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Evaluation of Infiltration Rate of Landmark University Soils, Omu-Aran, Nigeria

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Abstract

The processing of adequate information of characteristics of soils is essential for designing quality soil management and construction practices on agricultural and urban lands. Little is known about the infiltration capacity of soils in institutions of higher learning, this study therefore evaluated the infiltration capacity of soils in the Landmark University, Omu-Aran. The double ring infiltrometer with an inner ring of 30 cm and a 50 cm diameter outer ring with a height of 30 cm above the ground was used to test infiltration rates at two sites, namely the University of Omu-Aran's orchard area (OA) and the new college building area (NCBA). Six points labelled (A, B, C, D, E and F) were identified at 10 m grid intervals at which infiltration rates were determined using a 30 cm inner ring double ring infiltrometer and a 30 cm height outer ring. Results of soil analysis suggests sand dirty and silt texture and bulk density and particle density varied from 2.54–3.03 g/cm^3 and 1.31–1.52 g/cm^3 respectively. The infiltration rates ranged between 0.007 to 0.011 cm/sec with a mean of 0.009cm/sec in orchard area (OA) and 0.011 to 0.035 cm/sec with a mean value of 0.021 cm/sec in NCBA indicating a significant difference at both locations. The infiltration rate of soils at the OA is very low compare to that of NCBA therefore the OA is more prone to flooding. Effective drainage control system is recommended along the orchard area to prevent flooding.

Keywords: Infiltration rate, double ring infiltrometer, Landmark University Omu-Aran

Introduction

Infiltration is vital in modelling of surface runoff (Suresh, 2008), and it is usually difficult to be evaluated or measured accurately (Ildefonso, 2013). The infiltration rate is the amount of water going into the soil per unit of time that determine the soil moisture availability for plants. The rate of infiltration and evaporation are the two important parameters in soil water conservation (Asdak, 2004; Mawardi 2011; Mawardi, 2012). Infiltration reflects the proficiency of a soil profile to absorb water (Mawardi, 2012). Soil with extremely high infiltration rate have poor aeration because the pores are filled with water, which is not suitable for plants. Excess water in the soil is often as a result of construction and agricultural activities, such as the unsuitable use of irrigation systems. However, some zones are naturally vulnerable to water-logged soil because of the type of soil, topography, torrential showers, overflowing, or a high water table. Soils which has high composition of clay have the tendency of greater more drainage difficulties than sandy soils because they have the tendency to be of the ease of compaction (Macie, 2013). Estimation of crop water requirement in dry lands need information about soil infiltration characteristics. Many storm water management measures are grounded on the retaining of storm water and its infiltration into nearby soils. Consequently, having information of the capacity of soils to infiltrate water, is one of the significant parameters when designing storm control measures (Radinja, Comas, Corominas & Atanasov, 2019). This information is also useful in the management of dryland and can suggest an idea about the crop water requirement during their growing seasons. Wang *et al*., (2012) proved that water is fundamental to the biophysical processes to maintain the functioning of the ecosystems and food production in drylands. Drylands are usually located on a landscape that was not flooded during certain times of the year, and relies on rain water (Abdurachman, Dariah & Mulyani, 2008). The aim of this paper is to assess the infiltration rate of soil and compare the observed infiltration rate with calculated infiltration with the Kostiakov equation, at the Landmark University, Nigeria.

Material and Methods

The study area is Landmark University which is situated in Omu-aran, in the southern part of Kwara State, Nigeria. It is an indigenous town between 8 ° 8′00′N latitude, 5 ° 6′00″E longitude and 564 m above sea level. (Elemile, Raphael, Omole, Oloruntoba, Ajayi & Ohwavborua 2019). The climate here is tropical. There is a good amount of rainfall during the raining season, while during the dry season the rain is very little. In Omu Aran, the average annual temperature is 24.9 °C with an annual precipitation of about 1273 mm of precipitation. (Elemile *et al.,* 2019). The major type of soil in landmark and its environs are clayey, sandy or gravely in texture with either reddish-brown or brownish grey in colour with a profile depth ranging from 3.5-5 m, the parent materials are either migmatite or quartzite. Figure 1 shows the description of the Study Area and the locations of the sampling points.

