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Impact of long-term cultivation on selected soil physicochemical properties in the coastal savanna zone of Ghana

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Abstract
It is known that long tern cultivation combine with inappropriate land management can lead to nutrient decline and soil physical properties degradation. Soil analysis can provide information about physical and chemical properties such as bulk density porosity, soil field capacity, pH and NPK content. Soil from selected land use systems: cultivated (C) and uncultivated (U) from Coastal savannah zone of Ghana were sampled for laboratory analyses to compare the physico chemical properties of the two land use systems. The land use systems are on different soil series, namely: (Adentan. Toje and Haatso series all lying within at the University of Ghana. The results showed that the three soils series were slightly acidic, ranging between 5.5 to 6.6. Toje and Adenta series was sandy clay loam and Haatso serie was sandy loam with low percentage of OC which ranged from 0.11 to 1.11. The organic matter content was higher in uncultivated soil compared to cultivated and also decrease with depth. The bulk density pb was slightly higher in cultivated soil than uncultivated soil. In generally all the three-soil had higher AWC ranged between 91.52 to 66.30 mm where the highest AWC were recorded by uncultivated soil. The saturated hydraulic conductivity (Ks) for cultivated soil was greater than uncultivated soil. Along the three-soil series Toje and Adenta also had higher Ks compared to Haatso serie. Phosphorus under both cultivated and uncultivated soil were low in most of the time which was range from 2.78 to 17.34 mg/kg Moreover, Adenta and Toje had medium available phosphorous concentration under uncultivated soil been 20.45 and 20.41 mg/kg respectively.

Key word: Long-term cultivation, Soil physico-chemical properties

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I. Introduction

Soil quality is the soil's capacity to function within natural to sustain plant and animal productivity while preserving environmental stability and ecosystem functions (Karabulut et al. 2023). A substantial increase in food production over the last century has been noted due to agricultural intensification use which negatively affect soil physicochemical by increasing soil erosion, and soil degradation (Oliveira et al. 2024). Thirty-three 33 percent of the world's soils are moderately to highly degraded (FAO. 2015).

Soil degradation is a major challenge that threatens agricultural production worldwide. This degradation is due to suboptimal management practices that lead to a decline in the biological, chemical and physical quality of soils, thus reducing their capacity to support production and environmental functions (Tully et al. 2015). Hence Sustainable soil management practices could be a solution to this problem (FAO. 2015) such as organic farming and conservation agriculture can reduce an impact of intensive use of agriculture land. Organic farming focuses on adaptation to local resources and conditions, limiting external inputs such as chemical fertilizers and pesticides (El-Hage Scialabba. 2013) and building on natural soil fertility. Conservation agriculture relies on the three principles of 1) crop diversification. 2) permanent soil cover. and 3) minimal soil disturbance to achieve soil protection and a better use of natural resources (FAO. 2022). Intensive and poorly managed land use often leads to nutrient depletion, soil degradation and pollution (Guo et al, 2023). Under such condition soil organic matter

content SOM, pH, exchangeable calcium and potassium, available phosphorus, field capacity and bulk density are generally use to assess soil quality due to land-use shifts and Long-term cultivation condition (Macheroum et al,. 2025). In Sub Sahara Africa specially in Ghana, smallholder generally remove weed and crop residue in order to feed animal or use it for cooking, these practices expose soil to erosion. However, in areas dominated by small farms, such as much of sub-Saharan Africa soil health is also influenced by interactions between different farms and between agricultural and non-agricultural parts of the landscape. It is the aim of this research to evaluate the effect of long-term cultivation on soil physico-chemical characteristics in coastal savannah zone of Ghana on three soils taken from the farm of university of Ghana.

