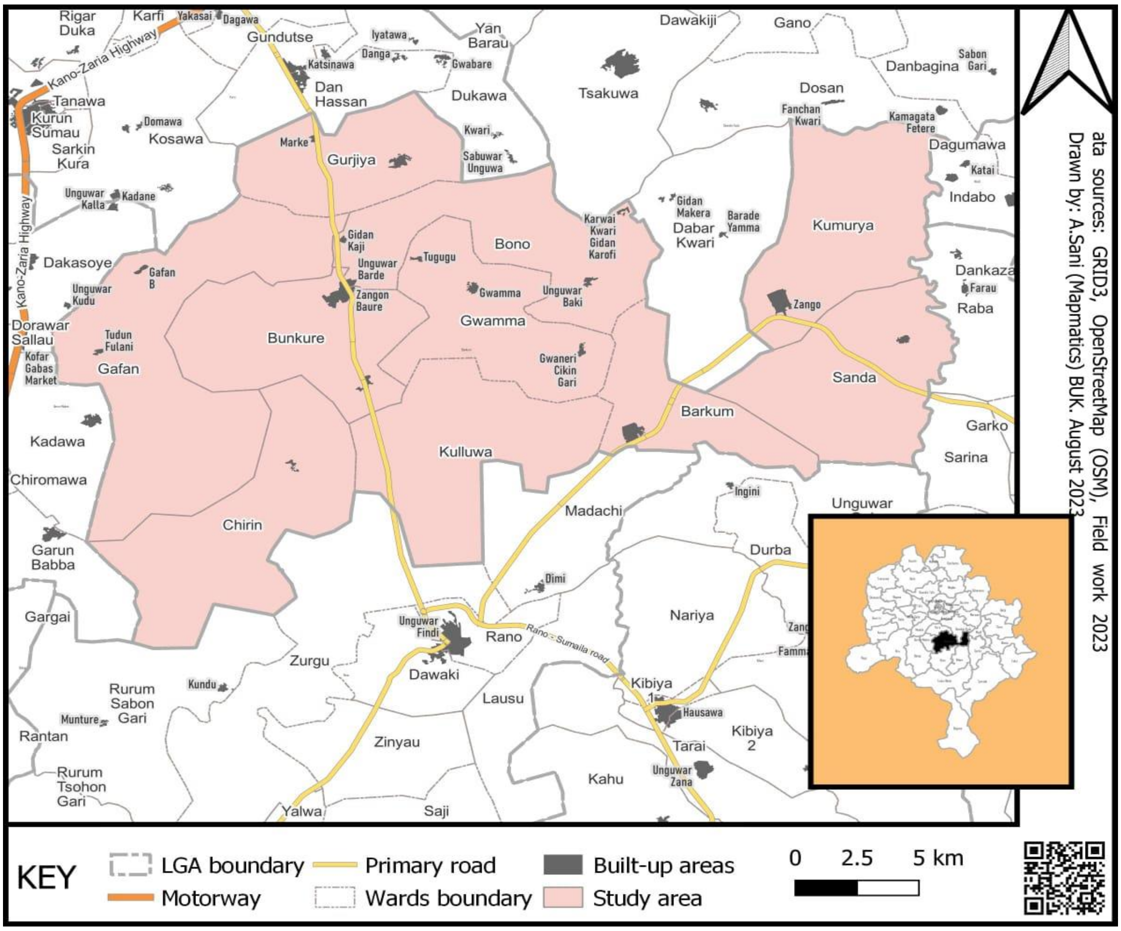


Figure 1: Study area

Sampling Frame and Techniques

The sampling frame for this research included the 7 villages in Bunkure LGA; the sampling technique applied for this research was simple random sampling techniques. This technique ensured unbiased representation, offering equal chances for all elements, enhancing the study's generalizability and validity. Out of the 5250 farmers in the population, 365 farmers were chosen at random using a confidence interval of 5 and a 95% (0.05) confidence level.

