Effect of Integrated Soil and Water Conservation on Selected Soil Physicochemical Property and Factors Determining its Adoption in Wulbareg District, Southern Ethiopia

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Abstract

To overcome the problem of land degradation expanding the elephant grass to the degraded land for soil and water conservation in sustainable land management practice were better option for farmer. Objectives are *assesses the effect of integrated soil and water conservation on selected soil physicochemical property and factors determining its adoption in, Ethiopia.* Materials and Methods **of** data *were collected through soil sampling, field observation and household interviews. SPSS software version 21, the data were analyzed using descriptive statistical. Survey data was analysis for continuous variables by using independent sample t-test and for dummy variable chi-square and logistic regression to determine the predictive variable.* Results, *Based on the finding sand, silt and clay contents were varied significantly (P < 0.05) between the land management practices. There was significantly higher mean bulk density value for the soil bund compared to the values for the rest of the land management practices. When comparing the soil bund with elephant grass to the soil bund without elephant grass, the mean value of hydrogen power was much higher. The trend was similar for total nitrogen, available phosphorus. Furthermore, sex, total tropical livestock unit, and information about agriculture were significantly influenced adoption of soil and water conservation technology (elephant grass).* Main finding *the soils under the bund with elephant grass revealed that overall change towards the direction of increasing their fertility status compared to soil bund alone. Thus, stabilization of bunds with elephant grass significantly benefit to the soil for its fertility improvement.*

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Keywords: - Adoption, Elephant Grass, Farmers, Soil Bund, and soil erosion, Wulbareg district

Introduction

Land degradation is a huge environmental, social, and economic issue all across the world, particularly in Africa (Ayal and Olayide, 2021. For many years, the Ethiopian highlands, which are the site of important agricultural and industrial operations, have been subjected to soil erosion. For example, the problem of degradation is rising in the highlands, where over 88 percent of human and 77 percent of cattle populations are housed (Bjornlund and Van Rooyen 2020).According Yigezu (2021), reported that the heavy reliance of some 85 percent of Ethiopia's growing population on an unfair kind of subsistence agriculture is a major reason behind the current state of land degradation. The loss of agricultural value due to soil degradation in Ethiopia between 2000 and 2010 is estimated to be $US 7 billion, a colossal number in comparison to current investments in sustainable land management (Haile, 2019). Every year Ethiopia is losing billions of birr in the form of soil, nutrient, water and agro biodiversity losses (Abebaw, 2019). As a result, poverty and food insecurity are concentrated in rural areas (kassegn and Endris, 2021).

To reduce the consequences of soil degradation, the Ethiopian government has implemented a variety of soil and water conservation initiatives (Gessese, 2022). Although soil and water conservation technologies play important roles in soil property and socioeconomic improvements, adoption of the interventions is minimal (Yaekob *et al* ., 2020).

Studies conducted in different parts of the Ethiopia came-up with different factors that explains the failure of soil and water conservation technology (Wolka *et al* ., 2013). Furthermore, a top-down approach to extension activity, focusing primarily on structural conservation technologies, as well as a lack of integration of physical conservation with biological measures, and land security challenges, all contribute significantly to the failure of SWC work). Soil and water conservation strategies are currently focusing on both physical and biological methods (Wolka 2014). However, the rate of adoption, sustainability, and effectiveness of the techniques remains very low due to community mismanagement and misunderstanding about the relevance of agricultural technology in enhancing soil fertility status and socioeconomic conditions (Bardgett et al., 2021). The farmers in the study area also less awarded on the importance of SWC technology practices. This implies the potential socioeconomic and environmental effect of elephant grass in some parts of Ethiopia however in southern parts of Ethiopia particularly in Wulberag district limited information is available on effect of elephant grass on soil properties, and factors determine elephant grass adoption. In generally integrated use of soil and water conservation were vigorous role for sustainable land management practices. .Therefore, this study is underway to explore the effects of elephant grass on selected soil properties and the adoption of elephant grass by smallholder farmers in Wulberag districts. The main goal of this study was expanding the elephant grass to the degraded land for soil and water conservation in sustainable land management practice better option to farmer and paved for policy makers.

