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Original Research

Appraisal of Soil Fertility Management Practices and Affecting Factors in Shabeley District of Fafan Zone, Somali, Ethiopia

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Abstract

Low soil fertility and poor soil fertility management practices are the main constraints on crop production in the Shabelle district. In this regard, analyzing soil fertility problems is paramount for formulating appropriate soil fertility management practices. The main objective of this study was to evaluate soil fertility management practices and their limitations in Shabeley District. The district was purposively selected, whereas Kebeles was selected randomly. Ninety-seven households from all kebeles of the district participated in the semi-structured questionnaire. Furthermore, key informants' interviews and observations in the field were carried out during this study. In addition, thirty composite soil samples of 0-30 cm depth were collected from cultivated lands in study sites to verify farmers' perception of soil fertility with the actual soil nutrient status. The study revealed that topsoil removal by water erosion, and insufficient fertilizer supply are the main causes behind soil fertility loss. Whereas, crop Residue maintenance, manure application, and crop rotation were some of the soil fertility management improvement practices in the area. According to the result of the current study, only 26.8% of the respondents use chemical fertilizers. The main reason for not using chemical fertilizer was the physical unavailability of the fertilizer. The farmers of the Shabeley district have noticed a decline in their soil fertility over time. To overcome the nutrient depletion problem and to maintain the fertility status of their fields, farmers have traditionally used different fertility management options. Crop residue, manure application, crop rotation, and fallow were the main soil fertility management practices commonly used in Shabeley by varying degrees. The household survey and the laboratory test results were consistent regarding the soil nutrient status and decline in the study area. This suggests that external application of nutrient and organic matter sources through an integrated soil fertility management approach is needed.

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INTRODUCTION

Soil fertility decline is a major concern in sub-Saharan Africa (SSA) (Bationo and Waswa, 2011). Low soil fertility and inefficient management of soils have been the major challenges facing productivity among smallholder farmers in many developing countries in general (Raimi *et al*., 2017). In a smallholder mixed farming system, the loss of soil fertility results from, soil erosion and excessive nutrient mining through complete crop harvest for food, animal feed, and fuel, without adequate replenishment (FAO *et al*., 2017; Lewoyehu *et al*., 2020). However, Strategic soil fertility and crop management approaches are needed for heterogeneous small-scale farming systems of the SSA region which face various challenges including declining soil fertility, high soil variability, increasing population density, low agricultural productivity, socio-economic constraints, and climate change. This raises the need to address factors that limit agricultural productivity by matching appropriate crop genotypes, soil fertility management (SFM), and environmental interactions that increase agricultural productivity. This was linked with soil fertility and nutrient management practices in the correspondence that we observed between input use, soil fertility management, and cropping patterns. (Mairura, 2022). Hence, crop production in semi-arid areas can be improved with the use of various SFM strategies can be a solution to improving crop yields in smallholder farming environments (Kugedera *et al.*, 2023).

Several SFM practices exist to farmers in semi-arid areas including conservation agriculture (Mugandani and Mafongoya, 2019), agroforestry (Kugedera *et al*., 2022), organic manure (Gram et al., 2020), mulching (Masaka *et al*., 2020) and mineral fertilizer (Kubiku *et* *al*., 2022). Intercropping cereals with legumes is another SFM practice available for smallholder farmers to improve crop yields, and this can be integrated with water conservation techniques to maximize yields and farm profit (Kimaru-Muchai *et al*., 2021).

Perhaps, to improve soil fertility, the Government of Ethiopia has made many efforts, most of which mainly focus on the adoption and dissemination of cereals-based conventional agriculture that uses chemical fertilizer and pesticides and physical soil and water conservation (Raimi *et al*., 2017). On the other hand, farmers of Shabelle district practice the indigenous way of soil fertility management and rarely chemical fertilizer (Mohamed *et al.,* 2023) which is organic more sustainable, and compatible with the farmer's socioeconomic status (Raimi *et al.,* 2017).