II. Material and methods

Soil description

According to Soil Taxonomy the three soils used for this study was classified as Typic Kandiustal (Adenta), Rhodic Kandiustalf (Toje) and Kandic Haplustalf (Haatso). According to the world reference base (WRB) Toje series is classified to be a Nitisols whereas Adenta and Haatso series were Lixisols (Eze 2015). The Toje. Adenta and Haatso soil series lie on the upland, mid-slope and lower slopes, respectively on the Legon Hill Catena (Dowuona et al..2012). In general, the Toje series had a pale soil colour compared with Adenta. Also, the cultivated soils had less vegetation cover compared with the uncultivated soil. Hence soil moisture content in cultivated soil was obviously higher than uncultivated soil which generally increase with depth. Moreover, uncultivated soil had more clod compared to cultivated soil this may be due to the cultivation materials impact on soil structure.

Soil sampling and laboratory analyse

Based on the objectives this study the soil sample were from selected land use systems: cultivated (C) and uncultivated (U) soil from Coastal savannah zone of Ghana. The landuse systems are on different soil series, namely: Adentan, Toje and Haatso series all lying within at the University of Ghana. The soil sampling depth was ranged between (0-20) and (20- 40) cm.The cultivated soil had been continuously cultivated about more than 20 years to maize (Zea mays) and cassava (Manihot esculentum) crops. The uncultivated land had been in fallow about 10 years. The core sampling method was used to sample soil from (0-5) and from (20-25) cm for soil bulk density determination. Soil at both ends of the core sampler were trimmed with a straight-edged knife. Soil corers were used to sampling soil from (0-20) and (20- 40) cm for hydraulic conductivity determination. Disturbed soil samples were also taken for soil chemical and other physical analysis. These samples were air-dried for 24 hours and sieved through 2 mm-mesh for physical and chemical analyses. The electrometric method developed by (Peech. 1965) was be used to determine the pH of the soil. Organic carbon was analyzed using the wet oxidation method developed by (Walkley & Black. 1934). Bray 1 method (Bray & Kurtz. 1945) was used for soil available phosphorus determination. The hydrometer method was used for this analysis Soil texture analysis. Bulk density was determined as the ratio of the mass of dry soil to the total volume of the soil.

Available Water Capacity deternination

Available Water Capacity for the sampled soils was determined by measuring the water content at field capacity and permanent wilting point in the laboratory and calculating the difference (Harold et al; 2016). One hundred (100 g) of sieved soils were placed on plastic containers and water saturated. The containers had drilled holes at the bottom to allow for water drainage. The surface of the container was covered with polythene back to arrive water loss by evaporation during draining. After the drainage had ceased, it was assumed that the soils have attained field capacity. Thereafter, 50 g of the wet samples was put into the moisture can and oven dry at 105oC for 48 hours. The oven dry weight of the soil was determined using electronic balance. The mass of water in the soil at field capacity (FC) was calculated as: $Mass\ of\ water\ in\ soil\ = wet\ soil - oven\ dry\ soil\ (g)$
And the water content corresponding to the FC as:

$$\theta_g = \frac{wet\ soil - oven\ dry\ soil}{oven\ dried\ soil}$$

Or

$$\theta_v = \theta_g \times \rho_b$$

where θ_v = Volumetric water content, θ_g = gravimetric water content
In the case of the PWP, the laboratory lacked a functioning equipment for its determination. Therefore, an indirect procedure was adopted whereby an indicator plant sunflower (Helianthus) was grown in PVC-filled soil columns of depth 3cm under well-watered conditions until flowering after which watering was ceased until the plants died.

The details of the procedure are available in Taylor and Ashcroft (1972). The soil was then sampled and the water content determined, and this was taken as the PWP.
The available water capacity was then calculated using:
AWC = FC-PWP
this was converted into water storage by multiplying with soil depth.

