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An Evaluation of the Parameters of Philip's (1957) Infiltration Equation on Wetland Ecosystem in Agwagune Rural Catchment, Cross River State of Nigeria

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Abstract
The parameters of sorptivity(S) and transmissivity (A) inherent in Philips (1957) infiltration equation are often employed to explain the effects of capillary action and that of gravity as water moves from the surface down the soil profile. The model was derived from diffusion theory as a basis for evaluating water holding capacity of soils beyond which fluvial processes of overland flow, runoff and erosion might be initiated on a given landuse. The study area is prone to ecological risks of flooding, water logging and landslide which calls for a proper geotechnical investigation with the need to proffering mitigation measures of sustainable land management. Infiltration data were gotten from rainy and dry seasons measurement in the field to establish mean values used for computation. The result obtained from the differentiated equation of di/dt showed negative (0) values after a period of 50 minutes which continued till a time interval of 180 minutes (3hrs). The plot of di/dt against ½√t gave a straight line graph whose slope value was less than 1 (0.05). This indicate, landuse soil with very low infiltration capacity since parameters(S) and (A) broke down easily upon wetting in less than one hour. Unsustainable land use practices as continues cultivation, wetland conversion for dry season farming, destruction of riparian vegetation among others should be avoided.
Keywords: Philip's equation, sorptivity transmissivity, soil water holding capacity, fluvial processes

Introduction

Philips equation is one of the physical based models variously adopted by researchers to explain the behaviour of moving liquid (water) from the earth surface down a soil profile. Inherent in the assumptions of this equation are the facts that, for infiltration to take place, the soil must be a porous medium, and also have the ability to conduct water from the surface down the profile. Besides the quality of water must be relatively pure and free from dissolved salts; since unclean water reacts with soil chemical compounds to form hard pans that limit the infiltration process (Don-scott, 2002).

The model was derived from the diffusion theory and is explained by the equation $I=st^{1/2} + At$. Where I is the cumulative infiltration, t is the time of infiltration and parameters S and A are sorptivity and transmissivity respectively. The (A) parameter is a constant characteristics of the soil and is a measure of the ability of the soil to transmit water. The S parameter is a measure of the capillary uptake or removal of water from the soil (Tillman, 2001). It is essentially the property of the medium with some resemblance to permeability which is the ease with which the soil can permit the passage of air and water (Bonsu, 2007, Antigha, 2007, Ukata, 2010).

Of all the physical based models (Green Ampt, Kostiakov, Horton and Richard) Philip (1957) equation is the most attractive since the infiltration time can be expressed explicitly as a function of the cumulative infiltration. However, there are few limitations observed in using it. These include, the little effect of gravity observed at the early stages of infiltration process. Consequently, parameter (A) becomes insignificant relative to the (S), parameter. This affect the overall value of the parameter (sorptivity) which is overestimated by 15 per cent (Tillman, 2001) and according to the author, the final value of the S parameter should be multiplied by 0.85 to take care of the short fall observed at the initial stages of infiltration. There is also the possibility of lateral flow of water into the soil which is not accounted for by the model. Also, after about 3-4 hours of experimental runs, Philips equation breaks down probably due to the swelling of colloids brought about by prolonged saturation.

Despite these, there is a great advantage of using it to determine the infiltration rates of soils because the equation gives an insight into the cumulative infiltration of water which is required in the root zone for uptake by plants. The model has been used or tested in the laboratory by Diamond (2004) in east-water fold, Ireland, while Amalu and Antigha (1999) employed it to study the relationship between the physical properties and moisture rention of some characteristics of some coastal plain soils in Calabar South East, Nigeria.

Moreso, equilibrium infiltration rate which is usually determined after 3-4 hours will give information to the irrigation agronomist on time of scheduling irrigation water in the field. In this study, Philips equation enabled the comparison between the effect of capillary action and gravity in water movement into wetland soils as a function of water holding capacity of a given soil, quite needful by extension in the construction industry.

