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EVALUATING HYDRAULIC PROPERTIES OF SOILS: A MANAGEMENT STRATEGY TOWARDS FIGHTING THE 21ST CENTURY FLOOD DISASTER

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Abstract. *The continual destruction of the environment due to anthropogenic and natural factors has played a role in increasing global flood disaster, acting like a hindrance in meeting the target of global sustainability. Flood has been looked at as an overland flow of water into land which is naturally dry after filling-up of natural open and close water holding bodies. The impact caused by flood disaster has been recorded and include death of humans and animals, apart from the massive destruction of properties and infrastructures, thereby limiting human development. Looking at land and water as a scare and unrenewable natural resources, then it follows that effective management of land and water resources is one way a society can maximize it economic growth and development. Studying the flux of fluid especially water into the soil profile is a great approach in investigating a soil towards the tendency for flooding. Infiltration is the key to soil water conservation and management. The ability of the soil to act as a sponge in-other to cut-down the raising cases of loss of lives and property with associated impact due to flood disaster lies on its infiltration capacity. The study evaluated the strength of soils of University of Abuja Flood meadows to absorb hydrological shock as flood. Outcome of the study revealed that dry land of University of Abuja flood meadow is able to absorbed reasonable quantity of water as flood, with coefficient of variability value of (CV=12%) for the hydraulic conductivity of the site. While bulk density of the area was found to be (2.30 g cm^{-3}) and Porosity of (8%). Conclusion of the study states that most of the sites investigated have a weak hydrological potential in regards to adsorbing and transporting of the water down the soil profile, hence the area should be put to vegetation cover to reduce the flooding impact, alongside an advance drainage system in the area.*

Keyword: *hydrology, soil infiltration, water flux, vegetation, water.*

1. Introduction

1.1 Background of the Study

Human-kind has experienced several challenges including flooding. Flood is defined as a very large amount of water that has overflowed from a source as a river, a pond or a broken pipe to cover a previously dried area (Oku and Aiyelari, 2011). With the increasing frequency in the impact of climate change the manse of flood has been severe here-and-there, especially in the tropical regions (IPCC, 2000). Flooding occurs when soil and vegetation of an area is unable to absorb the volume water released through rainfall or water bodies overflow (Hume, 1993, Ogban et al., 2000)

Damages caused by flood have been reported globally to include: crop loss, destruction of lives and properties, distortion of economic activities and the psychological trauma associated with the disaster. Flooding is one of the major environmental crises one has to contend with within the 21st century. Floods are among the most devastating natural disaster in the world, claiming more lives and causing more property damage than any other natural phenomena (UNFCCC, 2009).

Flood events have been frequent during the last decade, causing loss of lives, extensive damage to properties, including houses, destruction of transport infrastructures, agricultural land degradation, breakdown in educational system and food production (NEMA, 2008).

The number of reported flood disaster in Nigeria has been huge, especially during the rains. The Federal Capital Territory of Nigeria have experienced it own share of flood cases, with several cases of loss of human (NEMA, 2008) lives. Against the increasing disaster due to flood, this study aimed at evaluating the infiltration behavior (hydrological property) of soils in-other to prepare against flood shock.

2. Materials and methods

2.1 The Study Area

University of Abuja lies at Latitude Abuja is 8°.95' 43" and Longitude is 7°.07' 47". University of Abuja is located in sub-locality

of Gwagwalada a times can record extreme maximum temperature which varies from 37°C in the south west (Bida) to about 30°C in the north-east (Jos) (NIMET, 2009). The two distinct seasons within the zone are rainy and dry season. The parent material of the area is characterized by the presence of stones, gravel with ironstone sand to loamy texture.

