Vol. 15(4), pp. 509-523, April, 2020
DOI: 10.5897/AJAR2019.14547
Article Number: 2BFE29B63374
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Assessment of physicochemical properties of Besease wetland soils, Ghana

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Received 22 October, 2019; Accepted 22 January, 2020

The shallow and erodible soils of low fertility uplands have led to farmers extending their cultivable areas to wetlands for optimal crop production since these systems have the potential for exploitation in the dry season. To ensure its sustainable use, the physicochemical and the hydrological characteristics of the valley bottom should be ascertained. Studies were conducted to assess the suitability of wetlands for crop production by analysing the physicochemical properties of Besease wetland soils. Soil samples were collected from specific sites and profile pits for physical and chemical analysis in the laboratory. Field experiments were also conducted for soil physical properties. Soil textural analysis revealed that the average texture of the Besease inland valley was sandy loam with the distribution of sand, silt and clay as 55.42, 35.04 and 9.50%, respectively. Bulk density and moisture content on the field increased with depth in all profiles. Results of hydraulic conductivity using the mini disk infiltrometer ranged from 2 to 88.3 cm/day. The infiltration rate on the studied wetland ranged from 0.02 to 0.78 cm/min. The pH, OC, TN and CEC of the soil profile distribution for site P11-P14 obtained ranged from 6.9-4.6, 4.69-0.19%, 0.2-0.01%, 9- 2.6 meq/100 g down the horizon respectively. The study unraveled a sustained plant nutrient availability and elongation of water level ponding which will result in increased water storage under rice cultivation in the studied wetland.

Key words: Wetlands, physicochemical, crop production, nutrient, water storage.

INTRODUCTION

Production of crops in Ghana has generally been restricted to upland farms, which constitute about 70% of the country's total land area (Masoud et al., 2013). In Ghana, rice production is mostly confided to the inland valleys (e.g. wetlands) forming about 12% of the total land area. Inland valleys in Ghana have been documented to exhibit high potential for rice production, especially at the small-scale level, due to their suitability in terms of physical, chemical and biological properties (Annan-Afful et al., 2005; Nakamura et al., 2016). Wetlands have been endowed with specific structural and functional attribute performing major ecological roles in the biosphere

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(Mahajan, 1991; Reddy et al., 2013; Alam et al., 2018). The quality of soil in wetland is of vital concern for mankind since it is directly linked with human welfare (Sultana et al., 2017). In Ghana, there exist fragmented areas of inland valleys, especially in the semi-deciduous agroecological zone, which has been left unattended to or underutilised. Crop production in upland areas within sub-Saharan Africa have been faced with increased limitations chiefly from erratic rainfall patterns and poor soil fertility. These limitations have led to increased awareness and development of inland valleys for sustainable crop production (Andriesse et al., 1993). Ejisu-Besease, located in the semi-deciduous agroecological zone of Ghana, is endowed with the presence of the Oda River with which sustenance small-scale farmers usually crop in wetlands around the river boundaries as an alternate source of irrigation. Several initiatives by the Rice Sector Support Project (RSSP), Council for Scientific and Industrial Research (CSIR) and the Government of Ghana (GoG) have revealed the important role of wetlands, which can be used for crop production during the dry season to ensure food security (Atta-Darkwa et al., 2016).

The people of Besease normally use the swamp land for rice cultivation. During high rainfall intensities, the runoff and overflow of the river run over the cultivated area causing it to be flooded. The flood damages the crops, stays on the field for few weeks leading to subsequent leaching of fertiliser applied to the field. The behaviour of the catchment (alternating flooding and receding of water in the wetland) will have ramifications on the soils fertility. Therefore, understanding the spatial and temporal characteristics and variability of wetland soil physical and chemical properties is key for proper utilization and management of agricultural soils.

The cultivation of crops (e.g. rice, maize, millet) in any given environment encompasses a complex interaction between the environment, soil parameters and nutrient dynamics (Ololade et al., 2010). The physical properties of soil according to Mamun et al. (2011), determines the availability of oxygen, the mobility of water into or through soils and the ease of root penetration. The chemical properties of soils include Soil pH, cation exchange capacity, mineral solubility and availability. Delgado and Gomez (2016) posited that soils offer support and act as a reservoir of water and nutrients. Lack of agricultural inputs, continuous cultivation practice, uncontrolled drainage, coupled with environmental factors aggravates the degradation of soil physicochemical properties (Habtamu, 2011). Therefore, a decline in the fertility of soil and the weakening of soil strength would lead to low crop productivity and threatens food security. For wetlands which can support year round cultivation, there is the need to investigate its soil quality in an effort to stabilize and sustain agricultural productivity of the soils. This study sought to analyse the physico-chemical properties of Besease wetland soils and apply the necessary management options to sustain agricultural crop production.