Determination of the Soil Saturated Hydraulic Conductivity

The saturated hydraulic conductivity (Ks) was determined using field method which was based on water infiltration using the single steel ring method in the field. A steel ring of internal diameter of 16.2 cm and height 13 cm was inserted to 2 cm deep into the soil. The inside of the ring was lined with a polythene sheet and an initial water head of 10 cm of water maintained and prevented from infiltrating by the polythene sheet. The plastic sheet was gently but rapidly pulled out the times for the water head to recede by every 2 cm was recorded. The data obtained were used to plot a graph of water height vs time. The slope of the linear part of the curve was used to estimate the saturated hydraulic conductivity based on the dimensions of the ring and the following theory:

$$Q = Ksat.\{(C|G.pi.r) + 1\}$$

$$Ksat = \frac{\{(C|G.pi.r) + 1\}}{Q}$$

where
Q = statistically determined (cm/min)
C = wetting front potential (estimated for clays at 150 cm)
G = shape factor for infiltration (0.8456)
pi = 3.1415
r = radius of ring (10 cm)

III. Results And Discussion

Long-term cultivation on some soil physico-chemical properties

Long-term cultivation on some soil pH, bulk density, soil organic carbon content and Available Phosphorus content are presented in table 1. The pH (H_2O) was slightly acidic for all the soil series ranging between 5.5 to 6.6 these may be due to the leaching down of nonacid Ca2+, Mg2+, K+ and Na+ by rainfall since the catena down the Legon hill have bimodally rainfall season with about 900 mm of annual rainfall (Dowuona et al. 2012) or may be due to the chemical nature of the underlying parent material (Peter. 2015). In most of the case soil cultivation did not appear to affect soil pH (Table1) excepted the case of Haatso series at the two depth and Toje serie at 20-40 cm where pH was found to increase by 7.27 to 9.27%. Similar result was found by (Saviozzi *et al,.* Riffaldi. 2001) where they reported no significative change in soil pH under intensive corn cropping for 45 years. The pH was found to increase with depth. This trend can be attributed to the reduction in soil organic matter of the soil as affected by soil depth. Soil with high soil organic matter content tend to have more H+ which consequently decrease soil pH thereby increasing soil acidity (Ray & Nyle,. 2017).

Table 1: Effect of Long-term cultivation on some soil physico-chemical properties

Soil Series	Depth	pH (H_2O)		Bulk density		OC%		Available Phosphorus mg/kg	
		UC	CC	UC	CC	UC	CC	UC	CC
Adenta	0-20	5.60	5.70	1.24	1.38	1.09	0.72	20.45	17.34
Toje	0-20	5.60	5.70	1.27	1.29	1.16	1.1	20.41	11.53
Haatso	0-20	5.70	6.30	1.34	1.37	0.88	0.32	4.47	2.62
Adenta	20-40	6.30	6.50	1.26	1.30	0.55	0.17	3.92	3.71
Toje	20-40	5.50	5.90	1.27	1.34	0.32	0.17	18.35	3.61
Haatso	20-40	5.50	6.01	1.36	1.39	0.32	0.11	3.78	3.45

UC = uncultivated soil. CC = cultivated soil. OC = % Percentage soil organic matter content

The ρb was slightly higher in cultivated soil than uncultivated soil by 1.57 to 11.29%, which may be the result of the impact of continuous cultivation on soil structure. Ampadu et al (2017) reported the bulk density of cultivated to be 10.16% greater than the fallowed soil land, and the highest values was attributed to continuously cultivated as a result of continuous and intensive cultivation with heavy farm machineries. Between the different

soil Haatso soil had higher Pb than the other two soil which can be attributed to the lower clay and organic carbon content in Haatso serie. Therefore, soil that have high organic carbon and some friable clays tend to have lower bulk densities due to a combination of the low-density of the organic materials themselves and increased porosity specially for pead soil (Soane,1990). The ρb generally increased with soil depth because subsurface layers are more compacted and have less organic matter, less aggregation and less root penetration compared to topsoil, therefore contain less pore space.