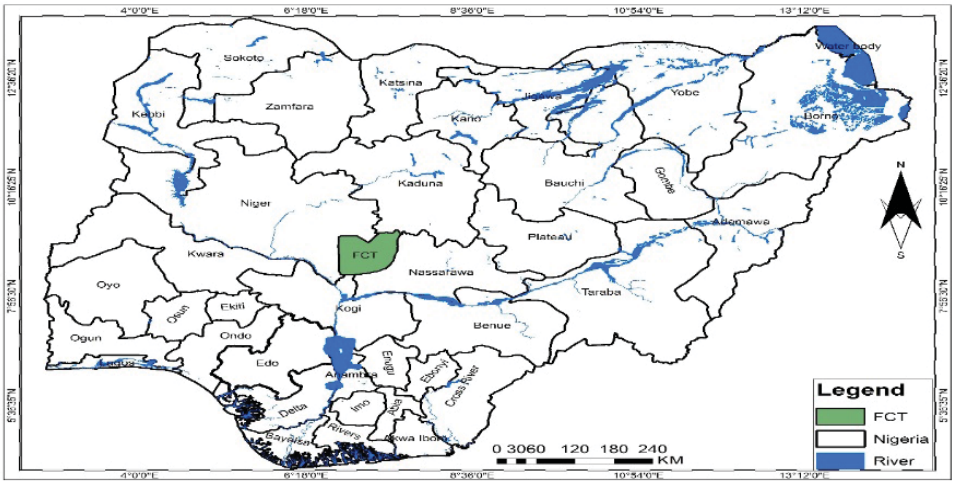

Figure 1. Extrapolated map of Abuja from the map of Nigeria

2.2 Study site Description

The study was conducted at the University of Abuja flood-meadow at a topo-sequence. These flood-meadow are among the major source of dry season vegetable crops for the local farmers.

2.3 Site Selection and Soil Sampling

Flood meadows areas were surveyed along the Giri River, and the following were selected:

1. Cultivated flood meadow with code (CM)
2. Dried Land (Control) with code (C)
3. Fallowed flood meadow with code (FM)

2.4 Experimental Procedures

Two replicate infiltration runs was carried out in all the site selected. The experimental set up is presented in Figure 2 and 3.

2.5 Infiltration Experimentation and Modelling

The double ring infiltrometer method was used (Anderson and Ingram, 1989). Infiltration model as proposed by Philip (1957) and Kostiakov (1932) were used. They are represented by the following equations:

$$I = C\, t\, \alpha; \quad (1)$$

$$I = St^{1/2} + At, \quad (2)$$

where I – Cumulative infiltration (cm);

t – time (minute);

A – transmissivity or adsorptivity (mi^{n-1} or cm hr^{-1});

C – Initial infiltration (cm);

α – Index of stability of soil structure upon wetting;

S – Sorptivity.

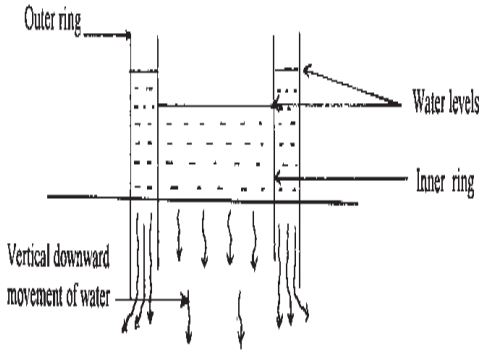

Figure 2. Double ring Infiltrometer experiment

Figure 3. Infiltration experiment with soil infiltrometer

2.6 Estimation of Infiltration Characteristics

Optimal values of the parameters of the two models were estimated using regression module of the GENSTAT package. To estimate the Kostiakov model parameters, the cumulative infiltration and time data were subjected to a non-linear regression analysis ($z = kt^a$) to find the parameters k and a. Using the final infiltration rate, the cumulative infiltration and time data were subjected to a non- linear regression analysis ($z - ft = kt^a$) to determine parameters k and a for the modified Kostiakov model. The Philip's model parameters were estimated by subjecting the cumulative infiltration and time data to a linear regression analysis ($zt - 0.5 = S + At0.5$) to find the parameters S and A.

2.7 Fitting infiltration models

The infiltration data were analyzed according to the model of Kostiakov (1932) using Equation 1 and Philip (1957) using Equation 2 as these two models are frequently used in the humid forest zone to characterize infiltration.

Results and discussion

Analysis as presented in (Table 1 and Figure 4 shows infiltration behavior on the flood meadows. The trend of infiltration characteristics differed with the different landuse with slope positions. Infiltration of water into the soil along the toposequence was lowest on the fallowed area of the meadow, presenting a view that soil bulk density could enhance high infiltration rate in the soils, this view was also made in the work of Oku and Aiyelari. The flooding treatments exerted significant influence on the investigated hydrological property of the different landuse. The flux in hydrological strength of the soils occurred at an unequal rate, this could be attributed to the different topo-unit of the sites, this view confirms the study of Wu et al (1997; Pagliai, 1988; Oku et al., 2010; Suleiman and Ritchie2001).