Study area

The study was conducted in the Besease inland valley which has a total land area of about 72 hectares (Figure 1). Besease, a farming community found in the Semi-deciduous agro-ecological zone of Ghana, is located in the Ejisu Municipal District of the Ashanti Region in Ghana. The area geographically lies between latitude 1º 15` N and 1º 45` N and longitude 6º15` W and 7º 00` W. The area is marked by a bimodal rainfall pattern, thus the rainy season and the dry season. The two distinct seasons are conditioned by the Inter Tropical Convergence Zone (ITCZ). Typically, the major rainy season starts from mid-March to July, followed by a short dry spell, which is then followed by the minor rainy season and begins from September to mid-November. The main dry season proceeds after the minor rainy season and begins from mid-November to mid-March (MoFA, 2018). The Besease inland valley records a mean l rainfall of 1450 mm per annum, with a mean annual temperature ranging from 24 °C to 29 °C and an evapotranspiration (ETo) rate of 1230 mm per year.

According to Kankam-Yeboah et al. (1997), Besease is seasonally drained by the Oda River with a basin extending for about 143 km^2. Soil around the Besease in Ejisu is described as the Offon soil series. This soil series is generally grey to light brownish grey, which are poorly drained alluvial sands and clays. Specifically, the soils are Orthi-ferric Acrisol, Eutric Fluvisol, Gleyic Arenosols, Eutric Gleysols and Dystri-Haplic Nitisol. The Besease aquifer is composed of heterogeneous sequence of layers which is dominated by sand, clayey sand and silts. The valley bottom is developed by small holder farmers who cultivate rice in the wet season and also grow vegetables like cabbage, lettuce, sweet pepper, cauliflower, cucumber and okra and other cereals like maize in the dry season when the water table is low. Internal drainage in the catchment areas of the Besease wetlands are very slow, exhibiting rapid permeability and moderate moisture holding capabilities. Dominant grasses and tree species in the area includes *Chromolaeve ordorata, Imperata cylindrical, Mimosa pigra, Ceiba patendra, Centrosema pubescens, Raphia hookeri (Raphia palm), Alstonia boonei,* and *Malotus oppositifolius*.

MATERIALS AND METHODS

Soil physical properties

Sample collection

Soil samples were collected as described by Tuffour et al. (2019) with core samplers of height 10 cm to an average depth of 100 cm from the field at site P1-P2, P7-P8, P11-P14, and P13-P4 (Figure 1)

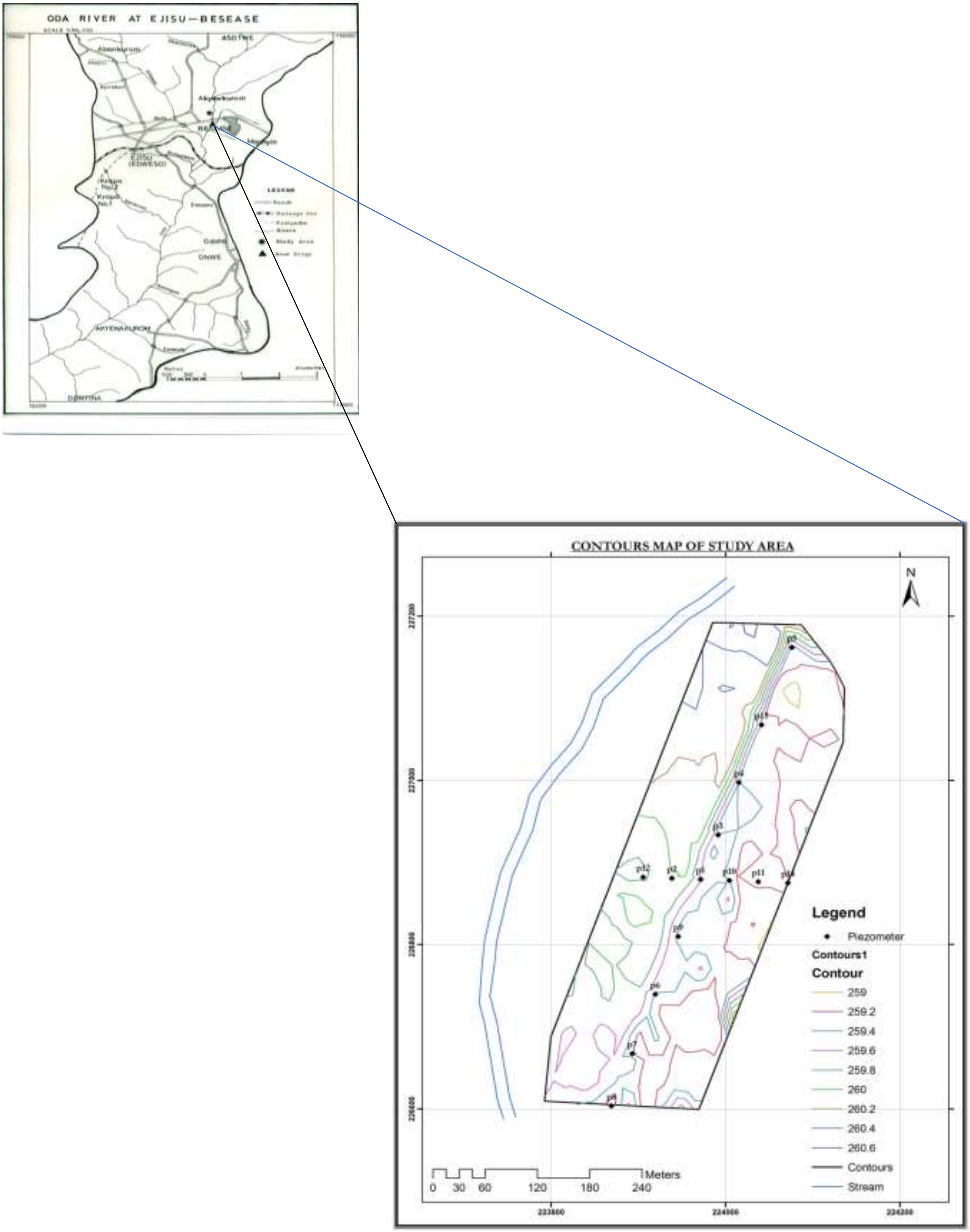

Figure 1. Map of the study area.