The topsoil of Uncultivated Toje , Adenta and Toje series (0-20 cm) had a medium soil organic matter content. A part of that all the remain soil organic carbon content was generally low. This may be due to lower organic materials added to some of the soil in addition to high rate of soil organic matter mineralization (Lal & Morgan, 2004). In most of the case Adenta and Toje series have more SOC than Haatso soil. which can be attributed to the differences in biomass production and litter mineralization rate. both of which are affected by soil moisture content (Eze, 2015). SOC was also generally decrease with depth. The ranges were 1.09 to 0.88 (0-20 cm) and 0.55 to 0.32 (0-40 cm) for uncultivated and 1.1 to 0.32 (0-20 cm) and 0.17 to 0.11 (0-40 cm) for cultivated. The decline of SOC with depth can be attributed to the high amount of organic matter present in the top soil than deeper soil. According to Brady & Weil. (2002) carbon stocks are supplied by decomposition of organic materials. Chandler. (2016) found SOC content to be different with soil depth. ranging from 2.2 ± 1.0% down to 0.4 ± 0.3%. As reported by (Sebastien et al,. 2007) topsoil is generally dominated by young fast-cycling carbon compared to deeper soil which is dominated by ancient slow-cycling carbon. Apart from soil depth. cultivation has been found to reduce SOC (Table 1) probably due to the exposition of cultivated soil to the erosion. and by removal of the natural vegetation and crop residue for other use. Hence transformation of natural ecosystem to an agroecosystem generally affects both the quantity of soil organic matter and its chemical composition (Gerzabek et al,. 2006). Long-term cultivation was found to decrease SOC by 5.17 to 63.64 % for (0-20 cm) and 46.88 to 69.09 % for (0-40 cm) of three investigated soil , the lowest values were recorded for Toje serie followed by Adenta serie. The similar result was found by Tuffa & Belachew (2010), they found the SOC to be 12.95% and 2.56 % under natural uncultivated soil and cultivated respectively. They suggested that lowest SOC content in cultivated soils could be due to reduced inputs of organic matter and frequent tillage which encouraged oxidation of organic matter.

Phosphorus under both cultivated and uncultivated soil were low in most of the time which was range from 2.78 to 17.34 mg/kg. Moreover, Adenta and Toje had medium available phosphorous concentration under uncultivated soil been 20.45 and 20.41 mg/kg respectively. The similar result was founded by Eze (2015) who observed a spatial variability along the Legon hill catena of the low to medium AvP may be attributed to the generally low pH of the soils. The result showed the AvP declined under cultivation condition by about 5.36 up to 80% these can be attributed to the removal of fine particle from cultivated soil due to soil erosion and the removal of crop residue which is often rich in phosphorus. A similar result was found by Jaiyeoba(2003) who reported soil available phosphorus to decline by about 40 – 65% after 25 years cultivation.

Long-term cultivation on soil Available water capacity

The soil field capacity and the permanent wilting point for the threes soils under uncultivated soil were height than those for cultivated soil (Table 2). The field capacity of Adenta, Toje. Haatso soil series