However, farmers have indigenous knowledge of how to manage their farms, but the resources they possess limit them from management such as organic matter management by leaving the crop residue on the field and applying cow dung or manure to their field (Kassu, 2011)

The agro-pastoralist farmers in Shabeley in the Ethiopian Somali Regional State are producing cereal crops particularly Maize, Sorghum, and Wheat which is the principal staple grain (CSA, 2013). However, the productivity of the crop is very low with an average grain yield of 1.0 tons ha-1on farmers' fields (Somali Region LNCDB, 2022 annual report). This yield is much lower than the national average yield of 2.11-ton ha-1 (CSA, 2013). In general, the low average yield of the crop is primarily due to depleted soil fertility, low fertilizer usage, and lack of access to other improved crop management inputs (Mohamed *et al.,* 2023).

Therefore, low soil fertility is one of the central challenges to achieving food security and poverty reduction in the Somali region. Considering that fact, soil fertility is one of the challenges to crop production in the Shabeley district. However, little attention has been given to soil fertility management problems in the Shabeley district. Therefore, this assessment provides a basis for the understanding of the possible management practices for better soil fertility management and increased land productivity. Thus, the study was designed to assess the existing soil fertility management practices and the problems associated with them.

METHODS AND MATERIALS

Description of the Study Area

The study was conducted in Shabelley district, Fafen Zone of the Somali region. Shabeley is located 25 km away from the regional capital, Jigjiga in the Northern part of the Somali Regional State of Ethiopia. It is bordered in the East by the Kabri-Bayah district, in the West by the Gursum district, in the South by the Goljano district, and in the North by the Tuli-Guled district. However, at the micro-level, the physiographic feature is a rolling type of landmass, which forms several Tributaries and Streams that facilitate runoff towards the Jerer and Fafan Valley. The district is located between 8° 40` 0`` N to 8° 26` 15`` N latitude and 42° 2` 45`` E and 43° 13 25`` E longitude (Figure 1). The altitude is 1634 meters above sea level. The climate of Shabeley district is arid and semi-arid influenced by the Gulf of Aden and the Indian Ocean to the North and East and by the highlands of Ethiopia lying in the North-West of the region. Shabeley district is characterized by having a bimodal type of rainfall with an average annual precipitation of less than 200 mm in the southeast to some 600 - 700 mm in areas of the north and western parts of the district and maximum and minimum temperature of 26.49 °C and 12.27 °C, respectively. The Northern and Northwestern parts of the Shabeley district are characterized by having two cropping seasons, the first rainy season comes as the 'Dira' rain which commences during mid-March and extends to the end of May and the second rainy season comes as 'Karan' rain which starts during the mid of July and ends in late September. In this part of the plain, the 'Karan' rain is normally heavier than the 'Dira' rain. Both sets of rain are equally important for the cultivation and maturation of crops. The texture of the soils in most areas is almost clayey, except for some exposed soils with steep slope gradients, which are sandy or grave. Agro-pastoralism is the dominant production system in the district where the majority of rural households practice mixed crop and livestock farming.

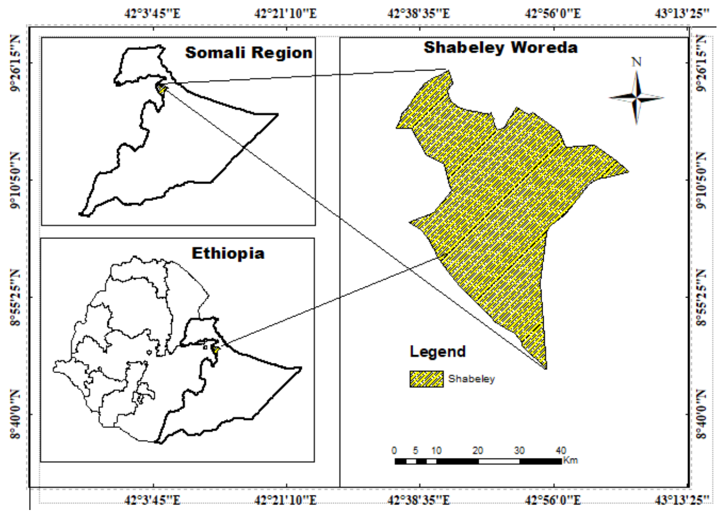

Figure 1: *Map of the study area*

Data collection and data source

The study area was purposively selected based on the existence of soil fertility management practices such as crop residue management and the existence of crop rotation and fallowing practices. The specific Kebeles for the study were selected purposively based on the presence of soil fertility management practices. This study employed three data collection strategies: (a) Household survey to acquire soil fertility management practices through a questionnaire, (b) Key informants interview and Focus group discussion to get additional information on soil fertility management practices, extension service, fertilizer consumption issues, and (C) soil sample analysis to acquire basic information about the actual nutrient status of the study area. Key informants were selected purposively based on their knowledge and experiences in soil fertility management practices. A total of nine Key informants were selected and interviewed using a checklist. A sample size of farmer households was determined using the simplified formula provided by Yemane (1967). This formula is used widely, because it gives a reasonable amount of sample that can for a population, is simple to use in determining sample size compared to other methods of sample size determination and is the most widely used formula for determining sample size compared to other methods.