and were used for the determination of bulk density and unsaturated hydraulic conductivity. Disturbed soil samples were also taken and air dried, ground and passed through the 2 mm sieve to obtain the soil fractions for the determination of soil physicochemical properties.

Field methods

In the determination of unsaturated hydraulic conductivity, the mini disk infiltrometer was used. The infiltrometer filled with water was positioned to touch with the soil surface at time zero. The volume was recorded at regular time intervals of 30 s as the water infiltrated into the soil at a suction rate of 2 cm which is suitable for most soils. Excel was used to calculate the slope of the curve of the cumulative infiltration versus the square root of time from the infiltrated volume of water recorded. Zhang (1997) formulated an equation for determining the hydraulic conductivity of soil. Infiltration is calculated using the equation: $I = C_1 t + C_2 \sqrt{t}$ Where, C_1 (ms^{-1}) and C_2 ($ms^{-½}$), and C_1 is related to hydraulic conductivity and it is the soil sorptivity. The hydraulic conductivity of the soil (*k*) was then computed from: $k = \frac{C_1}{A}$ Where, C_1 is the slope of the curve of the cumulative infiltration versus the square root of time, and A is a value relating the van Genucthen parameters for a given soil type to the suction rate and radius of the infiltrometer disk.

Double ring infiltrometers, consisting of two concentric rings, were used to measure the infiltration rate. The rate of fall of the water level in the inner cylinder was measured at 2, 3, 5, 10, 15, 20, 30, 45 and 60 min and at 30 min intervals thereafter. This was done to obtain a steady-state infiltration rate.

Laboratory methods

The bulk density was determined by using the core sampler method. That was calculated by dividing the oven dried soil mass at 105°C for 24 h (Black, 1965) by the internal volume of the cylinder that was used to collect the sample. The total porosity was then calculated from the bulk density using the equation: Porosity = $(1-\rho_b/\rho_s) \times 100$…(1). Where, ρ_b [g/cm^3] is bulk density and ρ_s is particle density (2.65 g/cm^3). The saturated hydraulic conductivity (K_{sat}) measurements were made on core samples with a length of 10.0 cm and diameter of 8.3 cm using the falling head method developed by Klute and Dirksen (1986). The saturated hydraulic conductivity of the soil samples was calculated by the equation: $K_{sat} = \left(\frac{AL}{A_t}\right) ln \left(\frac{H_1}{H_2}\right)$..(2). Where, K_{sat} is the hydraulic conductivity (LT^{-1}), A is the cross-sectional area of the sample, H_1/H_2 is the difference in the hydraulic head between the up gradient end of the sample and the down gradient end, L is the length of the sample or the distance over which the head is lost, and t is time. The bouyoucos hydrometer method was sued to determine soil texture after deflocculating soil with sodium hexametaphosphate.

Soil pH was determined by using a pH meter (H1 9017 Microprocessor) in a soil-water ratio of 1:1. Carbon content and total nitrogen (TN) concentration at the study site was done using the Walkley and Black method (Nelson and Sommers, 1982) and Kjeldahl digestion and distillation procedure as described by Soil Laboratory Staff (1984). Available phosphorus (P) was determined using a spectronic 21 D spectrophotometer. Exchangeable cations (calcium (Ca), magnesium (Mg), potassium (K), sodium (Na)) were determined using the ammonium acetate (1.0 *M* NH4OAc) (Black, 1986). Effective cation exchange capacity (ECEC) was determined by the summation of exchangeable base (Ca^{2+}, Mg^{2+}, K^+ and Na^+) and exchangeable acidity (H^+ and Al^{3+}). Electrical conductivity of the study site was also determined using the electrical conductivity meter and probe.