Soil sample collection

Sixteen (16) soil samples were collected from different farmlands. Fourteen (14) of which were collected from farmlands under the use of agrochemical management, while the remaining two (02) samples were collected from farmlands that are not under the use of this agrochemical management. At each sampling point, 3-4 sub-samples were collected and harmonized to have a composite sample. Portions of soil where crops have been locked out, such as places where burning of plant residues had taken place and beneath tree shade, were avoided. Each of the soil samples collected was put in a polythene bag with a level inside each sample and another tied for easy identification. Soil samples were transported for soil analysis in the laboratory immediately after sampling (Leena *et al*., 2021).

RESULTS AND DISCUSSION

Types of Agrochemicals Used by Farmers

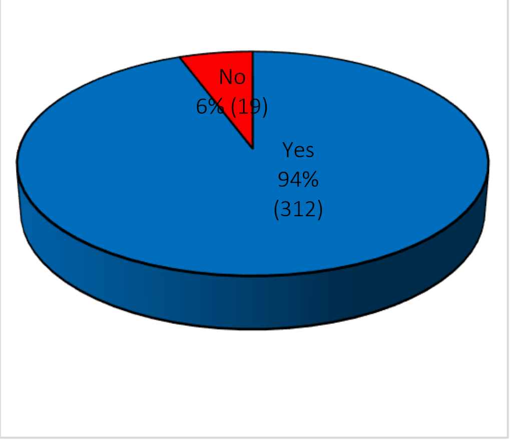
Table 1 showed the types of agrochemicals being used by farmers in the study area. The results revealed that the major types of fertilizers used by the respondents were Dangote Urea fertilizer 312 (94.3%), Indorama 248 (74.9%), Golden 48 (14.5%), and Notore-NPK15 fertilizer 281 (84.9%). In addition, the respondents indicated the most frequently patronized herbicides to include ForceUp, ParaeForce, Dragon, and Glyphosate (Sunphosate). The results also showed that the major types of insecticides used by the respondents were Dominator 301 (90.9%), DD Force 242 (73.1%), and Perfect Killer 325 (98.2%). From the results, Emzeb 80 (Mancozeb 800 WP) and Z-Force (Mancozeb 80% WP) were indicated by the respondents to be the major fungicides being used in the selected villages.

Table 1: Types of Agrochemicals used by Farmers in Bunkure LGA

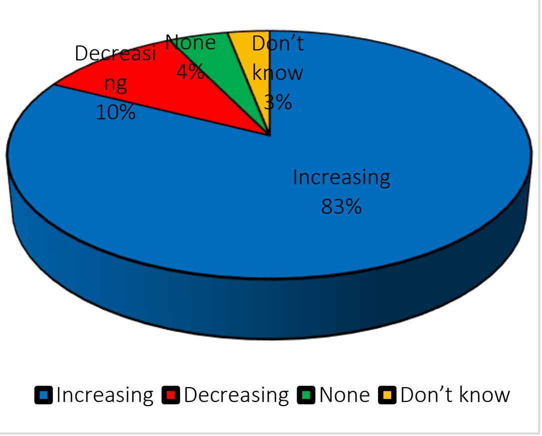
Input	Agrochemical	Frequency	Qty
Fertilizer	Dangote Urea	312(94.3%)	50kg
	Indorama	248(74.9%)	
	Golden	48(14.5%)	
	Notore NPK15 -15-15-15	281(84.9%)	
Herbicide	ForceUp,	279(84.3%)	1L
	ParaForce	311(94%)	
	Dragon	297(89.7%)	
	Glyphosate (Sunphosate)	183(55.3%)	
Insecticide	Dominator	301(90.9%)	1L
	DD Force	242(73.1%)	500ml
	Perfect Killer	325(98.2%)	1250ml
Fungicide	Emzeb 80 (Mancozeb 800 WP),	198(59.8%)	1kg
	Z-Force (Mancozeb 80% WP)	216(65.3%)	1kg

Farmers Perception on the Effects of Agrochemicals on Soil Quality

Figure 2a showed that majority of the respondents, 312 (94%) respondents indicated their thought that agrochemical use has an impact on soil quality. However, 19 (6%) indicated that application of agrochemicals does not affect soil quality. Moreover, Figure 2b showed the results of how agrochemicals affect soil quality. Majority (83%) of the respondents indicated that application of agrochemicals have positive increasing impact on soil quality, 34(10%) of the interviewed farmers indicated that agrochemicals have negative decreasing impact on soil quality, while 14 (4%) of the respondents indicated that agrochemicals have no effect on soil quality. The results revealed that 10(3%) of the respondents were not sure whether agrochemicals have effect on soil quality.