$$n = \frac{N(3645)}{1 + N(3645)(e)^2\,(0.1)^2} = 97$$

Where n is the sample size, N is representing total household size, and e- is the level of precision at 95% level of confidence. Accordingly, sample households were selected using the above equation. Then, a proportional probability sampling technique was employed to determine the required number of respondents from each kebele (Table 1).

Table 1: *Proportional probability sampling size of Kebeles*

No	Kebele Name	Number of Population	Respondents

1	Amadle	1372	37
2	Bolidid	1252	33
3	Sheik Isman	10,21	27
	Total	**3645**	**97**

Soil Sampling and Analysis

Thirty composite soil samples (0–30 cm depth) of cultivated lands were collected using Auger. All soil samples were air-dried, crushed, and passed through a 2-mm sieve and analyzed for selected chemical properties at Haramaya University soil laboratory. Soil pH was determined potentiometrically with a digital pH meter in the supernatant suspension of a 1:2.5 soil water ratio and soil organic carbon was determined by the wet oxidation method (Walkley and Black 1934). Available P was determined following the Olsen extraction method as described by Olsen *et al*. (1954), while total N was determined by digestion, distillation, and titration procedures of the wet digestion (Kjeldahl, 1960) method. Exchangeable K was analyzed using a flame photometer following an ammonium acetate extraction. Cation Exchange Capacity **(**CEC**)** was determined at pH **7** using ammonium acetate extraction procedures, and the electrical conductivity (EC) of the soil was estimated using EC meter.

Data analysis

The collected data about household surveys and soil parameters were coded and tabulated for computer entry and analyzed using descriptive statistics with SPSS-16 and Microsoft Excel.

RESULTS AND DISCUSSION

Soil Fertility Status of Shabeley District

The survey results showed that farmers in the study area were aware of the constraints and the decline of the soil nutrients in the area. However, they did not know the exact rate and extent of the soil nutrient loss. The soil fertility analysis was conducted to verify and compare the farmers' perception of soil fertility with the actual soil nutrient status. This section presents the findings of the soil fertility analysis of Shabeley district.

Soil pH has a significant influence on the availability of nutrients to plants. The nutrients that are essential for plant growth, such as nitrogen, phosphorus, and potassium, are most available to plants at a soil pH of between 6.0 and 7.0. When the soil pH is too low or too high, the availability of these nutrients decreases, and plants may suffer from nutrient deficiencies (Zhang *et al*., 2016). Hence the current result showed that the pH of the soil samples ranged from neutral (6.7 -7.3) to strongly alkaline (>8) (Table 2). A recent study conducted by Ahmed *et al*. (2018) reported similar findings for the soil of Jigjiga plains, which had a strongly alkaline reaction. This finding is consistent with the results of Hag Husein (2021) and Debela *et al*. (2011) who reported that arid soils often have neutral and alkaline pH, because this particular environment is known for its low rainfall and high temperature.

The organic carbon (OC) content of cultivated land in the study area varied from 0.04 to 2.14% (Table 2). The organic carbon content in the area is low to medium. The baseline limit of OC is 3.5%. Hence, the OC content of the current result was below the limit which indicates high biological soil quality degradation observed in the study soils. In line with this, Gebrayes (2014) emphasized that the lower soil OC could result in poor aggregate stability and, thus, aggravate soil degradation. This finding is in line with Ahmed *et al*. (2018), who reported that the OC content of the soils in the Jigjiga plain was low to medium. The low content of organic carbon could be attributed to the relatively higher organic matter content of the surface soil layers because of residual root debris, deposition from wind, and water erosions, high biological activity, and soil conditions suitable for the decomposition of organic matter in the surface soil layer as compared to sub-surface soils (Ahmed *et al*., 2018). Furthermore, Naorem (2023) reported that because of climate constraints, the soils in arid regions have an inherently low stock of organic carbon.