RESULTS AND DISCUSSION

Dynamics of soil physical properties

Soil texture has been regarded as a very stable soil physical property with little or no change from external factors (Msanya et al., 2003). It typically influences soil erodibility, water holding capacity, texture, cation exchange capacity, and soil penetrability. Characteristically, the textures of the soils at the Besease Wetlands contrasted distinctly from silt loam to sand among the various soil profiles (Table 1). The average soil texture was loamy sand (73.6% sand, 22.22% silt, 4.15% clay) in the profile pit P1-P2, loam (51.57% sand, 35.70% silt, 12.70% clay) in the profile pit P11-P14, loam (37.80% sand, 47.16% silt, 15.0% clay) in the profile pit P7-P8, and sandy loam (58.64% sand, 35.07% silt, 6.12% clay) in the profile pit P4-P13 respectively. As evident from the Table 1, the average texture of the Besease inland valley was sandy loam with the distribution of sand, silt and clay as 55.42 %, 35.04 % and 9.50 % respectively. From our findings, the coarser nature of the soil exhibited at site P1-P2 controls variations in cation exchange capacity, increased soil permeability and water leaching, hence leading to less water storage. These varied soil textures exhibited at the Besease floodplains could be due to the nature of the parent material which formed the soil above it. Beasease in the Ejisu Municipal is underlaid with complex associations of pre-Cambrian igneous (Birimian formation) and metamorphic rocks. Smyth and Montgomery (1962) reported that parent material (rocks) exhibits various minerology and texture ranging from pegmatite to fine grained schist, and from acid quartzite to basic rocks consisting largely of amphibolites. In their studies on soil texture, Hekstra and Andriesse (1983) observed correlations between rocks and soil texture and they concluded that metamorphic rocks generally tend to generate fairly fine-textured soils, whilst soils formed from granitic parent materials are relatively coarser in nature.

In all the soil profiles, soil bulk density generally increased with increase in soil depth (Figure 2), with its associated decrease in soil porosity. Bulk density and the moisture content on the field increased with depth in all profiles as shown from Figures 2 and 3. As observed from Figure 2, profile pits P7 – P8 and P11 – P14 recorded soil bulk density values ranging from 1.1 g cm-1 to 1.9 g cm-1 within the depths of 0 – 100 cm. However, profile pits P1 – P2 and P13 – P4 generally recorded bulk densities value beyond 2.0 g cm-1 when soil depth increased after 70 – 80 cm. The increase in soil bulk density with increasing soil depth in the various soil profiles could be indicative of dense packing of soil particles (compaction), and thus impact on soil porosity and root permeability. Landon (1991) observed that increase is soil bulk density significantly influence soil aeration and porosity, affecting root establishment, and ultimately impact on nutrient uptake and crop yields. Low

Table 1. Particle size analysis for the Besease Inland valley bottom site.

Profile pit	Depth of soil (cm)	% Sand	% Silt	% Clay	Texture
P11-P14	0-10	31.58	56.42	12	Silt Loam
	20-30	17.54	60.46	22	Silt Loam
	20-30	38.32	44.58	16.8	Loam
	30-40	51.94	36.06	12	Loam
	40-50	45.58	36.22	18.2	Loam
	50-60	63.9	24.1	12	Sandy Loam
	60-70	76.38	17.42	6.2	Loamy Sand
	70-80	87.32	10.28	2.4	Sandy
P1-P2	0-10	63.04	34.96	2	Sandy Loam
	20-30	62.06	35.74	2.2	Sandy Loam
	20-30	63.34	31.66	5	Sandy Loam
	30-40	63.92	29.88	6.2	Sandy Loam
	40-50	61.76	31.84	6.4	Sandy Loam
	50-60	60.14	31.86	8	Sandy Loam
	60-70	59.34	32.66	8	Sandy Loam
	70-80	65.6	28.2	6.2	Sandy Loam
	80-90	80.58	17.42	2	Loamy Sand
	90-100	87.58	10.42	2	Sand
	100-110	95.12	2.88	2	Sand
	110-120	96.69	1.04	2	Sand
	120-130	97.76	0.24	2	Sand
P7-P8	0-10	17.2	69.2	13.6	Silt Loam
	20-30	15.84	65.96	18.2	Silt Loam
	20-30	21.02	60.98	18	Silt Loam
	30-40	27.16	50.74	22.1	Silt Loam
	40-50	31.38	45.62	23	Loam
	50-60	34.96	47.84	17.2	Silt Loam
	60-70	40.82	42.18	17	Loam
	70-80	45.68	40.42	13.9	Loam
	80-90	59.64	35.36	5	Sandy Loam
	90-100	84.74	13.26	2	Loamy Sand
P4-P13	0-10	65.22	32.78	2	Sandy Loam
	20-30	64.18	31.82	4	Sandy Loam
	20-30	59.96	34.04	4	Sandy Loam
	30-40	57.04	37.16	5.8	Sandy Loam
	40-50	56.34	34.46	9.2	Sandy Loam
	50-60	55.74	35.86	8.4	Sandy Loam
	60-70	56.84	34.76	8.4	Sandy Loam
	70-80	56.84	34.76	8.4	Sandy Loam
	80-90	57.38	33.82	8.8	Sandy Loam
	90-100	54.38	39.82	5.8	Sandy Loam
	100-110	54.68	39.52	5.8	Sandy Loam
	110-120	60.76	33.44	5.8	Sandy Loam
	120-130	62.96	33.84	3.2	Sandy Loam

soil compaction observed in the top layers of our study could be linked to presence of organic matter at this layer, low soil strength, and less mechanical manipulation by tillage implements (Gachene and Kimaru, 2003). Thus, the only restrictive conditions in such layers may arise from the depth of the underlying water table, which