Materials and Methods

The study was conducted in Wulbareg district which is found in Silte Zone southern Nation Nationalities and People Regional State of Ethiopia. The most overriding soil in the area is Nitosol and Vitric covering the whole district (FAO, 2002). The district receives mean annual rainfall of 1001-1200 mm and temperatures ranges of 15-20^{0}c. Agro ecologically the district has as 32% midland (*Weynedega*) and 68% Lowland (*Qolla*) land coverage (WUOANR, 2021). The livelihood of the people in the district depends mainly on mixed agriculture (crop and livestock production). Based on the land management practices are the dominant soil and water conservation measures that introduced to the farmlands are physical structures (soil bunds) and biological SWC (elephant grass)

Data for this study was collected from two sources: primary and secondary data sources. To determine the effects of elephant grass on selected soil physicochemical properties, composite soil samples were collected from croplands managed with soil bund alone and soil bund stabilized with elephant grass. Soil samples were collected from cropland at 30cm sampling depth (Margesin and Schinner 2005). The size of each plot from which the composite soil samples had been taken was 5 m × 5 m at 1m away from the bunds. From structures of treated with elephant grass and without elephant grass the soil samples were collected from two slope range (upper 15-30%and lower 3-15%) of the cropland .The slope ranges were measured using clinometers and the lower and upper ranges were determined during field work for soil sampling. Composite soil samples were collected using simple random sampling via auger (Margesin and Schinner, 2005). To determine soil bulk density, undisturbed soil sample were collected using core-sampling method. Total 20 composite soil samples were collected 30 cm sampling depths. The age of bunds considered in this study has the same year of construction and plantations of elephant grass to stabilize the structure were undertaken in similar year. To assess factors determining adoptions on the grass in the study area structured and semi-structured questionnaires were used. In the study area Wochoobiso kebele (small unit administration) has total of 960 total households, of these 121 respondents were selected using Cochran's (1977) sample size determination formula

Soil Laboratory analysis

Analysis was carried out at Wolaita sodo soil laboratory according to the standard of soil analysis procedures provided by Sahlemedhin and Taye (2000). The collected soil samples were air-dried, mixed well and pass through a 2 mm sieve to analyze the selected. Soil particle size distribution was determined by Boycouse Hydrometer method (Houba et al., 1989) after organic matter was destroyed by addition of hydrogen peroxide (H2O2), disperse cementation with hexametaphosphate (NaPO3)6 and sodium carbonate (Na2CO3), and removes foam via amyl alcohol. Bulk density of undisturbed soil sample were determined by core method (FAO, 2007), using the ratio of solid mass to total volume when the sample was dried in an oven at 105°C for 24 hours. The gravimetric method was used to determine soil moisture content. Soil reaction (pH) was measured with pH meter glass electrodes in 1:2.5 (soil: water on a mass to volume basis) suspension after calibration of the pH meter with buffer solutions (pH 4, 7 and 10). Soil electrical conductivity (EC) was measured by conductivity meter 1:2.5 (soil: water on a mass to volume basis) suspension after the calibration of EC meter. Walkley and Black wet digestion method was used for organic carbon determination (Walkley and Black, 1934). Soil total nitrogen was determined by Kjeldahl digestion procedure (Bremmer, 1996). Bray II method was used to extract available phosphorus (Av. P) from soil (Van Reeuwisk, 1993), and the extracted Av.p was determined using spectrophotometer at a wavelength of 820 nm.

Data Analysis

Soil laboratory data were subjected (SPSS version 21 software) to determine analysis of variance (ANOVA) and significant means were compared using LSD at 0.05 probability level. Correlation analysis was made using Pearson's simple correlation coefficient between all soil parameters. Household survey was analysis for continuous variables by using independent sample t-test and for dummy variable chi-square and Logistic regression model used in this study.