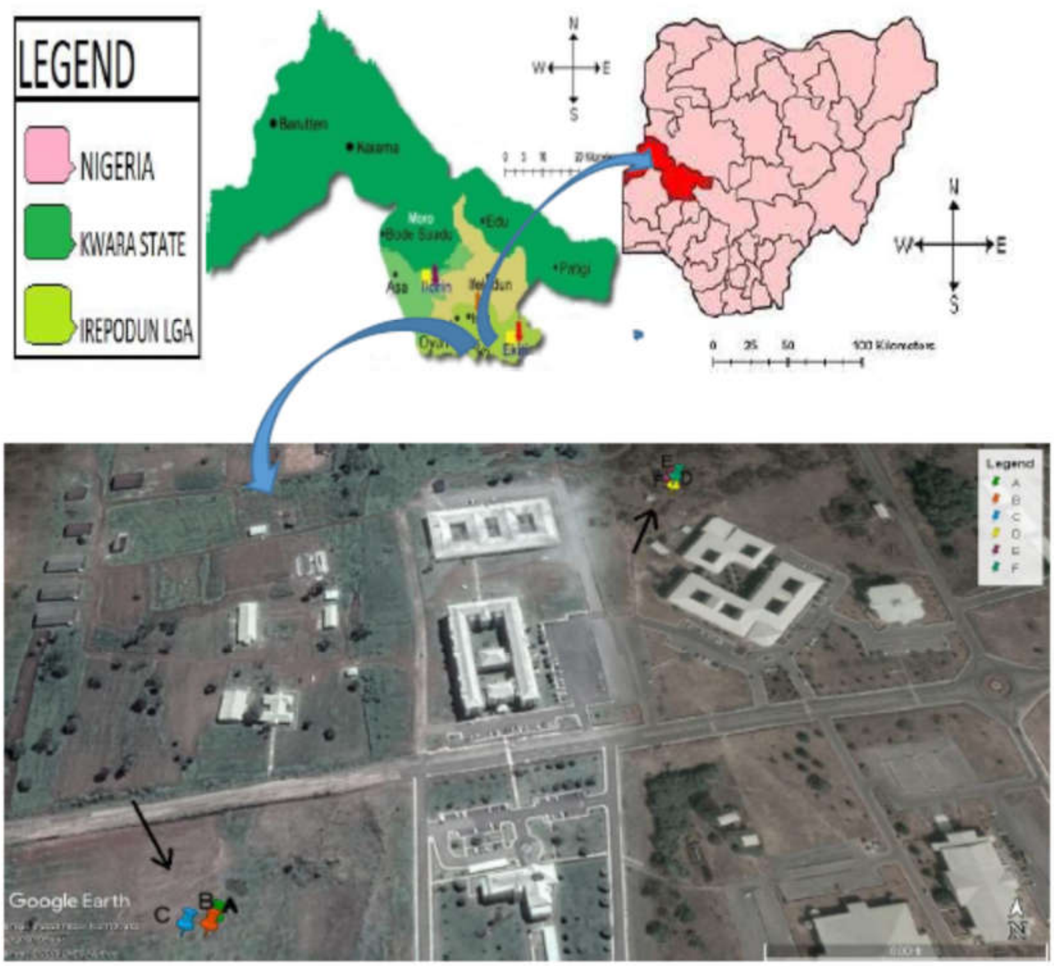


Figure 1: Location of test points (A, B, C, D, E & F) in Landmark University

Sample collection and geotechnical tests

The study area is the Orchard and the proposed site for the School of Post Graduate Studies Building. Three samples were collected per location, which made a total of 6 samples. The soil samples were collected using a soil auger at a depth of 6 to 8 inches from the surface and were stored in a transparent polythene bag. Each polythene bag was marked clearly with a label indicating the coordinates, location and time from which the sample was taken. The soil samples were taken to the Geotechnical laboratory of the Civil Engineering Department of Landmark University, where the geotechnical test was performed.

Geotechnical tests

The following geotechnical properties were tested for: Atterberg limits, the different densities, particle size distribution, permeability, and the parameters related to consolidation and shear strength.

Sieve Analysis: This test method includes the determination of the distribution of particle size by sieving of fine and coarse aggregates. The results were used to assess particle size distribution compliance with relevant specification specifications, the data is useful in the creation of porosity and packaging relationships.