(a)



(b)

Figure 2(a-b): Agrochemicals effect on Soil Quality

Physicochemical Characteristics of Soil Samples

Organic Carbon (OC %) in Sampled Soils

Table 2 showed the percentage Organic Carbon (OC %) concentration in the soil samples from various sampling sites. The mean OC% observed across the various sampling sites ranged between 0.52±0.17 % and 0.92±0.06 %. The OC% of all the samples was lower compared to the control (0.86±0.25%) except samples from S1. The findings revealed that the OC% concentration of the soil samples at the different sampling locations did not differ significantly (P = 0.380).

Phosphate Concentration in Sampled Soils

The results of the phosphate concentrations of the soil samples across the sampling sites (Table 2) showed no significant difference (*P* = 0.382) in the phosphate concentration of the soil samples across the various sampling sites (Appendix III). The mean phosphate concentration of the investigated soil samples across the sampling sites were 37.02±1.98 mg/g (S1), 26.89±8.40 mg/g (S2), 19.56±6.84 mg/g (S3), 19.56±8.89 mg/g (S4), 25.49±5.43 mg/g (S5), 60.07±9.47 mg/g (S6), 32.13±3.95 mg/g (S7) and 22.35±8.84 mg/g (control sample).

Nitrogen Percentage (%N) Concentration

Table 2 showed the Nitrogen (%N) concentration in the soil samples from various sampling sites. The mean %N observed across the various sampling sites ranged between 0.04±0.01 % and 0.25±0.17 %. The %N concentration did not differ significantly (P = 0.120) in the soil samples across the various sampling sites.

Cat ion Exchange Capacity (CEC) in all Sampled Soils

Table 2 showed the cat ion exchange capacity (CEC) of the soil samples across various sampling sites. The mean CEC observed across the various sampling sites ranged between 3.43±0.03 Cmol/k and 4.23±0.09 Cmol/k. The CEC did not differ significantly (P = 0.055) in the soil samples across the various sampling sites.

Table 2: Physicochemical Characteristics of Soil Samples

Sampling Sites	O.C (%)	P (mg/g)	%N	CEC (Cmol/kg)
S1	0.92±0.06	37.02±1.98	0.20±0.04	3.76±0.04
S2	0.82±0.20	26.89±8.40	0.25±0.17	3.43±0.03
S3	0.78±0.25	19.56±6.84	0.11±0.04	4.23±0.09
S4	0.58±0.03	19.56±8.89	0.08±0.01	3.75±0.01
S5	0.64±0.00	25.49±5.43	0.04±0.01	3.79±0.46
S6	0.52±0.17	60.07±9.47	0.07±0.02	3.47±0.26
S7	0.60±0.28	32.13±3.95	0.07±0.00	3.56±0.22
Ctrl	0.86±0.25	22.35±8.84	0.09±0.00	4.21±0.34

Metal Concentrations in the Soils Samples across the Sampling Sites

The results of the metal concentrations in soil samples in seven villages of Bunkure LGA (Table 3) revealed that the concentration of Calcium (Ca^{2+}) in soil samples ranged from 1.63±0.18 – 2.19±0.32 Cmol/kg and this is below the maximum permissible limit (MPL) for calcium in soil. The FAO and WHO permissible standards of ≤100 (ppm) were met by the mean Ca^{2+} levels in the soil. The test and control samples did not differ significantly (p=0.398). In S1, S3, and Ctrl, the Ca^{2+} levels showed an upward trend. The highest Ca^{2+} concentrations, 2.19±0.32 Cmol/kg, were found in S3. The fact that the observed levels are below the maximum permissible limit (MPL) for calcium in soil suggests that, in this study, there is no excessive accumulation of calcium, which could potentially lead to soil imbalances as observed in a similar study by Luo *et al*. (2022).