Results and Discussion

Effects of Elephant grass on selected physical properties

There was a significant ($p<0.05$) difference in sand percentage between soil bunds treated with elephant grass and soil bunds not treated with elephant grass, as shown in (Table 1). The mean (21.55±2.62) percentage value of sand at lands treated with soil bund was higher than land treated with both soil bund and elephant grass and lower mean value (21.00±3.22) from bund with elephant grass whereas, the higher clay percentage (46±3.81) was found at lands treated soil bund with elephant grass and lower (45 ±3.55) percentage of clay in soil bund alone. This might be due to elephant grass has a massive root system that anchoring fine soil particles and strength the bund. This current study in line with (Umer *et al* ., 2019) whose report that desho grass is massive root system strengthens the soil structure and improves water conservation capacities. According to USDA (2004), soil textural classification, soil of the study area lands treated with both soil bund and elephant grass, have clay texture. A significant difference ($P < 0.05$) was observed for sand, and clay percentage between the upper and lower slope positions. Between the slopes positions the highest mean percentage of sand (24±2.10) was recorded at upper slope position while lowest value (21.65±1.91) at lower slope position (Table 1). Further, highest silt fraction was observed at lower slope at lands treated with elephant grass. The textural class was found clay loam in the upper and clay in the lower slope positions. This indicated that highest clay content observed under the bund with elephant grass and at the lower position might be due to the slope stabilization ability of the elephant grass that results in the accumulation of finer soil material that is being transported from the upper slope positions in contrast to the sand and silt fractions. This is in line with Muleta, (2016) ,reported that considering soil bunds of similar age and the bund that stabilized with vetiver grass had significantly highest proportion of clay particles than the bund without vetiver grass. Similar, the lower slope position was higher amount of clay particle through inducing the loss of fine particle or clay separate. This is because of it aggravates the surface soil detachment and runoff loss.

Table 1. Effects (mean ± MSD) of soil with elephant grass selected soil physical properties

Soil parameters	Management practice SBWE	Management practice SBWOE	P-value	Slope position **Upper**	Slope position **Lower**	p-value
Sand (%)	21.00±3.22^{b}	21.55±2.62^{a}	0.0011	24.00±2.10^{a}	21.65±1.91^{b}	0.0014
Silt (%)	34.26±2.82^{a}	36.04±2.61^{a}	0.2231	31.00±2.67 ^{a}	32.00±1.99^{a}	0.0761
Clay (%)	45±3.55^{a}	46±3.81^{b}	0.0001	45.850±3.43 ^{b}	47.00±2.02^{a}	0.0023
Textural class	Clay	Clay		Clay loam	Clay	
BD (g/cm^3)	1.03±0.03^{b}	1.21±0.04^{a}	0.0003	1.08±0.06^{a}	1.06±0.08^{b}	0.0001
MC (%)	18.01±1.53^{a}	13.10±1.64^{b}	0.0002	11.43±12.56^{b}	12.78±1.75^{a}	0.0004

SBWE= Soil bund with Elephant grass, SBWOE= Soil bund without Elephant grass, BD = Bulk density, MC = Moisture content, in column two superscript followed with a same lower letter for the same soil parameters are not significantly different at P=0.05

Besides, statistically a significant difference (p [?] 0.05) in soil bulk density at lands managed with soil bunds with elephant grass both in the upper and lower slope position (Table 1). The highest mean value ($1.08 g/cm^3$) of soil bulk density was found at the upper slope position while the lowest was at the lower slope position ($1.06 g/cm^3$). Whereas the highest mean value ($1.21 g/cm^3$) were recorded soil bund without elephant grass and lowest mean value ($1.03 g/cm^3$) were observed soil bund with elephant grass. This is decreased soil bulk density under the soil bund with elephant grass is might be due to organic matter accumulation, more clay content and at the lower slope position soil bulk density has a direct relation with slope position which might be attributed to the corresponding decline in soil organic carbon content with the increase in slope position. This is in line with Tadele*et al* ., (2011), indicated that relatively lower bulk density is associated with the presence of higher OM and clay content.

The Correlation coefficient also shown the negative relationships between bulk density and clay contents ($p<0.001$, r= -0.30), bulk density and organic matter ($p< 0.001$, r = -0.64).The study conducted by Frank (1990) the bulk density of agricultural soil ranges from 0.9-1.2 gm/cm^3.The mean bulk density result obtained ranged between 1.06 and 1.08gm/cm^3under the bund with and without elephant grass were therefore within the normal range for agricultural soil for both conservation measures.