Permeability: Permeability was computed by using equation;

$$K_T = \frac{Q\ xL}{A\ x\ t\ x\ h} \quad (1)$$

Where:

K_T = coefficient of permeability at temperature T, cm/sec.
L = length of specimen in centimetres
t = time for discharge in seconds
Q = volume of discharge in cm^3 (assume 1 mL = 1 cm^3)
A = cross-sectional area of Permeameter ($\frac{\pi}{4}$ D^2)
D= inside diameter of the Permeameter)
h = hydraulic head difference across length L, in cm of water; or it is equal to the vertical distance between the constant funnel head level and the chamber overflow level.

Measurement of infiltration rate

The infiltration rate was measured with the double-ring infiltrometer. The driving cap was placed on the outer ring and centered thereon, then the ring was driven into the soil with the use of a sledge hammer. The ring was driven to a depth at which water is prevented from leaking to the surface surrounding the ring (a 150mm depth is usually sufficient) after which the smaller/inner ring was also driven into the ground. A foam or large paper was placed in the rings so as to avoid compaction of soil due to pouring of water. The apparatus was filled with water and the infiltration readings were taken using the staff gauge at the intervals of 2 minutes, 5minutes, 10minutes, 30 minutes and 60 minutes of which the total time elapsed was 2 hours. This was also repeated at the second location which is the proposed site for the school of postgraduate studies. Plate 1, 2 and 3 shows the measurement of infiltration rate with the double ring infiltrometer

Kostiakov equation: Kostiakov equation was applied in this study so as to compare the calculated infiltration rate to the observed ones.

This equation is given by:

$$f_p = K_k t^{\alpha} \quad (2)$$

Where:

fp = infiltration capacity

t = time after infiltration starts [t]

K_k [L] and α [unitless] are constants that depend on the soil and initial conditions.

Taking the logs of both sides gives:

$$log f_p = log K_k - \alpha \log t \quad (3)$$

Parameter values were determined for K_k and α by plotting log fp against log t. This results in a straight line if the Kostiakov equation applies to the results. The equation intercept (infiltration rate at time t= 1) is log Kk and the pendulum is-α. The equation logarithmic form has been used: log f

p= log K k-α logt (4)

where:

fp = infiltration capacity

t = time after infiltration starts [t]

K_k [L] and α [unitless] are constants that depend on the soil and initial conditions.

Plate 1: Double ring infiltrometer and driving cap

Plate 2: Double ring infiltrometer filled with water

Plate 3: Double ring and driving cap filled with water with the measuring staff gauge

Results and Discussion

Infiltration rate at the two ocations

Table 2 shows the infiltration rates at the sampling points of the two locations. For the Orchard, the infiltration rate ranged between 0.007 to 0.011 cm/sec. with a mean of 0.009cm/sec in comparison with the values of 0.011 to 0.035 cm/sec with a mean value of 0.021 cm/sec. This shows that the infiltration rate of the soil at the orchard is lower than that of the soil behind the New College Building and there is a significant difference. The reasons that can be adduced is that the infiltration rate at the orchard is low because the soil had not been cultivated for a while and it agrees with the study by (Kumar, 2014) that agricultural activities also affects infiltration rate. For the soil to be useful for agricultural activities, there is need to plough the soil, to increase the infiltration rate. For the soil behind the New College Building, the infiltration rate is high and this implies that the soil is less dense therefore in order to use the soil for construction purpose, it had to be compacted to eliminate the voids.

Infiltration rate and cumulative time

Figure 2 shows the comparison of the infiltration rate with the cumulative time for the two locations. It revealed that the infiltration rates were: 0.04 and 0.008; 0.051and 0.011; 0.015 and 0.01; 0.015 and 0.01; 0.009 and 0.001 cm/sec at 0.0, 6.0, 10.0, 20.0, 60 and 120 secs at behind the New College Building and the Orchard respectively. The result shows a clear difference between the two locations and also it shows the spiking behaviour of the infiltration at the beginning of the experiment before a uniform reading was gotten, this is because the initial moisture content of soil was low and requires time to saturate

The profiles of the respondents and organizations were investigated according to the opinions of the respondents and presented in Table 1.