Table 2: *S*oil Available water capacity under cultivated and uncultivated soil

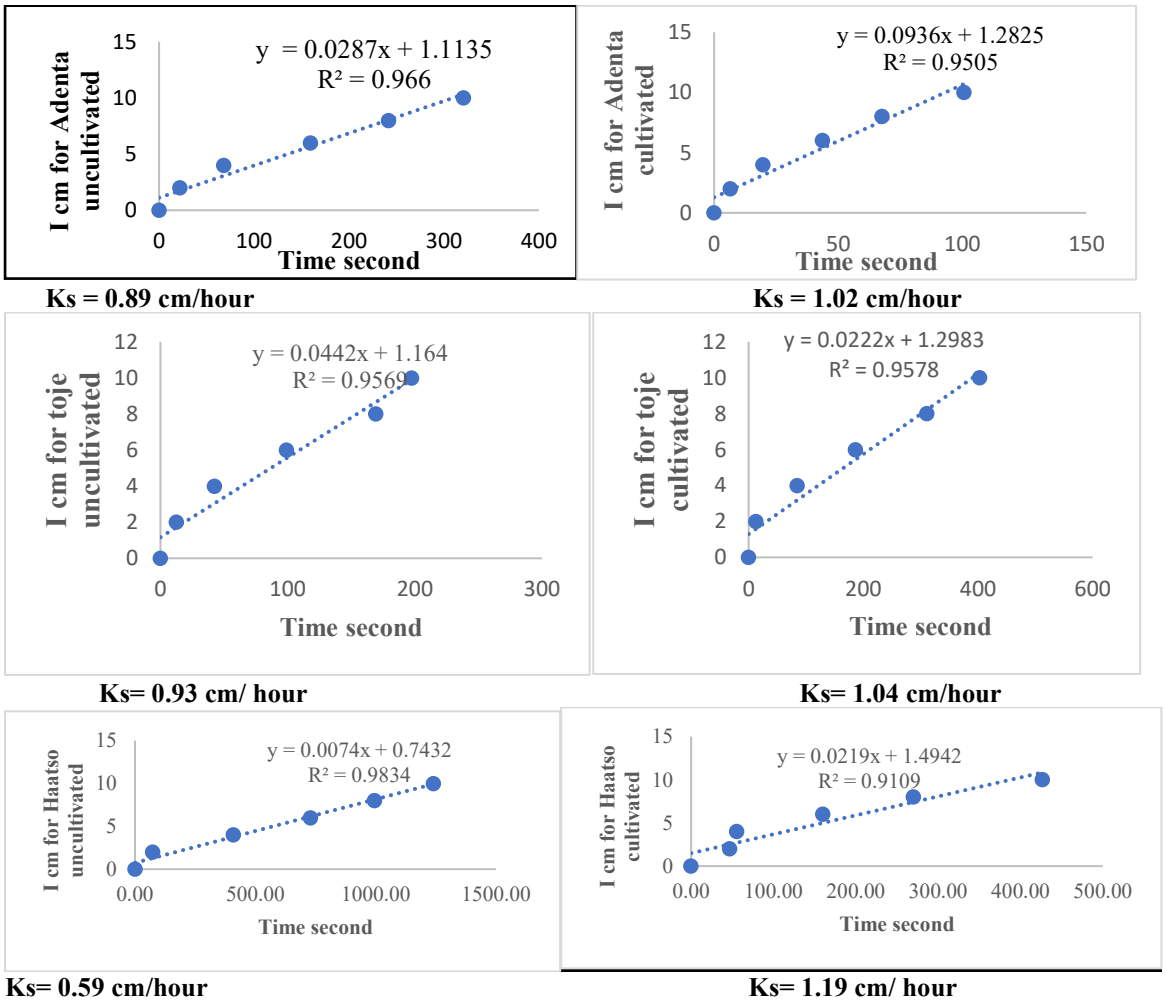
	Soil water content cm3/cm3			
uncultivated	**FC**	**PWP**	**AW**	**AWC (mm)**
Adenta	0.50	0.04	0.46	91.52
Toje	0.45	0.02	0.43	85.10
Haatso	0.35	0.02	0.33	66.55
cultivated				
Adenta	0.48	0.03	0.45	89.25
Toje	0.40	0.01	0.39	77.19
Haatso	0.34	0.01	0.33	65.30

followed the same trend as soil organic carbon content. while the latter two soil had the same permanent wilting point been 0.02 cm3/cm3 for uncultivated soil and cm3/cm3 for cultivated soil (Table 2). The higher available water capacity (Table 5) for the uncultivated soil and topsoil soil can be attributed to the high organic carbon content whish can improve soil water holding capacity. It has been found that increasing the SOM by 1% can improves soil AWC by more than 1.5- 4% (Hudson 1994). According to Ray & Nyle.(2017), when the soil is

rich is organic matter at the field capacity it water volume is much higher than that of an equal volume of mineral matter. Soil with lower FC can be improved by the incorporation of higher levels of organic matter with aim of improving their soil water holding capacity (Adamu & Aliyu. 2012). In generally all the three-soil had higher AWC ranged between 91.52 to 66.30 mm which can be attributed to their loam content because loamy have been reported to have largest plant AWC as well as relatively equally sized gravitational and unavailable water contents (Zachary & Emily.2016). Compared to Haatso serie. Adenta and Toje series were rich in clay whereby higher FC. PWP and AWC this can be attributed to the fact that contrary to sandy loam soil, soil rich in clay have a slight plant-available water content due to enhanced aggregation, but also have a higher unavailable (PWP) water content because the water is held so tightly in the micropores (Zachary & Emily.2016).