The mean level of Mg^{2+} in soil were within the FAO and WHO acceptable limits of ≤100 (ppm). There was no significant difference among the test and control samples (p=0.135). The highest mean values of Mg^{2+} were recorded in S3; 0.29±0.06 Cmol/kg and S7; 0.25±0.00 Cmol/kg. The mean levels of Na^{+} in soil were within the WHO acceptable limit of ≤100 (ppm). There was no significant difference among the test and control samples (p=0.222). The level of Na^{+} in the control sample was higher compared to the test samples. The mean levels of K^{+} in soil were within the WHO acceptable limit of ≤100 (ppm). The S1 and S4 samples did not differ significantly (p=0.008). A notable distinction was found between S4 and S7 samples (p=0.009), with the highest K^{+} value recorded in S4 (0.25±0.01 Cmol/kg). The test and control samples' absence of a discernible difference suggests consistent magnesium levels throughout the studied regions.

Table 3: Metal Concentrations in the Soils Samples

Sampling sites	Ca^{2+} (Cmol/kg)	Mg^{2+} (Cmol/kg)	Na^{+} (Cmol/kg)	K^{+} (Cmol/kg)
S1	$2.04±0.24^{a}$	$0.17±0.00^{a}$	$0.49±0.02^{a}$	$0.16±0.03^{d}$
S2	$1.77±0.03^{a}$	$0.21±0.06^{a}$	$0.44±0.06^{a}$	$0.21±0.01^{a}$
S3	$2.19±0.32^{a}$	$0.29±0.06^{a}$	$0.45±0.04^{a}$	$0.21±0.01^{a}$
S4	$1.85±0.21^{a}$	$0.21±0.06^{a}$	$0.73±0.16^{a}$	$0.25±0.01^{b}$
S5	$1.94±0.38^{a}$	$0.21±0.06^{a}$	$0.53±0.04^{a}$	$0.21±0.03^{a}$
S6	$1.63±0.18^{a}$	$0.17±0.00^{a}$	$0.48±0.08^{a}$	$0.20±0.00^{a}$
S7	$1.69±0.38^{a}$	$0.25±0.00^{a}$	$0.56±0.04^{a}$	$0.16±0.02^{ab}$
Ctrl	$2.13±0.18^{a}$	$0.17±0.00^{a}$	$0.83±0.38^{a}$	$0.19±0.01^{a}$
MPL	≤100 (ppm)	≤100 (ppm)	≤100 (ppm)	≤100 (ppm)
P-value	0.398	0.135	0.222	0.009

Means with various superscript letters indicate significant differences at $p < 0.05$. Values are mean±SD of duplicate estimation. Ctrl – Control soil sample; MPL – Maximum permissible limit by FAO & WHO (2018).

Discussion

Rate of Agrochemicals Application by Farmers

Agrochemicals are used by farmers to either improve crop development or manage pests and illnesses that endanger the crops' ability to survive and produce (Murray *et al.*, 2002). The finding of Wang'ombe (2014) also aligns with the present study that farmers utilize agrochemicals to improve crop growth or manage pests and diseases. The farmers discovered various pests and disease indications on their crops and discussed them. Farmers applied large quantities of agrochemicals for control after identifying pests and diseases they thought were harming crops.

Farmers Knowledge on the Application of Agrochemicals

The self-assessment of proficiency in using agrochemicals aimed to gather insights into farmers' perceived competence in handling these substances. The study found out that 58.3% of the farmers are able to read agrochemicals instructions, while 61% of them indicated that they are aware of the effect of agrochemicals on soil quality. This suggests that if farmers are aware of their deficiencies, it may be simpler to plan pesticide usage trainings. People's views play a significant role in the decisions they make about the use of chemicals, such as whether or not they will use them at all. Take the risk they assign to a particular pesticide's effects on human health or the environmental matrix of soil, water, air, and beneficial creatures. This consequently affects how farmers utilize agrochemicals, such as the necessity of wearing protective gear, disposing of them safely, and preventing environmental and human contamination. Similar research conducted in India revealed that farmers rarely investigated other approaches because they had a strong belief in the efficacy of pesticides in controlling illnesses and pests (Shetty *et al.*, 2010).