Permeability and infiltration rate

Table 2 reflects the comparison of permeability with corresponding infiltration rate while Table 3 shows the soil classification according to range of hydraulic conductivity as documented by (Varun, 2017). The results from table 3 shows that the coefficient of permeability were 1.14 x 10^{-6}, 6.75 x 10^{-6} and 2.16 x 10^{-6} and 2.34 x 10^{-5}, 1.82 x 10^{-5} and 9.65 x 10^{-5} for the orchard and behind the New College Building respectively and it was revealed that there were significant differences between the two locations. This reveals that the soil at the orchard is less permeable than the soil behind New

College. Building According to the classification in Table 3, the soil at the Orchard lowly permeable while that at the back of the New College building is classified as permeable. In comparison of the various infiltration rates in Figure 2, it revealed that the infiltration capacity of soil is directly proportional to its coefficient of permeability and this is in agreement with Yu et al., 2015

Table 1: Infiltration rate at the Two Locations

	Location							
	Orchard				Behind New College Building			
	A	**B**	**C**	**Mean + SD**	**D**	**E**	**F**	**Mean + SD**
Infiltration Rate(cm/sec)	0.007	0.011	0.009	0.009 + 0.002	0.017	0.011	0.035	0.021 + 0.010

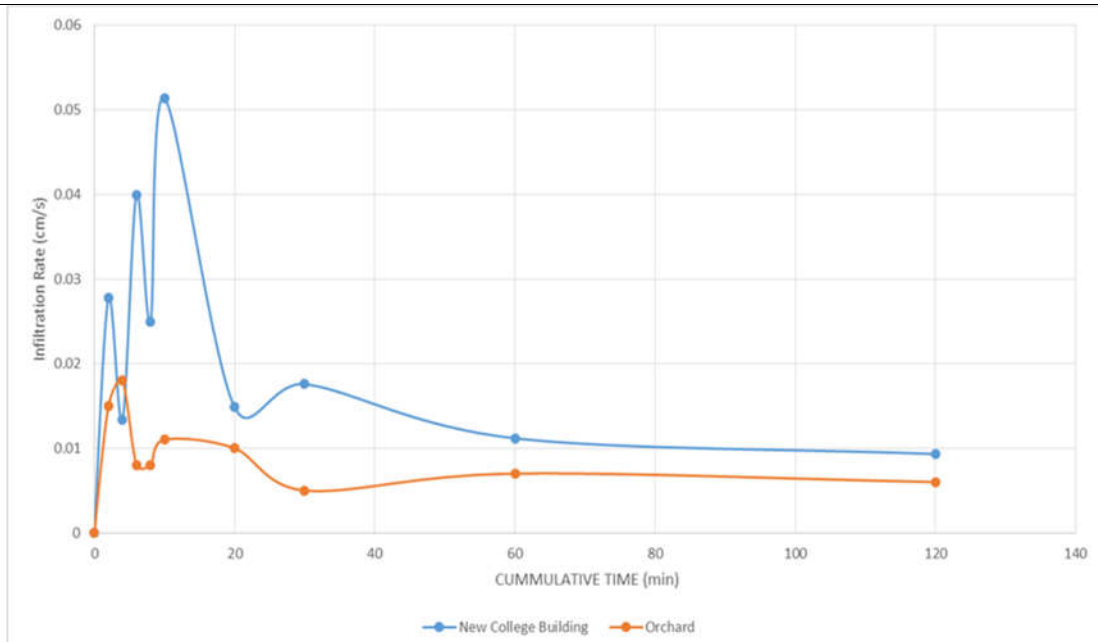


Figure 1: Comparison of Infiltration Rate with Cumulative Time at the Two Location

Table 3: Soil classification according to range of Permeability

S/N	Soil Type	Permeability coefficient, k	Relative Permeability
1	Coarse gravel	Exceeds 10^{-1}	High
2	Sand Clean	$10^{-1} – 10^{-3}$	Medium
3	Sand Dirty	$10^{-3} – 10^{-5}$	Permeable
4	Silt	$10^{-5} – 10^{-7}$	Lowly permeable
5	Clay	Less than 10^{-7}	Impervious

Source: (Varun, 2017)