Long-term cultivation on soil Saturated Hydraulic Conductivity

Figure 1 presents the graphs of cumulative infiltration I vs time for the various soils and management systems for field conditions and Figure 2, the Ks from laboratory determinations using the constant head permeameter. Generally, the cultivated soils had higher Ks, apparently due to the frequent soil disturbance that "opened" the soil and led to macro-pores. Hence study done by Lado et al,. (2004)



Ks = 0.89 cm/hour **Ks = 1.02 cm/hour**

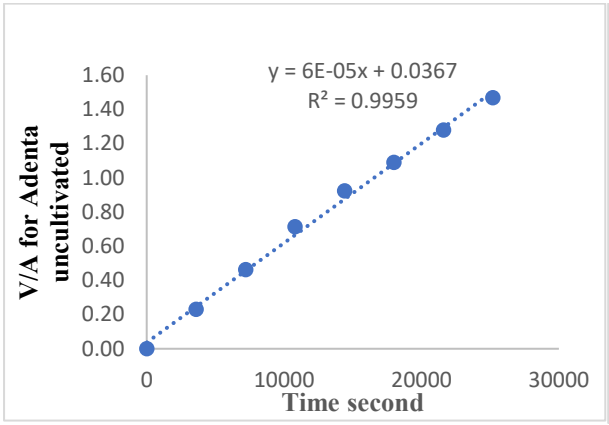
Ks= 0.93 cm/ hour **Ks= 1.04 cm/hour**

Ks= 0.59 cm/hour **Ks= 1.19 cm/ hour**

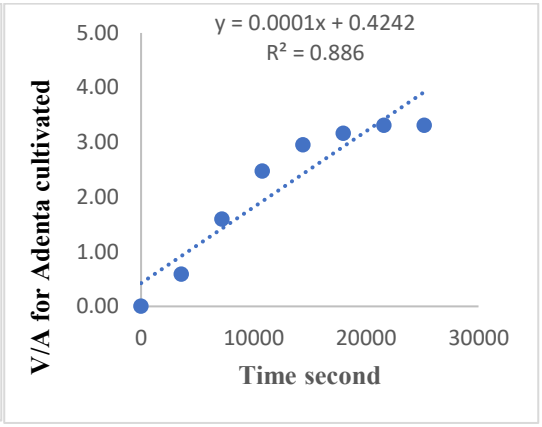
Figure 1: *Infiltration and estimation of saturated hydraulic conductivity using single ringe*

indicated that soil with higher aggregate sizes from 2 -4 mm generated higher Ks than aggregate size <2 which have less macro-pore compare to the first aggregate size. Therefore in all the cases the cultivated soils recorded the highest ks than uncultivated soil which range 1.09 to 20.6 cm/hour and 0.59 to 5.04 cm/hour (Figure 1 and 2). The underlying reasons of this founding may be due to the higher capacity of uncultivated soil to hold more water than cultivated soil. Moreover, it can also be attributed to the loss of soil structure under cultivation condition (Kopittke *et al.*. 2004). The ks under uncultivated soil could have been greater than those in cultivated soil due to greater amount of organic matter content in uncultivated soil as reported by (Kopittke et al, 2004) contrary to this founding. This can probably be attributed to the fact that cultivated soil pore big enough whish can allow downward movement of the dispersed particle with the percolation water without plugging the pores (Lado *et al.*. 2004). The magnitude of ks for the different soil was in a decrease order of Toje >Adenta >Haatso (Figuere 1. 2)