The total nitrogen (TN) content of soils of Shabeley district farmlands varied from 0.01 to 0.06% (Table 2). The total nitrogen content of the soil was low to medium. However, the mean value of the entire cultivated lands was recorded to be 0.04%, which indicates the low potential of the soil to supply TN to plants. Therefore, there is a need to apply external sources of nitrogen, such as inorganic and organic fertilizers, to enhance crop production in the study area. This finding is consistent with Ahmed *et al*. (2018), who reported that surface layer soils in this area had low TN content.

The available phosphorus (AP) content of the soil ranged from 0.2 to 4.5 ppm (Table 2). The available phosphorous content of the soil was below the baseline limit low. This low available P status might be related to losses associated with erosion and removals during harvesting and continuous cropping in addition to limited or no biomass return to the soil. The findings of this study are in agreement with the findings of Girma and Endalkachew (2013) who indicated that low available phosphorus might be related to continuous cropping, surface erosion, and absence of biomass addition to the soils. Furthermore, this result is in agreement with Ahmed *et al.* (2018) who reported low available P amounts both in surface and sub-surface soil layers. Therefore, it can be concluded that the low amount of AP in soils is the most important factor constraining crop production in the Shabeley district.

The exchangeable potassium content of the soil in the Shabeley district ranged from 0.45 to 4.35 Cmol**/**kg with a mean value of 1.4 cmol/kg (Table 2). According to the rating of FAO (2006), the content of exchangeable potassium in the soil falls at a very high rate, which means the nutrient is sufficiently available in the soil and its status would not limit crop growth and development. A similar finding was reported by Ahmed *et al*. (2018), who revealed that exchangeable K in the Jigjiga plain was abundant and is not a limiting factor for crop production.

Generally, soil fertility under arid and semi-arid conditions is constrained by environmental extremes of hot and cold temperatures, as well as by low water availability. With some exceptions, these soils have inherently low fertility, low availability of nitrogen and phosphorus, low water-holding capacity, high pH, low soil organic matter (ranging from 0.1 to 3%), shallowness, stoniness, and other specific problems (Husein *et al*., 2019 and Sahrawat, 2016).

Table 2: *Mean values of surface soil fertility status of Shebeley district*

Variables	Mean (0-30 cm)	Ranges (0-30 cm)
PH (H_2O)	7.66	8.4-6.7
EC (dS/m)	0.29	0.70-0.01
Na (Cmol/kg)	0.05	0.3-0.01
Exchangeable K (Cmol/kg)	1.41	4.35-0.45
CEC (Cmol/kg)	21.80	69.1-3.9
Available P (ppm)	4.66	4.5-0.2
TN (%)	0.04	0.06-0.011
OC (%)	0.84	2.14-0.04

Soil Fertility Management Practices in Shebelley District

Agro-pastoralists in the current study area had an understanding of how to manage soil fertility problems. Farmers in the study area were found to use crop residues or leftovers in various ways as soil fertility enhancement measures. More than 45% of the respondents used crop residues as soil fertility enhancement measures (Figure 2). Farmer respondents reported that they would burn the leftovers after the livestock feed on the lands and incorporate them in the soil, or just incorporate them without burning. They suggested that crop residues incorporated in the soil had great nutrient value. The importance of crop residue could be because they increased soil fertility by returning back the elements that were drawn from the soil by plants. However, burning of crop residues in the soil can decrease nitrogen supply in a short term, but it can also create favorable conditions for nitrogen fixation by microbes. (Lal, 2005) reported that burning or removing crop residue from field seriously depletes SOM and, thereby, the nutrient supplying capacity of soils.

The respondents reported that importance of using or applying of animal manure or farmyard manures (FYM) as a way of improving soil fertility. 10% of respondents replied that they frequently incorporated farmyard manure (FYM) or animal manure into their farmlands (Figure 2). They explained that applying FYM is a traditional practice of maintaining soil fertility, as the manure would decompose and enrich the soil. However, most of the agro-pastoralists did not use or apply FYM, even though they had plenty of it from their livestock. The combined application of fertilizers and farmyard manure that unfailingly sustained soil fertility and productivity (Katyal *et al.,* 2001). Singh and Singh (2015) report the application of organic manures can help reduce or eliminate the emergence of micro- and secondary nutrient deficiencies and prevent a fertilizer-induced drop in pH of poorly buffered acid soils. Similarly, very small proportion of agro-pastoralists had practiced of using compost as soil fertility management measures. Less than 5% of the respondent agro-pastoralists made and used their own compost for their soil.