Particle size distribution and infiltration rate

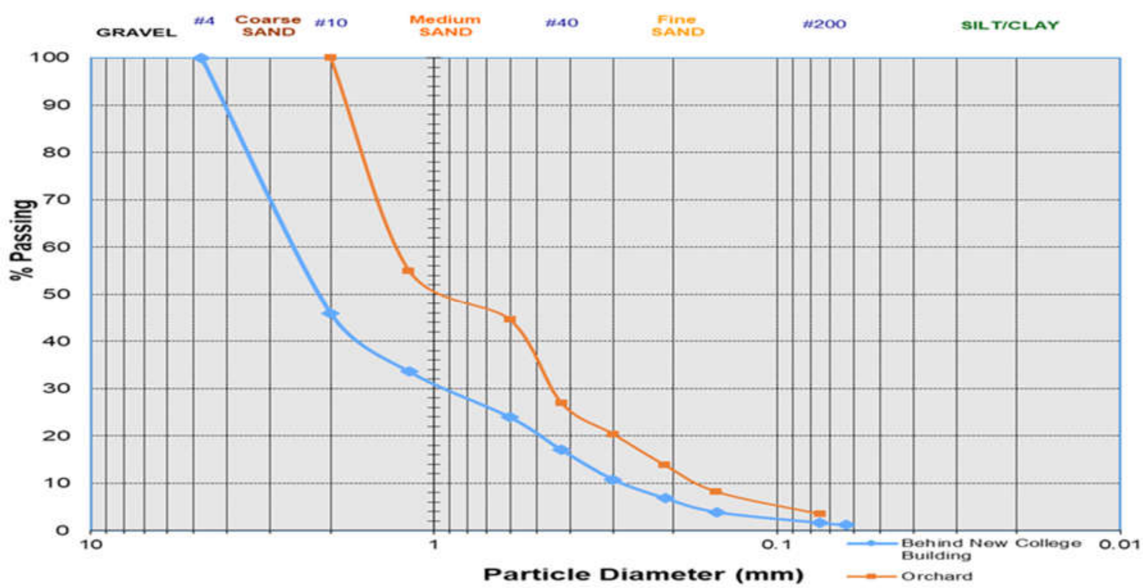
Figure 3 reflects the mean values of the particle size distribution of the soil samples at the Orchard and behind the New College Building respectively. The results showed that the values were 2.68 and 2.30; 0.90 and 0.633; 0.29 and 0.25; 9.48 and 9.44; 1.02 and 0.72 for D60, D30, D10, CU and

CC for the soil samples at the Orchard and behind the New College Building respectively. It showed that the particle size of soil samples at the Orchard were larger than that of the soil behind the New College Building while the infiltration rate was lower at the orchard than that of the soil behind the new college building. According to (Mazaheri, 2012) D30, D40, and D60 showed higher relationships with infiltration rate than the others. These diameters are attributed to the average of particle sizes the soil at the orchard is better graded than that one behind New college building which means the soil is closely packed and the implication is lower infiltration rate.

Calculation of infiltration rate using Kostiakov equation

Figure 4 shows the calculation of the infiltration rate using the Kostiakov equation. The figure revealed that the two empirical constants were $10^{1.7539}$ and $^{-}0.2546$ for K_k and α respectively.

Kostiakov equation was evaluated after determining the two constants and used to find log of the infiltration. Comparison between the Kostiakov's calculations with the observed infiltration rates is enumerated in the Table 4. The results showed that the values ranged between -1.824 to -2.244 and -1.831 to – 2.283 at a cumulated log of time of 0.301 to 2.079 secs. The mean deviation of between the two rates was 0.044 which indicated that using the Kostiakov's calculations showed great promise.



Legend

D60=Particle size at 60%

D30=Particle size at 30%

D10=Particle size at 10%

CU (Coefficient of Uniformity) = D60/D10

CC (Coefficient of Curvature) = $D30^2$ / (D60 x D10)