Moreover, statistically a significant differences ($p<0.05$) were observed in soil moisture contents between lands managed with soil bund and with elephant grass. The highest mean values (18.01%) of soil moisture was found at land managed with elephant grass while, the lowest mean value (13.10) was at land managed with soil bund alone. This increased soil moisture under the soil bund with elephant grass is might be due to organic matter accumulation, more clay content and contribution of slope position of the soil under the bund with elephant grass and at the lower slope position. The mean values of soil moisture content at upper and lower slope position were also significantly different ($p<0.05$); the highest mean value (12.78%) was observed at lower slope position and lowest (11.43%) in the upper slope positions. This might be due to associated with the difference in the distribution of SOM and clay fraction in the lower slope positions.

Effect of Elephant grass on soil chemical properties

As presented in below (Table 2) significant ($p<0.05$) variation of soil pH between lands managed soil bunds alone and soil bunds with elephant grass. The highest mean pH value (5.76) was found at soil bund stabilized with elephant grass while the lowest (5.70) was at lands managed with soil bund alone. This was most probably attributed to the presence of higher amount of clay fraction and major basic cations (Ca^{+2}, Na^{+}, $Mg^{+2}$and K^{+}) under the structure. This finding is in line with Demelash and Stahr, (2010),who reported that soils with high organic matter content have a higher soil pH which favors better exchange of bases. Hence, the lower mean value of pH might be related to the relatively lower base saturation percentage and lower soil organic matter content. Similar to land management practices, the pH of soil was significantly different in upper and lower slope position (Table 2). The mean values observed at the slope positions the highest mean value of pH (5.73) was recorded at the upper slope position. The lower pH value at the lower slope position might be related with the release of organic acids from the decomposition of the highly accumulated organic matters and the abundant concentration of soil micro-organisms than at the upper slope position those facilitate the decomposition processes and release of CO_2 at this position. Hence, this release of organic acids may increases the accumulation of acid and decreases soil pH at this position. This is in agreement with the findings of Mulatu *et al.* (2014) and Fungai (2006), who reported that release of organic acids from the decomposition of organic matter lower the pH value of the soil. However, the finding argue with Shimeles *et al.* (2012) and Tadele *et al.* (2013) who reported that pH is higher at the lower slope position.

The results that are presented in the (Table.2) below a non-significant difference at ($p<0.05$) was observed both in EC between the bunds with and without elephant grass whereas, similar in slope position of soil bunds (Table 2). Higher mean values of EC (0.136ds/m) were recorded from the bund with elephant grass while the lower figure was from the bund without elephant. The comparative change of EC was increased under with elephant grass as compare to the value under soil bund alone. When comparing the value of at different slope position of bund with elephant and soil bund alone with each together, the mean value of EC at lower and upper slope position of the bund elephant grass was enhancing. The correlation matrix shown positive and highly significant relationship between pH and EC(r=0.50**).

Table .2 Effect of elephant grass on selected soil physicochemical properties (Mean ±MSD)

Soil parameters	Management practice	Management practice	P-value	Slope gradient	Slope gradient	p-value
	SBWE	SBWOE		Upper	Lower	
pH	5.76±0.36[a]	5.70±0.09[b]	0.0003	5.73±0.51[a]	5.51±0.21[b]	0.0500
EC (ds/m)	0.136±0.05[a]	0.067±0.02[b]	0.0443	0.078±0.064[a]	0.087±0.028[a]	0.8773
OC (%)	2.43±0.55[a]	1.75±0.49[b]	0.0023	1.90±0.154[b]	2.30±0.302[a]	0.0001
TN (%)	0.22±0.06[a]	0.21±0.04[b]	0.0002	0.17±0.056[b]	0. 18±0.01[a]	0.0021
Av.P (ppm)	6.17±0.98[a]	4.90±0.71[b]	0.0012	4.69±0.65[b]	5.95±0.62[a]	0.0010
CEC(meq/100g)	28.82±2.99[a]	26.92±2.17[b]	0.0178	28.55±1.60[b]	31.49±1.86[a]	0.0007

EC = electrical conductivity, OC = Organic carbon, OM = Organic matter, TN = Total nitrogen, Av.P = Available potassium, SBWE= Soil bund with elephant grass, SBWOE= Soil bund without elephant grass in *column two superscript followed with a same lower letter for the same soil parameters are not significantly different at P=0.05*

Similarly, the soil bund stabilized with elephant grass had higher OC (2.43%), TN (0.22%) C: N (14.24) and Av.P (6.17) contents than the soil bund alone. The analysis of variance reveal that there was a highly significant (p [?] 0.05) difference in TN, OC C: N and Av.P between soil bund with elephant grass and soil bund alone (Table 3. The organic matter source from above ground biomass and underground biomass may causes for the higher mean values of OC and TN observed under land use conserved with bund stabilized with elephant grass. This result in line with the results of (Anggria *et al* ., 2012) stated that about 99% of the N in the soil is in the form of organic matter and in the process of mineralization N from organic matter converted to ammonium ($NH4^{+}$).