Some respondents also mentioned the use of different cropping systems as options for soil fertility management. 10% of the respondents replied that they practice crop rotation as an option for fertility enhancement. Similarly, other small group of respondents replied that they use fallowing as a method for soil fertility management which involves leaving the land uncropped for one or more seasons.

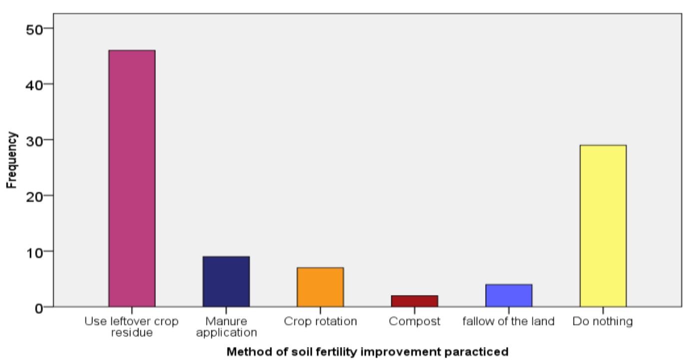

Figure 2: *Soil fertility enhancement practices*

Chemical fertilizer utilization and causes of soil fertility decline

In addition to the soil fertility management practices, farming communities of Shabeley district application of chemical fertilizers to overcome the soil fertility problem. According to the result 26.8% of the respondents used chemical fertilizer including Urea and DAP. While the majority of the respondents 73.2% have never used any form of fertilizer to enhance the fertility of the soil (Table 3). According to the key informant interview farmers believe that fertilizer application to the soil will lead high yield of the crop. The farmers intuitively know that secondary and micronutrients released from soil are sufficient to meet the crop need whatever the crop is (Bista, 2010).

According to the result in Table 2, the main reasons for not using chemical fertilizer among the farmers were the physical unavailability of the product. However, 57.7 % respondents reported that due to unavailability of chemical fertilizer was the primary constraint of fertilizer application to the farmers. 23.7% of the respondents indicated that they didn't use chemical fertilizer because they did not know much about it. Other respondents 15.5% replied that they didn't use chemical fertilizer because they did not know how to apply it properly. Only very small proportion of the respondents 3.1% replied that the cost of chemical fertilizer was too high and that they could not afford it.

Table 3: *Soil nutrient decline and Reasons for not using chemical fertilizers in Shabeley district*

Parameter	Response	Frequency (n=97)	Percent %
Chemical fertilizer use	Yes	26	26.8
	No	71	73.2
Reasons for not using fertilizer	Lack of awareness	23	23.7
	Due to unavailability	56	57.7
	Due to the cost of fertilizer	3	3.1
	Do not know how to use	15	15.5
Soil nutrient decline	Yes	75	77.3
	No	22	22.7
Total			**100**

The study revealed that the respondents of current study area have observed that their soil fertility is declining over time. The household survey result indicated that about 77.3% of the respondents of Shabeley district described that the soil fertility has declined while the remaining 22.7% responded that there was no decline in soil fertility status (Table 3). This implies the majority of the farmers in the area recognized the decline of the soil fertility.

According to the result in Figure 3 the farmers' response to the soil fertility management constraint of Shabeley district were topsoil removal by water, insufficient fertilizer supply and lack of government support major soil fertility management problems. The respondent had an understanding of soil fertility reduction over time. More than 40% of the respondents indicated that topsoil removal due to erosion is a major factor, while others claimed that insufficient or lack of fertilizer application was a major factor. Similarly, 20% of respondents replied that lack of government support and attention resulted in soil fertility decline. On the other hand, some few respondents reported that use of chemical fertilizer has resulted in increase in soil acidity and thereby reduced fertility (Figure 3). Similarly, the KII revealed that soil fertility decline was experienced in the area. While soil erosion by water and deforestation is the major factors of the soil fertility management problem.