Figure 2: Particle size distribution of soil samples at the two locations

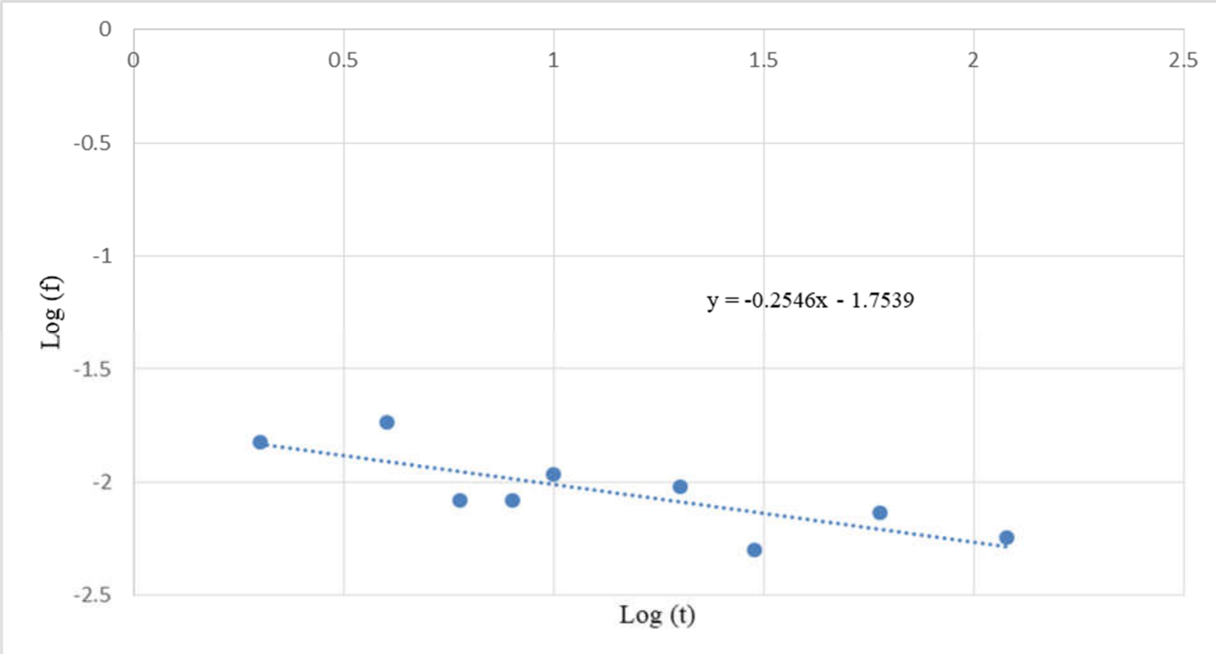


Figure 3: Calculation of infiltration rate using kostiakov equation

Table 4: Comparison of calculated infiltration rate with observed infiltration rate

Cumulative Time Log (t)	Observed Infiltration Rate (Log (f))	Calculated Infiltration Rate (Log (f))	Standard Deviation
0.301	-1.824	-1.831	0.003
0.602	-1.737	-1.907	0.085
0.778	-2.079	-1.952	0.064
0.903	-2.079	-1.984	0.048
1.000	-1.965	-2.009	0.022
1.301	-2.0223	-2.085	0.031
1.477	-2.301	-2.130	0.086
1.778	-2.134	-2.207	0.036
2.079	-2.244	-2.283	0.019

Conclusion

The study investigated the infiltration rates of six sampling points at two locations in Landmark University using double ring infiltrometer. The soil at the new college building has higher infiltration rates which ranged between 0.011 and 0.035 cm/sec with a mean value of 0.021 cm/sec than the orchard with the values which ranged between 0.007 to 0.011 cm/sec and a mean of 0.009 cm/sec respectively. The initial infiltration rates were high and decreased with time up to constant infiltration rate. Permeability of soil was directly proportional to its infiltration capacity, although the soil at the two locations were both permeable; the soil behind new college building was more permeable. The study of grain size distribution at the two locations showed that the orchard had more fine-grained soil in the composition than the soil at back of the new college building of which the result of infiltration rate coincided with the analysis particle size distribution results, indicating that the particle size of soil highly affects the infiltration rate. The comparison of the calculated soil infiltration rate using Kostiakov equation at any time showed great promise as the mean standard deviation in relation to the observed infiltration rate was ±0.044. It is thereby recommended that due to the high infiltration rate of the soil behind new college building, extra attention should be paid to compacting the soil for construction purposes. In driving of the university agrarian revolution, soil at the orchard should be properly ploughed due to the observed low infiltration rate and relatively low permeability. Further study on infiltration rate should be carried out on landmark university soil since properties of soil change due to chemical or physical change.

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