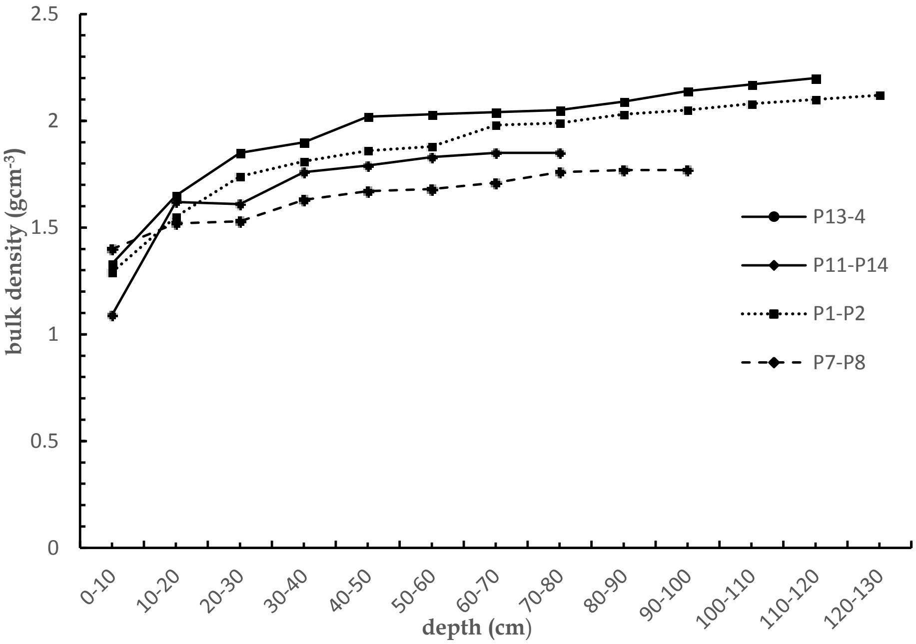

Figure 2. Relationship between bulk density and depth of the various profiles.

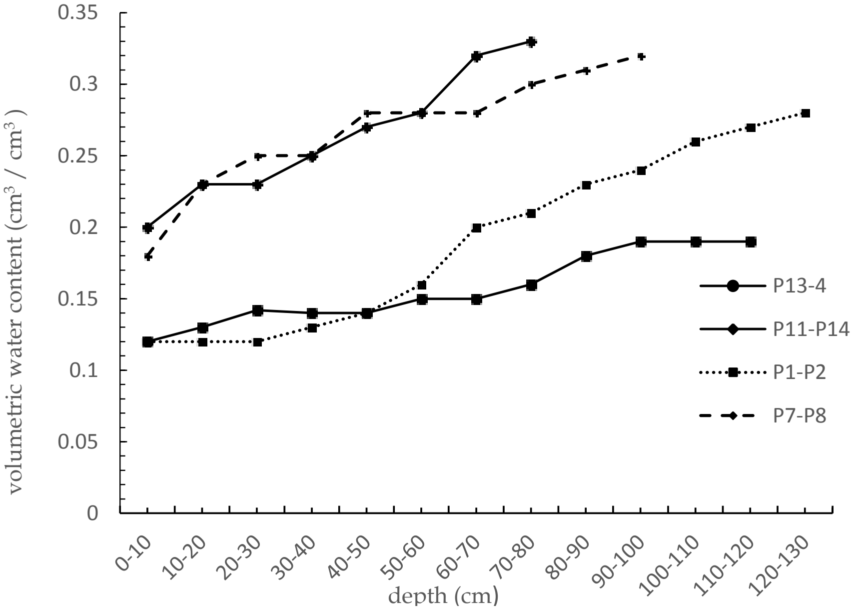

Figure 3. Relationship between volumetric water content and depth of the various profiles.

may come up due to capillary action, or varies between the dry and wet seasons. Porosity, an indirect measure of soil compaction was, however, higher in the surface layers, which decreased further down the soil profile. It could be observed from Figure 4 that, profile pit P7 – P8 generally recorded the highest porosity with increasing soil depth whilst profile pit P13 – P4 recorded the least values of soil porosity. This implies that the horizontal movement of moisture would be favoured as opposed to the vertical movement of soil moisture. This conclusion could further be explained from Figure 4 which demonstrated that, a fine textured soil with improved soil aggregation and high in soil OM exhibits high soil macro porosity than a compact and massive soil. Understanding

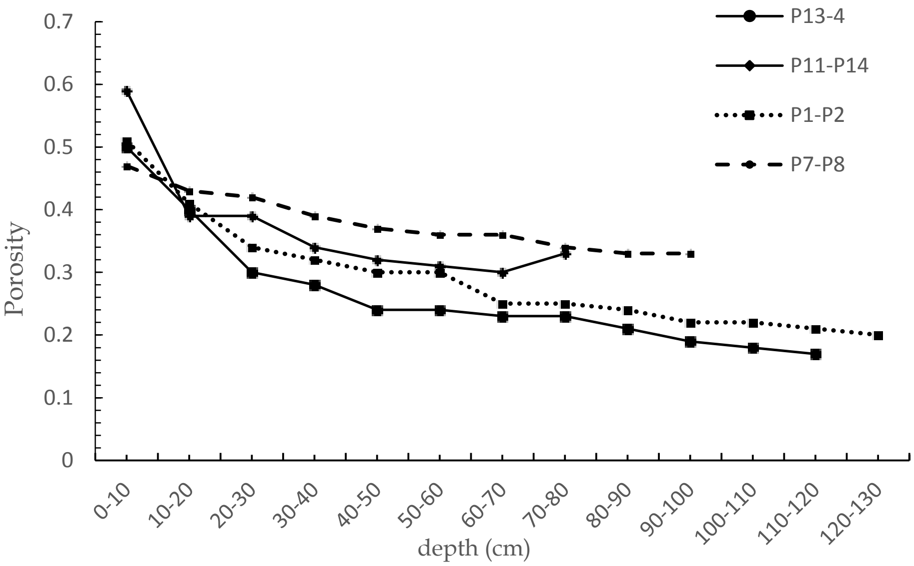

Figure 4. Relationship between porosity and depth of the various profiles.