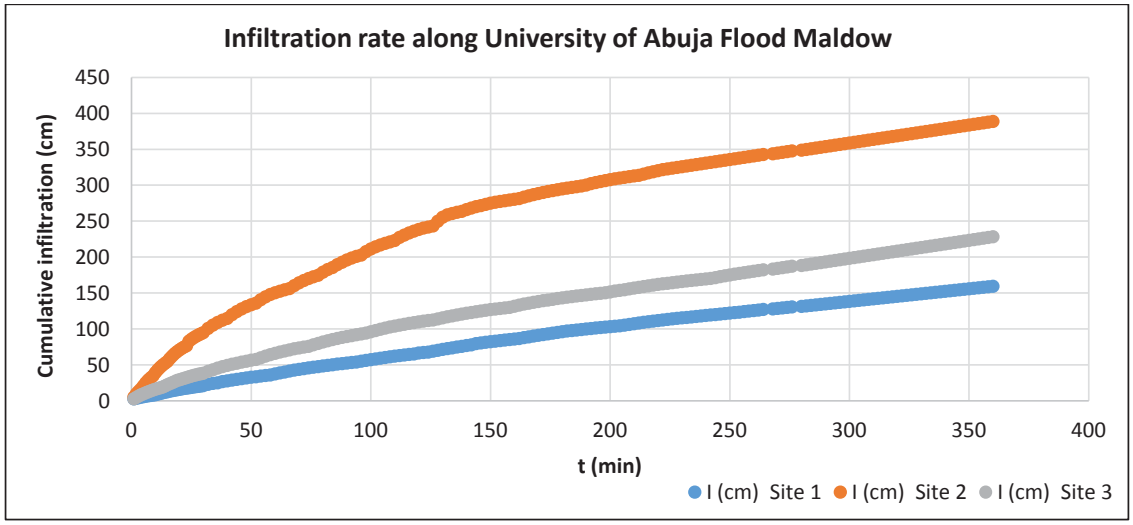

Figure 4. Hydraulic Behavior of the meadow soils of University of Abuja

1. Infiltration behavior along Flood meadows

Site	Slope Position	Philip Model				Kostiakov Model				i Initial Infiltration (cm/min)	I Cumulative Intake (cm/360 mins)
		A	S	R^2	r	C	ά	R^2	r		
CM	Foot slope	0.346	2.206	0.984	0.564	0.802	0.162	1	0.184	0.8	84.2
C	Middle slope	0.46	14.351	0.527	0.569	0.659	0.966	0.982	0.171	2	248.5
FM	Foot slope	0.387	5.139	0.931	0.656	0.725	0.516	0.999	0.268	1.2	126.1
X	0.398	7.232	0.814	0.596	0.729	0.548	0.994	0.208	1.333	152.933	
STD	0.047	5.174	0.204	0.042	0.058	0.329	0.008	0.043	0.499	69.707	
CV (%)	12	72	25	7	8	60	1	21	37	46	

Where: X = mean, SD = Standard deviation, CV = coefficient of variability, SE = Standard error, A = absorptivity, S = transmissivity, C = Index of initial infiltration, ά = index of soil stability, R^2 = Correlation Model, r = correlation coefficient

2. Infiltration behavior along Flood meadows

Site	Hydraulic Conductivity (cm/hr)	Model	R^2	Bulk density (gcm^{-3})	Porosity (%)
CM	0.346	0.432+12.009	0.9909	2.16	18
C	0.46	0.9717+86.05	0.9177	2.30	8
FM	0.387	0.588+27.78	0.9797	1.83	31

R^2 = Correlation Model, r = correlation coefficient

Conclusions and recommendations. The outcome of the study shows that the soils of the Flood meadows have low ability to infiltrate water into the soil profile. And for the area to be safe in the case of six hours continuous ponding from rain, irrigation or water overflow then evaluation of resident is advice. It could also be said that since the dried land (control site) indicated a highest water flux, it means that if proper drainage system is perform in the area then cases of water overflow in the area could be minimized if not eradicated. Outcome of this investigation shows that the fallowed land absorbed water than the cultivated land, and thus it could be concluded that for disaster due to flood to be minimized in the area such area with similar characteristics should be left on their natural vegetation or planted to grass like vetiver for cover.