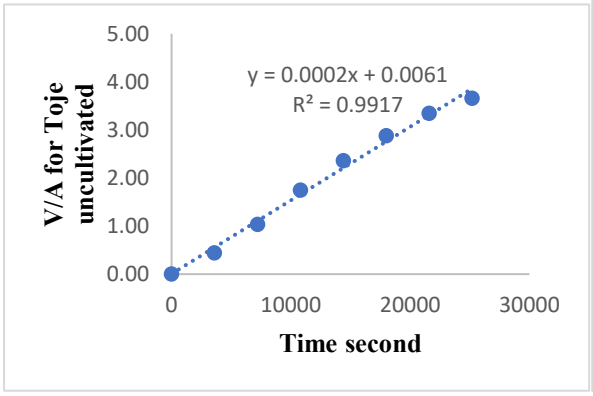
expected that Haatso cultivated had the highest ks using single ringe method. This can be attributed to the greater C content in Toje and Adenta soil compared to Haatso soil since the magnitude of Ks followed the same trend as their organic carbon content. Determination of Ks under both field condition (single steel ring) and laboratory method (constant head) followed generally the same trend for land management and soil types. Moreover, the constant head method always generated highest Ks compared to field condition this can be due to the pre-saturation of soil overnight whereby reduce soil infiltration capacity.



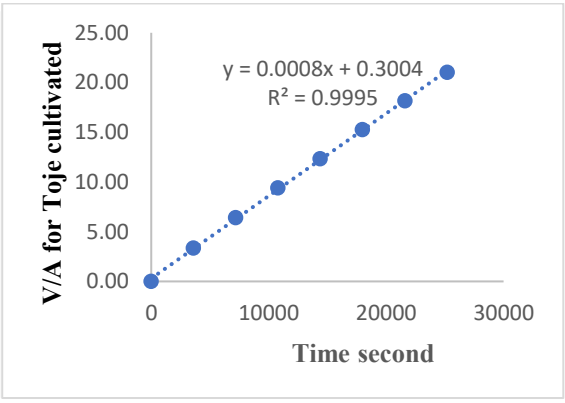
Ks= 1.51



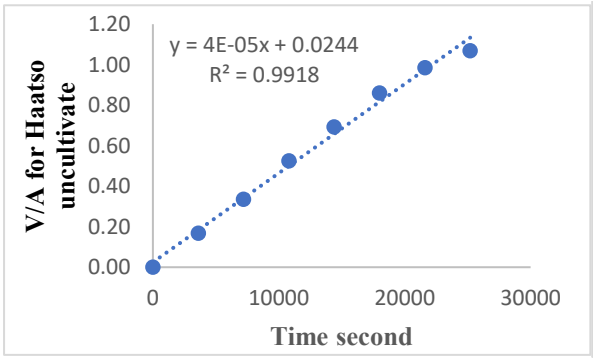
Ks= 2.52 cm/hour



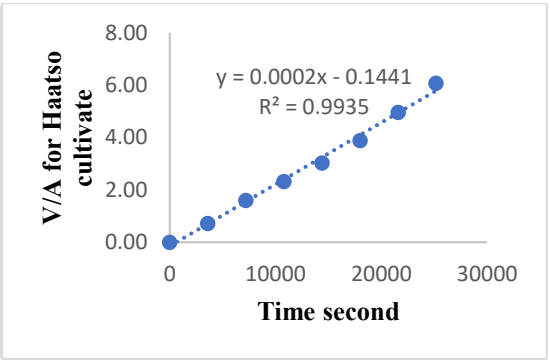
Ks= 5.04



Ks= 20.16



Ks= 1.01



Ks= 5.04

Figure 1: *Hydraulic conductivity using head constant water*

IV. Conclusion

soil pH did not change with longe tern cultivation but slightly low than uncultivated soil. Soil organic carbon, Available Phosphorus content and soil available water capacity for the three soil was found to decline under long tern cultivation condition and also decrease with depth. Contrary to soil organic carbon soil both ρb and saturated hydraulic conductivity (Ks) was slightly higher in cultivated soil than uncultivated soil.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared that there is no conflict of interest

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