According to the study's findings, farmers utilize a variety of agrochemicals in crop production, most notably fertilizers, insecticides, herbicides, and fungicides (Table 1). This finding aligns with that of Wang'ombe (2014) who observed the use of fertilizers, insecticides, and fungicides for vegetable growing. This study contrasts with one conducted in Tanzania that discovered that the production of vegetables hardly ever uses herbicides (Ngowi *et al*., 2007). According to a study conducted in Ghana by Ntow *et al*. (2006), farmers believe that herbicides can suppress weeds for a longer period of time and across a larger area than hand weeding with a hoe. Herbicides are the most commonly used pesticide class in vegetable cultivation. According to earlier research on fertilizer use in Kenya, farmers liberally applied fertilizers without following recommended dosages or taking soil testing into consideration to establish the right fertilizer rates (Njuguna *et al*., 2002). Similarly, according to study conducted the dryland of northwestern Nigeria on soil management practice and problems by Garba *et al.* (2024) about 95% of the farmers do not carry out soil testing before applying fertilizers to their farmlands.

Farmers Perception on the Effects of Agrochemicals on Soil Quality

The study findings showed that majority (94%) of the farmers perceive that the use of agrochemicals affect soil quality. This suggests that most farmers are at least somewhat aware of and have a sense of the agrochemicals they use. This finding aligns with that of Wang'ombe (2014) who observed that 68.9% of the farmers felt they knew enough about the agrochemicals they were using. Similar research on Pakistani farmers' attitudes and perceptions of the use of agrochemicals revealed a relationship between farmers' behavior and the perceived benefits or risks of a particular pesticide use practice. For instance, farmers who view pesticides as harmful to human health are more likely to take precautions, while others think they cannot produce a meaningful harvest without using agrochemicals (Lichtenberg and Zimmerman, 1999). Farmers' perceived degree of pesticide expertise is likely due to the fact that horticultural crops are typically vulnerable to pests and diseases, making it difficult for farmers to achieve significant yields without using them at some point throughout the crop production cycle.

According to the survey, 94% of the participants knew how agrochemicals affected the quality of the soil. This aligns with previous study that revealed that there is a significant impact of agrochemicals (pesticide, herbicide, fungicide and insecticide) contamination in soil ecosystem (Zhu *et al.*, 2014). The microbial life that is essential to a healthy soil ecosystem is inevitably killed by the frequent application of such complex compounds (Shang *et al*., 2019). Agrochemicals can be used to genetically alter soil-dwelling microorganisms so that they are no longer beneficial to the soil ecology and may eventually develop resistance to the chemicals meant to eradicate them (Kibata and Ongaro, 1999). Although not as much as fungicides, insecticides have a greater impact on soil bacteria than herbicides (Aktar *et al*., 2019). While certain insecticides may have stimulating or no effects on beneficial microorganisms, others may be harmful to their development and survival (Patnaik *et al*., 1996; Meena *et al*., 2020).

According to the results, the majority of respondents (83%) said that using agrochemicals had an increasing impact on soil quality, 34 (10%) said that agrochemicals had a decreasing impact on soil quality, and 14 (4%) said that agrochemicals had no effect at all. It's interesting to note that research on the negative effects of agrochemicals has been going on for more than a century, and there have been numerous documented legislative acts and pesticide-related occurrences (Pandey and Singh, 2014). More knowledge of the long-term impacts of pesticides and the associated risks to soil and natural ecosystems has been made possible by the development of quick and accurate analytical methods. Therefore, new legislative acts are being altered or adjusted at a rapid speed, suggesting considerable advances in more intelligent and efficient pest control, in light of the ever-increasing understanding of agrochemical-related health and environmental hazards (Enserink *et al.,* 2013; Owen *et al*., 2015).

Quality Status of Soils in Farmlands under Agrochemical Management

The mean concentration for OC were low (between 0.52±0.17% and 0.92±0.06%) across the sampling site. The present results is consistent with the observation by Bhandari and Bam (2013) who observed that soil organic carbon were significantly low in agricultural soils. Tillage farming and extensive use of chemical fertilizers cause significant disturbance of agricultural land, according to Paustain *et al*. (2017) and Drinkwater *et al*. (2018). According to the current study, these methods in the traditional agricultural system can reduce soil organic carbon.

When there is an excess of phosphorus in the water, it can accelerate river eutrophication because it tends to cling to soil particles and enter surface water bodies through runoff (Perlman et al., 2013). Phosphate concentrations in Table 2 varied from 22.35±12.84 to 40.07±14.19 mg/g. The natural background levels of phosphate in soils, which typically range from 0.005 to 0.02 mg/l, were lower than these amounts (Chapman, 1992). Due to an increase in organic and mineral nutrients, high phosphate levels in the soil can hasten the eutrophication process.