Comparing the mean values observed at the two slope positions there were statistically significant difference ($p<0.05$) on the values of OC. The lower slope position exhibited higher mean values of OC compared to the upper slope positions (Table 2). This shows soil at upper slope position might be usually affected by over topping detachments that displaces the nutrients down to the low lying positions and resulted in low accumulation of soil fertility indicators to this position. In contrast the highest accumulation of nutrients to the lower position indicated that the nutrients were highly transported down through runoff and abandoned the existence of the elements to this position. In line with this finding Yibabe *et al.* (2002) also reported that organic matter content increased at the accumulation zone than the loss zone

The analysis of variance showed that there was a highly significant (p [?] 0.05) difference in TN between soil bund with elephant grass and soil bund alone (Table 4). The soil bund stabilized with elephant grass had higher TN contents than the bund without elephant grass. This confirmed that bund with elephant grass may have the potential to stabilize soil bund than the bund without elephant o grass and plays a great role in the accumulations of the nutrients in the soil. This result in line with this finding Paul (2000), reported that vetiver grass will form a broad hedge and a living barrier which slows and spreads runoff water safely. When compare the mean values observed at the upper and lower slope there was statistically significant ($p<0.05$) difference on the values TN. Accordingly the lower slope position exhibited higher mean value of TN, as compared to upper slope position. Current result is comparable with the finding of Tadele *et al* . (2013), who reported that the difference between the deposition and loss zones for total N is statistically significant where the highest was found at the deposition zone. Besides, slope position indicated that the nutrients were highly transported down through runoff and deserted the existence of the elements to lower slope position.

In another hand the analysis of variance shown that there was a highly significant (p [?] 0.05) difference in Av.P between soil bund with elephant grass and soil bund alone (Table 2). While the difference between the land management practices could be related to OM content differences. This may confirms that with higher Av.p concentration in the depositions zone there were relatively higher biomass production and in turn produces higher soil organic matter which is the store of Av.P. This finding is comparable with Paul (2005) who reported that Av.p were higher in parcels of land bounded by Vetver grass than those without grass.When compare the mean values observed at the upper and lower slope there were statistically significant difference ($p<0.05$) on the values of Av.P. Accordingly, the lower slope position exhibited higher mean value of Av.p as compared to upper slope position (Table.2).The variation in Av. P between deposition and loss zones can be due to washing out in the upper parts and accumulation at the lower parts. And might be the surface runoff shifted nutrients downwards to the lower slope position.

Besides, the analysis of variance shown that the CEC was significantly ($p<0.05\%$) difference with studies land management practices soil bund with and without elephant grass. The highest mean value of CEC was found soil bund with elephant grass and the lowest mean value was found soil bund alone. The reason might be due to soil bund with elephant grass accumulated high organic carbon, clay and, has greater capacity to hold cations so that greater potential fertility in the soil. CEC is expected to increase through improvement the soil organic matter content. In addition to that CEC of the soil was positively correlated with clay($r= 0.34$) and organic carbon($r= 0.72^{**}$. Current finding is in line with Kibret (2008), reported that soil CEC is associated with clay and organic colloids and especially organic matter renders soils a better CEC. Between slope position, CEC was also significantly ($p<0.05$) different, the highest mean value (30.39 cmol (+)/1kg observed in lower slope position and lower mean value (cmol(+)/1kg) was observed in the upper slope position.

Farmer's adoption to stabilize soil bunds with elephant grass

To understand factors that determine the adoption of the elephant grass in the study area; farmers' perception on soil erosion problem, socio-economic, physical, technological and institutional factors were studied. To achieve this, farmers those who adopt elephant grass as conservation measure and non- adopters were interviewed, these results were presented in the following below.