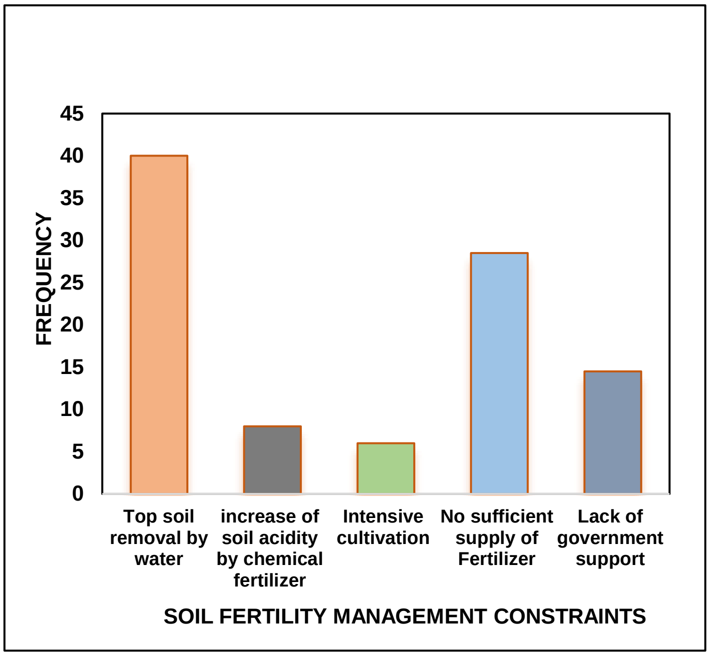

Figure 3: *Agro-pastoralist response on factors responsible for loss of soil fertility*

Causes of soil fertility depletion

During the survey, FGD discussant of agro-pastoralists have reported several constraints that cause soil fertility decline and ranked them in their orders of severity (Table 3). Soil erosion and Intensive cultivation were ranked the highest order. Furthermore, poor fertilizer application, lack of organic fertilizer, improper crop rotation were among the factors causing soil fertility decline. Accordingly, the cause analysis is briefly summarized in Table 3.

Table 4: *Pair wise ranking of Causes for soil fertility Management constraints*

constraint of soil fertility Management	SE	IC	IOM	UIF	ICR	PTP	Score	Rank
SE		SE	SE	SE	SE	SE	5	1
IC			IC	IC	ICR	IC	3	2
IOM				UIF	IOM	IOM	2	4
UIF					UIF	UIF	3	3
ICR						PTP	1	5
PTP							1	6

Source: Own survey 2022, SE: Soil erosion, IC: Intensive cultivation, In-adequate organic fertilizer, UIF: Use of inappropriate fertilizer, ICR: Improper crop rotation, PTP: poor tillage practices.

CONCLUSION AND RECOMMENDATION

The study revealed that the farmers of Shabeley district have noticed a decline in their soil fertility over time. To overcome the nutrient depletion problem and to maintain the fertility status of their fields, farmers have traditionally used different fertility management options. Crop rotation, manure, and crop residue application were the main soil fertility management practices commonly used by the local farmers. During the household survey, most of the respondents identified soil erosion and lack of fertilizer supply as the main causes for the observed depletion of soil fertility in the study area. Although most farmers recognized the benefits of using chemical fertilizer to improve crop productivity, only about a quarter of the respondents were using chemical fertilizer. The reasons for not using fertilizers were mainly the unavailability of fertilizers and the lack of awareness about their benefits among some farmers. On the other hand, despite the sufficient availability of FYM, only few farmers were applying FYM to their fields to improve their soil fertility. Furthermore, low OC, AP and TN contents suggest that external application of nutrient and organic matter sources through an integrated soil fertility management approach is needed for optimal crop growth and sustained yield improvement. The household survey and the laboratory test results were consistent regarding the soil nutrient status and decline in the study area. Future research needs to focus on investigating the effect of integrated soil fertility management options, developing site and crop specific fertilizer recommendations, and selecting crop species or varieties that are adapted to the Low-AP soil for enhancing crop production in the study area.

Authors' contributions

Only one author contributed in the acquisition of the data, data collection, data coding and entry, data analysis, interpretation of the result, preparation and revising the manuscript.

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Competing interests

The author declare that there is no competing interests.

Availability of data and materials

The data used in this paper is with the author and can be available upon demand.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable.

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