Numerous organic and inorganic substances contain nitrogen as a nutrient. The main Nitrogen level in the sampling sites ranged between 0.04±0.01 % and 0.25±0.17 %. This is lower compared to the range 0.37 – 0.96 mg/l observed by Jokha, (2015) in Weruweru Sub-Catchment, Tanzania. Because of its toxicity, nitrogen is especially significant when it comes to soil contamination. In most situations, the soil may contain either ammonia or nitrate-nitrogen, depending on the degree of nitrification that takes place. Because it oxidizes or converts to nitrate so quickly, the nitrite form of nitrogen is not present in significant amounts under typical conditions. A high oxygen demand may result from excessive ammonia concentrations in the soil. The transformation of ammonia into nitrate is what creates this need (Jokha, 2015).

The average Na^+ content in the soil was within the ≤100 (ppm) WHO recommended range. Although the concentrations were within the WHO recommended range of ≤100, Liu, Rong, and Zhao's (2017) findings demonstrated that land use practices had an impact on Na^+ levels (Liu *et al*., 2017). The average K^+ content in the soil was within the ≤100 (ppm) WHO recommended range. The variation in K^+ levels was significant (P = 0.009). Land use patterns, fertilizer runoff, and soil adsorption and leaching are the causes of the variances (Kharal, Khanal, & Panday, 2018). The average amount of Ca^{2+} in the soil was under the ≤100 ppm WHO recommended range. The average amount of Mg^{2+} in the soil was between 0.17±0.00 and 0.29±0.06 Cmol/kg, which was within the ≤100 (ppm) WHO tolerable limit. According to a study conducted in the East African Rift by De Bauw *et al*. (2016), the distribution of Ca^{2+} and Mg^{2+} varies and is influenced by altitude and human activity. It should be mentioned that Mg^{2+} is a crucial macronutrient that plants need in sufficient amounts for healthy growth. Tisadale *et al*. (2013) state that if the concentration of Mg^{2+} makes up less than 10% of the soil's cation exchange capacity, there may be a shortfall; however, the exact amount varies significantly depending on the kind of soil and crop. $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ was the pattern seen in the cations' profile distribution. Obi et al. (2009) discovered that the distribution of cations in the basement complex soils of southwest Nigeria followed the following pattern: $Ca^{2+} > Mg^{2+} > K^+$. Ca^{2+} dominates the exchange site, while Mg^{2+}, K^+, and Na^+ have smaller quantities, according to Enloe *et al.* (2006). Pedoturbation caused by topography (i.e., erosional/depositional), agrochemical runoff, and likely the formation of texture contrast soils (Phillips, 2007) may be the cause of the variation in these cations' levels across the different samplings, which may have implications for mineralogy. A poor correlation (P > 0.05) was found between exchangeable cations (Mg^{2+}, Na^+, and K^+) and organic carbon, phosphate, and nitrogen, but significant associations were found between Ca^{2+} and CEC (r = 0.767, P = 0.001) and Ca^{2+} and OC (r = 0.668, P = 0.005). This made it possible to draw the conclusion that the exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+) in the different sampling sites were correlated with organic carbon, phosphate, and nitrogen.

CONCLUSION

The findings of this study, suggest that while the distribution pattern of essential soil constituents such as Organic Carbon, Nitrogen, and Cation Exchange Capacity (CEC) does not indicate an adverse impact of agrochemicals surpassing permissible limits, there exists a knowledge gap among farmers regarding the potential consequences of their agrochemical practices. With a significant majority of farmers having utilized agrochemicals for extended periods, the lack of awareness, particularly highlighted by a majority believing in the detrimental effects on soil quality, calls for urgent attention. Despite exceeding permissible limits in phosphate levels, other critical parameters including Ca^{2+}, Na^+, Mg^{2+}, and K^+ remain within acceptable bounds. To address these issues, the study advocates for the implementation of robust agrochemical regulations to protect the ecosystem and human health from chemical pollution. Additionally, it strongly recommends the remediation of identified contaminated areas to ensure sustainable agricultural practices and the overall well-being of the environment

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