The t-test result indicated that there was statistically significantly difference ($P <0.05$) between adopters and non–adopters. Livestock production is one of the farming activities and source of income for working capital. Therefore, the owners of small number of livestock have better interest to use elephant grass to ensure the requirement of grazing for their livestock. This result is disagreement with (Sinore *et al* ., 2014) arising due to the use of similar land management practice for lands under different conditions: already degraded land for restoration. In order to test the relation between land holding and adopters of elephant grass and non-adopter in their cropland, t-test was conducted and the result indicated statistically significant difference in the size of landholdings ($P< 0.05$). Accordingly, farm household with relatively small farm size were the first in adopting elephant grass on their cropland. This in line with the findings of Girmachew (2005) reported that about determinants of adoption of soil and water conservation.

Table 3. Independent t-test on factors influence grass to stabilization soil bund

Dependent variables		Mean	S.D	t-test	Sign
Family size	Adopter	0.30	0.47	0.21	0.020
	Non-adopter	0.31	0.77		
Landholding size (ha)	Adopter	0.80	0.42	-2.7	0.002
	Non-adopter	0.56	0.67		
Farming experience (year	Adopter	24.4	12.14	1.21	0.211
	Non-adopter	22.5	11.32		
Livestock holding (TLU)	Adopter	1.87	1.23	2.56	0.061
	Non-adopter	2.45	1.42		

The result indicated in below (table 4) that there was statistically significance difference ($P <0.05$) the of elephant grass in their level of education. Education has vital importance to understand and interpret the information received from any sources. This is might be influences farmers' adopt technologies by enhancing farmers' ability to obtain, understand and utilize. Access to relevant agricultural information serves farmers for better understanding and facilitates behavioral change that result in making adoption. The test statistics revealed statistically significantly determine (P[?] 0.05). As a result, it can be users of elephant grass adopter have better opportunities to receive agricultural information from development agent. The test revealed that statistically significantly (P[?] 0.05) determines. The reason was that the non–adopter group was not invited for training.

Table 4. Chi-square test on the relationship between grass adopter and non-adopter farmers

Variables		Adopter	Non- adopter	p-value
Educational status	Illiterate	6.5%	3 .7%	0.003
	Elementary school	10.1%	8.3%	
	Secondary school	60.5%	16. 5%	

Variables		Adopter	Non- adopter	p-value
SWC information access	Development agents (DA)	49.1%	1.5%	0.005
	Family in neighbor	7.3%	2.4%	
	Media (FM radio)	12.8%	14.4%	
	NGOs	4.4%	6.5%	
Attend SWC training	Yes	69.2.0%	0.9%	0.001
	No	0.9%	31.2%	
Sex	Male	65.7%	7.9%	0.002
	Female	7.1%	21.4%	
Age	(> 18 < 65)	42.2%	11.4%	0.533
	(< 18 > 65	33.5%	12.9%	

Conclusion and Recommendation

The soils under the bund with elephant grass showed overall change towards the direction of increasing their fertility status compared to the soils under the adjacent soil bund alone. Statistical analysis of the results also indicated that significant ($P < 0.05$) difference on soil fertility improvement along the slope position of the bund with elephant grass compared to the soil bund alone. Hence, elephant grass plays a fundamental role in improving soil fertility and stabilizing the slope**.** So, results designate effectiveness of elephant grass on the selected soil physico-chemical properties slope stabilization and improve the soil in the study area. The outcomes of the descriptive analysis indicated that adopter of elephant grass have frequent contact with the extension service and hence better chance for participating in agricultural training and relatively many of them have agricultural information. Concerning to gender, the number of female adopter were insignificant when compared to their male counterparts; female households owned relatively small size farm land and training, extension service and are high in their educational level.

Access to extension service also significant at less than 5 percent probability level indicates that adopter of elephant grass have better access to extension service which enables them to gain more information about agricultural technology.

Based on the result the following recommendation was forwarded:-

Elephant grass has a great contribution on soil physicochemical properties improvement. Hence expanding elephant grasses within the same agro ecology is the better option for farmers.

Finally it is the felt need of the author, to see studies on elephant grass adoption determinants that are not addressed by this study such as leadership status, off-farm income, credit service, land security, soil type, and others.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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