the mechanisms that control the rate of water infiltration and percolation through the soil system are of great importance as they influence runoff and subsequent excess overland flow.

Hydraulic and infiltration properties of soils

Saturated hydraulic conductivity (K_{sat}), has been denoted as the degree of the soil to transmitted water under saturated conditions which has been subjected to a hydraulic gradient. A unit volume of water passing through a unit cross sectional area of soil in inland valley bottoms reflect differences in hydraulic properties of soils because as fluid flow increases, inter-aggregate pores reduce the possibility of obtaining equilibrated pore water pressure profiles. Hence, macropore continuity and the more tortuous pore system found at the western portion of the valley bottom where fauna activity and high root density dominated enable preferential flow particularly at saturation, thereby giving high conductivity values (Table 2 to 4).

Although macropores make up a relatively small fraction of a soil's total porosity (Watson and Luxmoore, 1986), they can have a disproportionate effect on the soil's infiltration properties. For example, German and Beven (1981) demonstrated that small amounts of macropores could increase saturated hydraulic conductivity by more than an order of magnitude in soils with low-to-moderate matrix conductivity. The vertical K_{sat} measured in Besease sites were not the same for each depth of sample collected. Conductivity tests revealed that K_{sat} varied spatially within the site, and that each layer possesses different conductivity values. For instance, over the first 20 cm of depth, K_{sat} ranged from 6.02-4.9 cm/day and in the lower depth of 70 cm was 0.002 cm/day (Table 3). The vertical flow direction within layers was likely to be different, because layers show marked differences in vertical hydraulic conductivity. Particle size also affects conductivity of soils. Soils constituted by clay can have different infiltration characteristics depending on the amount of aggregation present. The presence of clay mostly indicates a low K_{sat}, but may on the other hand be subjected to cracks and macropores (in comparison to a coarser grained soil), and thus give rise to higher K_{sat}. Profile P11-P14 pit had higher clay content than the other pit sampled which experienced a lower K_{sat} (Table 1). Such a site undergoes longevity in the hydro-period which also lowers hydraulic conductivity. Soils with high clay content subjected to decreasing water content govern the conditions for crack formation. The cracks form a network of macropores which will be of great importance for water infiltration (Vogel et al., 2005). The flow in the unsaturated soil at the study sites is more complicated than flow through a continuously saturated pore space. Within unsaturated soils, macropores are filled with air leaving the finer pores to accommodate water movement. Therefore, gravity does not dictate the movement of water through the soil but rather differences in matric potential. Sobieraj et al. (2004) attributed the differences in K_{sat} to microbial processes, especially in cases with clay rich soils at shallow depth. They also suggest that the classical theory of K_{sat} being mostly influenced by particle size is only true for soils consisting of more than 80% sand. Topography and slope greatly influence the microclimatic properties in the soil, and hence also the physical properties (Casanova et al., 2000). Fine textured soils are often found at the bottom of slopes, and have small water intake and large runoff potential (Casanova et al., 2000).

Table 2. Spatial saturated hydraulic conductivity of the site from falling head method.

Location	Depth of soil	
	10 cm	20 cm
	K (cm/d)	
P1-P2	6.021	4.896
P6-P9	4.885	1.438
P7-P8	0.198	0.365
P3-P4	5.502	5.178
P5-P13	1.091	0.155
P11-14	0.107	0.101
NU P6-P7	0.320	1.033
NRP4-P13	1.346	1.123
NUP4-P13	0.463	0.465

NR- Near river, UP- Near Upland.

Table 3. Spatial saturated hydraulic conductivity of the site from falling head method.

Depth (cm)	K_{sat} (cm/d) for P1-P2 Profile
10	6.021
20	4.896
30	0.463
40	0.877
50	0.620
60	0.107
70	0.002
80	0.119

Table 4. Hydraulic conductivity of the site using the mini disc infiltrometer.

Location	Hydraulic conductivity (cm/d)
NU P7-P8	88.3
NRP4-P13	22.0
NR P7-P8	2.20
P1-P2	66.3
P7-P8	5.44
P3-P1	44.2
P6-P7	66.3
P11-P14	2.00
P6-P9	66.3
P10-P11	54.5
P4-P13	18.1
P1-P9	16.7

NR- Near river,NU- Near Upland.

The process of erosion should be greater at higher slopes and thus give rise to a deposition of finer particles at gentle slopes (Casanova et al., 2000). Therefore, profile pit at P1-P2 at a higher elevation showed a high K_{sat}.