Study area

The study area is Agwuagune in Biase, Cross river State of Nigeria. It is located between longitude $8^0$06 and $8^0$10 E and latitudes $5^0$0N. The area is characterized by humid tropical climate with distinct wet and dry seasons. Rainfall amount ranges from 3.500 mm to 4,000 mm per annum. The rainy season falls between April and October, with a short dry spell usually referred to as August break during the month of August (NIMEST, 2009).

It also has a relative humidity of between 80 and 90 per cent the temperature is moderately hot and does not fluctuate greatly with a mean range of 27^0C to 33^0C (N.A.A., 2006). The geologic environment comprise of phyllites and schist with structural features as foliation, joints, fold intrusion, pegmatite and barite. The land use is covered by grasses and shrubs. Crops, such as okro, maize, garden eggs, tomato, pepper and pumpkin do well in such areas. Wetlands are noted for their low infiltration capacity due to the presence of hydromorphic soils in them. Despite this, they have the potential of filtering and recharging the regional water table in dry conditions.

Method of study

Infiltration rate of the wetland were empirically generated from experimental runs with the aid of Hillel (1970) cylinder infiltrometer. Equilibrium or steady state of water infiltrating into the soil was established after 3 hours or 180 minutes. In the process, care was taken to prevent physical damage to the soil in order to check lateral flow of water likely to impede the realization of accurate infiltration data. Reading were carried out in wet and dry seasons, to establish mean values used for final computation as implied in the parameters of the infiltration equation.

Result and discussion

Table 1, shows the variations of equilibrium infiltration rates of wetland soil in both rainy and dry seasons. The initial value of 0.6cm/hr^{-1} recorded in rainy season increased to 1.2cm/hr^{-1} or doubled in dry season. This was as a result of increase in matrix potential (energy level) on surfaces of soil particles and sorptivity of soil characteristics (Antigha, 2007). Besides, the effect of soil temperature change and decline in soil moisture content also contributed to the variation observed.

Table 1
Equilibrium infiltration rate of wetland in rainy and dry seasons

Interval (min)	Cumulative time (mins)	Cumulative intake (cm)		Infiltration rates (cm/hr^1)	
		Rainy season	Dry season	Rainy season	Dry season
0	0	0	0		
5	5	0.4	1.2	4.8	14.4
5	10	0.6	1.4	3.6	8.4
5	15	0.6	1.6	2.4	6.6
5	20	0.7	1.6	2.4	4.8
5	25	0.8	1.8	1.8	4.2
5	30	0.8	2.0	1.8	4.2
10	40	0.9	2.0	1.2	3.0
10	50	0.9	2.2	1.2	2.4
10	60	1.2	2.4	1.2	2.4
15	75	1.8	2.4	1.8	1.8
15	90	1.8	2.6	1.2	1.8
30	120	1.8	2.8	1.2	1.2
30	150	1.8	3.2	0.6	1.2
30	180	1.8	3.6	0.6	1.2

Source: Authors fieldwork, 2014

Table 2, presents infiltration data and time used in transforming Philips (1957) infiltration equation of I-St½+At into differentiated form from which di/dt was plotted against ½√t. the plots of di/dt versus ½√t gives a straight line graph indicating a slope value derived from the transformation (fig 1).

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Table II
A plot of di/dt against ½√ t (Philips, 1957) on Wetland

Infiltration Time (t) Mins	Mean infiltration Rate (c) (cm mins)	Di	dt	di/dt	½ √t
5	0.6	0	0	0	0
10	0.10	0.06	5	0.012	0.224
15	0.08	0.02	5	0.004	0.158
20	0.06	0.02	5	0.004	0.129
25	0.05	0.01	5	0.002	0.112
30	0.05	0.00	10	0	0.100
40	0.04	0.01	10	0.001	0.091
50	0.03	0.01	10	0.001	0.071
60	0.03	0.00	10	0	0.065
75	0.03	0.00	15	0	0.058
90	0.03	0.00	15	0	0.053
120	0.02	0.01	30	0.00	0.045
150	0.02	0.00	30	0	
180	0.02	0.00	30	0	

Source: Author's fieldwork, 2014

From the table, water holding capacity of wetland soil declined monotonically reaching an asymptotic state after a period of less than one hour (50mins), implying the susceptibility of land use to flooding and ponding during storm. From the differentiated values of infiltration and time (di/dt) capillary action sorptivity(s) and force an experimental interval of 50 minutes, which explains the low infiltration capacity of the soil.