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М.С. Адіаха, Е.Е. Оку

Оцінювання вологопровідності ґрунтів: стратегія управління для боротьби з катастрофічними повенями 21-го століття

Анотація *Постійне руйнування навколишнього природного середовища внаслідок антропогенних та природних факторів відіграло роль у зростанні кількості катастрофічних повеней по всьому світу, виступаючи перешкодою для досягнення мети глобальної стійкості. Повінь розглядається, як затоплення поверхні землі, яка природно є сухою, після заповнення природних відкритих та закритих водойм. Катастрофічні повені, окрім масового знищення об'єктів інфраструктури, спричиняють загибель людей і тварин, тим самим обмежують людський розвиток. Якщо дивитися на землю та воду, як на обмежені та не відновлювані природні ресурси, то випливає, що ефективне управління земельними та водними ресурсами – це один із способів, яким суспільство може досягти максимального економічного зростання та розвитку. Вивчення потоку рідини, особливо води, у ґрунтовому профілі є чудовим підходом для дослідження ґрунту щодо механізмів*

затоплення. Інфільтрація є ключем до збереження та управління ґрунтовими водами. Здатність ґрунту виступати в ролі губки, щоб зменшити випадки катастрофічних повеней, які призводять до людських та майнових втрат, полягає в його здатності до інфільтрації. У дослідженні було оцінено міцність лучних ґрунтів Університету Абуджі, які потерпають від повеней для визначення поглинання гідрологічного шоку при повені. За результатами дослідження було виявлено, що сухі угіддя заплави Університету Абуджі здатні поглинати розумну кількість повеневих вод зі змінним коефіцієнтом (CV = 12 %) для гідропровідності ділянки. Встановлено, що об'ємна щільність ґрунту ділянки складала 2,30 г/см$^{-3}$ і пористість – 8 %. У висновках дослідження зазначено, що більшість досліджуваних ділянок має слабкий гідрологічний потенціал щодо адсорбції та транспортування води вниз за ґрунтовим профілем, отже, ця територія майже завжди повинна бути вкрита рослинним покривом для зменшення впливу повеней, разом з ефективним функціонуванням дренажної системи, яка розміщена поблизу.

Ключові слова: *гідрологія, інфільтрація ґрунту, водяний потік, рослинність, вода.*

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Оценка влагопроводности почв: стратегия управления для борьбы с катастрофическими наводнениями 21-го века

Аннотация. *Постоянное разрушение окружающей среды в результате антропогенных и природных факторов повлияло на количество катастрофических наводнений по всему миру, выступая препятствием для достижения цели глобальной устойчивости. Наводнение рассматривается, как затопление поверхности земли, которая естественно является сухой, после заполнения естественных открытых и закрытых водоемов. Катастрофические наводнения, кроме массового уничтожения объектов инфраструктуры, вызывают гибель людей и животных, тем самым ограничивают развитие общества. Если смотреть на землю и воду, как ограниченные, но не возобновляемые природные ресурсы, то следует, что эффективное управление земельными и водными ресурсами – это один из способов, которым общество может достичь максимального экономического роста и развития. Изучение потока жидкости, особенно воды, в почвенном профиле является прекрасным подходом для исследования почвы по механизмам затопления. Инфильтрация является ключом к сохранению и управлению грунтовыми водами. Способность почвы выступать в роли «губки», чтобы уменьшить случаи катастрофических наводнений, которые приводят к человеческим и имущественным потерям, заключается в ее способности к инфильтрации. В исследовании оценивали стойкость луговых почв Университета Абудже, которые страдают от наводнений для определения поглощения гидрологического шока при наводнении. По результатам исследования было выявлено, что сухие угодья поймы Университета Абудже способны поглощать разумное количество паводковых вод с переменным коэффициентом (CV = 12 %) для гидравлической проводимости участка. Установлено, что объемная плотность почвы участка составляла 2,30 г/см$^{-3}$ и пористость – 8 %. В выводах исследования отмечено, что большинство исследуемых участков имеют слабый гидрологический потенциал по адсорбции и транспортировке воды вниз по грунтовым профилям, следовательно эта территория почти всегда должна быть покрыта растительным покровом для уменьшения влияния наводнений, вместе с эффективным функционированием дренажной системы, которая размещена поблизости.*

Ключевые слова: *гидрология, инфильтрация почвы, водный поток, растительность, вода.*