The results from Figures 5 to 8 show a plot of cumulative infiltration against the square root of time. The coefficients of correlation, R^2 ranges from 0.9915 to 0.9982 for hydraulic conductivity experiment from sites P1-P2, P6-P9, NR P6-P7 and NRP13-P4. Values of R^2 range from 0 to 1 and as the value approaches 1, the better the relationship between variables. The correlation coefficient obtained meant a very strong positive relationship between cumulative infiltration and square root of time.

Infiltration characteristics of Besease Inland valley bottom

From our results, the rate of infiltration in the Besease valley bottom varied remarkedly under gravity and capillary forces. From the study, the floodplains at Besease showed a high infiltration rate which declined gradually over time (Figures 9 to 11). The higher infiltration

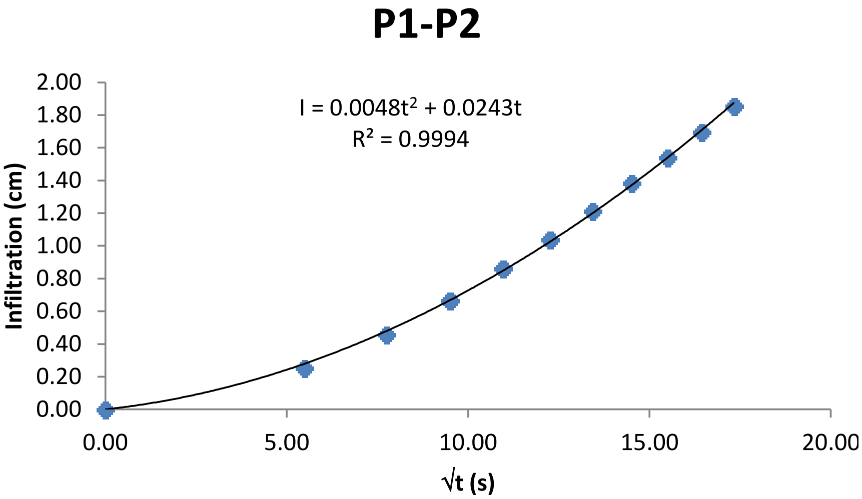

Figure 5. Cumulative infiltration versus the square root of time for P1-P2.

rate at the Besease inland valley bottom may be associated with capillary forces acting on the water, as well as the effect of gravity. Variations in infiltration rates are facilitated by extensive root system and animals burrowing in the soil, inadequate prewetting, and soil disturbance by the infiltration ring. The infiltration rate on the studied floodplain ranged from 0.02-0.78 cm/min (Table 5). The average infiltration rate for the entire population was 0.28 cm/min. Site P1-P2 with high percent sand fraction had the highest infiltration rate of 0.78cm/min. Site P11-P14 and site P8-P7 at lower elevation with low percent sand and moderate clay content (Figures 9 to 11) exhibited a low infiltration rate of 0.02 cm/min and 0.06 cm/min respectively. This shows that water level ponding could elongate, which could result in increased water storage under rice cultivation in the floodplain at Besease.

Characteristics of the soil chemical properties

The soil pH was higher at site P11-P14 followed by P4-P3, P7-P8 and P1-P2 (Figure 12). The OM content of the soils was highest (6.38%) in the P7-P8 area. A relatively higher value was recorded at P11-P14 (4.69%) and the lowest values were observed at P4-P13 and P1-P2 (Figure 13). Also, the highest level of total nitrogen was recorded at P7-P8 followed by P11-P14, P4-P13 and P1-P2. Site P11-P14 had the highest eCEC which was slightly higher than that of P1-P2 (Fig 17). This was followed by P7-P8 and P4-P13 in decreasing order. Again, the electrical conductivity (EC) was higher at site P11-P14 followed by P4-P3, P1-P2 and P7-P8 (Figure 14). The sodium absorption ratio (SAR) also varied in the wetland for which 0.376 mg/l was observed at P7-P8, as the highest. P11-P14, P4-P13 and P1-P2 followed in decreasing order (Figure 14). The soil profile distribution for the site from the top 10 cm to the bottom 80 cm horizon showed that pH, total nitrogen and organic matter decreased slightly with depth (Table 6). However, the exchangeable cations decreased with depth and there was a slight change at the 40 cm depth and continued to decrease again except Ca and Mg which showed some variations from high to low and vice versa from the 40 cm to the bottom 80 cm.

Dynamics of soil chemical properties

The valley system exhibits a slightly acidic to a moderate acidity and this was also replicated in the profile pit P11-P14 ranging from slightly acid in the topsoil to moderately acid in the bottom horizon. A lower soil pH may be due to addition of inorganic fertilizers (e.g. urea), loss of organic matter through erosion, and the leaching of basic cations as a result of seasonal flooding of the wetland (Nakamura et al., 2016; Agbeshie and Adjei, 2019). For rice production, the results obtained is suitable, considering that, upon reduction of the (top) soil following submergence, the pH tends to change towards neutral (pH 6.5-7.0). Most plant nutrients are most readily available for uptake by roots in a slightly- acid to near-neutral environment (IRRI, 1978). The high organic matter content and total nitrogen in the surface layers of P7-P8 and P11-P14 were attributed to concentration of vegetation litter and that decomposition processes are usually slow in hydromorphic soils. However, in waterlogging conditions as it is always experienced in valley systems, it reduces N, availability due to low mineralization rates and the risk of denitrification under alternating wet and dry conditions (Annan-Afful et al, 2005). These loss mechanisms act most severely in strongly alternating wet and dry environments such as the Besease Wetlands. During the soil drying phase,