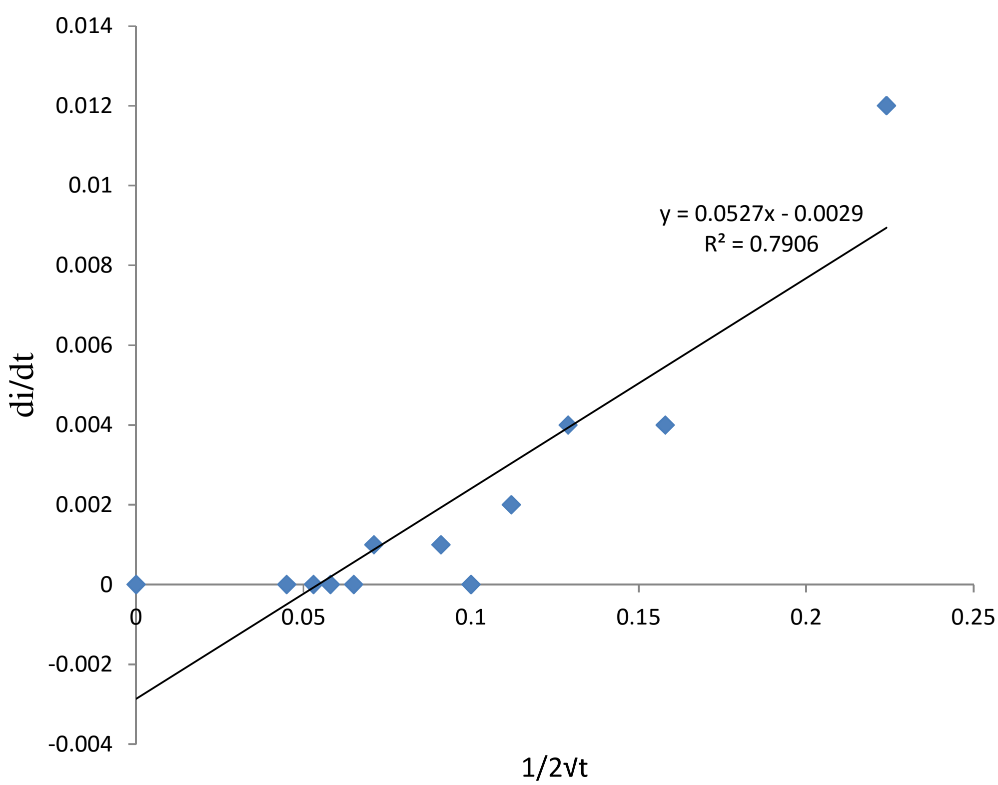

Figure 1: Plot of di/dt against $^1/_2$√t for wetland
Source: Author's fieldwork, 2014

This figure shows the slope value of 0.05 for the landuse, buttressing the fast that the wetland soil is at high risk of fluvial processes mostly engendered by human activities (poor cultural practices) Gosh, (198) opined that, slope values of less 1 indicate soils requiring proper land management to boast land suitability for multiple uses, and hence the relevance of this study.

Conclusion

The application of Philip infiltration equation by operationalizing the basic parameters inherent in it has been demonstrated in this research. The finding revealed the low infiltration capacity of the soil which apathy informs wise decision on landuse by various stakeholders to preserve the natural values of ecosystems, there is the compelling need to adopt sustainable land use approaches by all concerned.

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