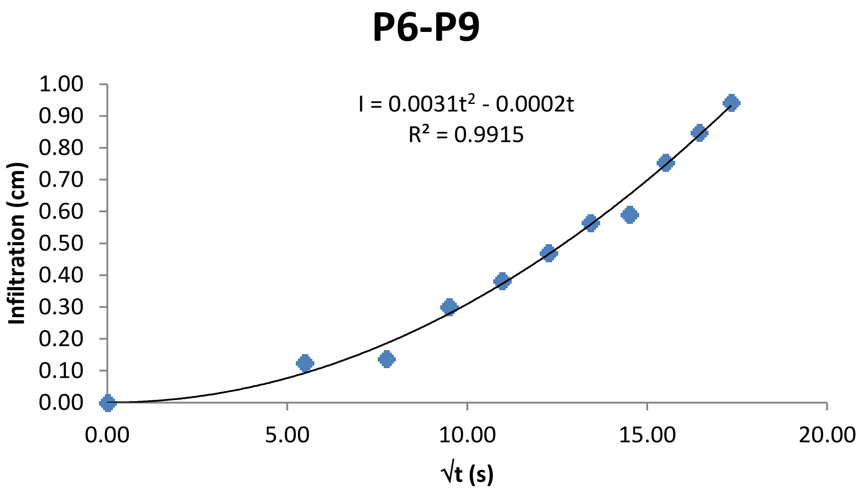

Figure 6. Cumulative infiltration versus the square root of time for P6-P9.

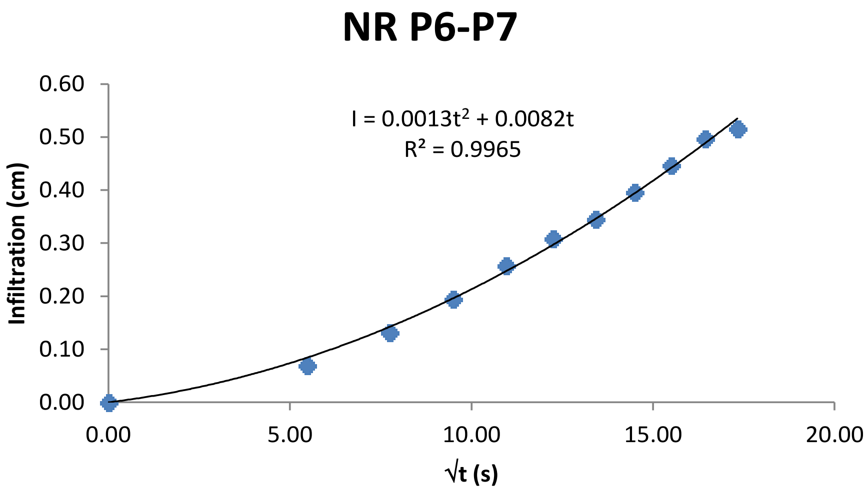

Figure 7. Cumulative Infiltration Versus the Square Root of Time for P6-P7.

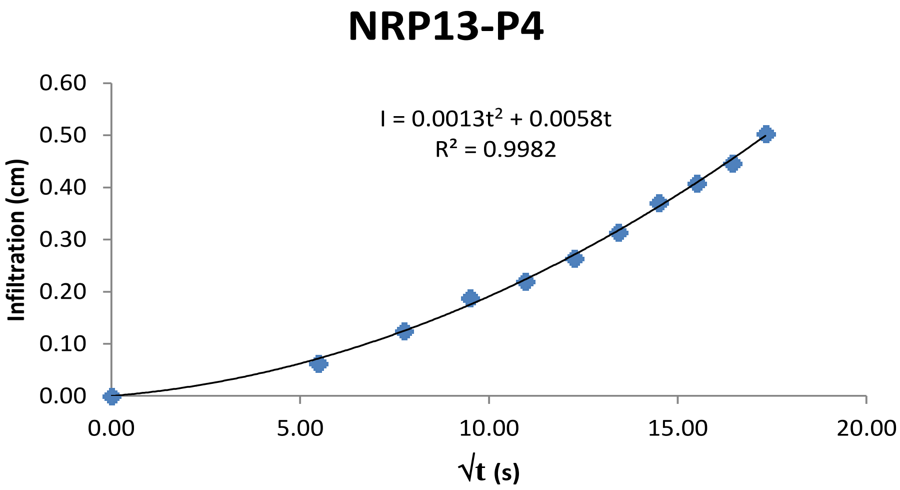

Figure 8. Cumulative Infiltration versus the Square Root of Time for P13-P4.

Table 5. Infiltration rates of the Besease Wetland Site.

Site	Infiltration capacity (cm/min)
P1-P2	0.78
P1-P9	0.63
P6-P9	0.05
P7-P8	0.06
P4-P13	0.15
P11-P14	0.02

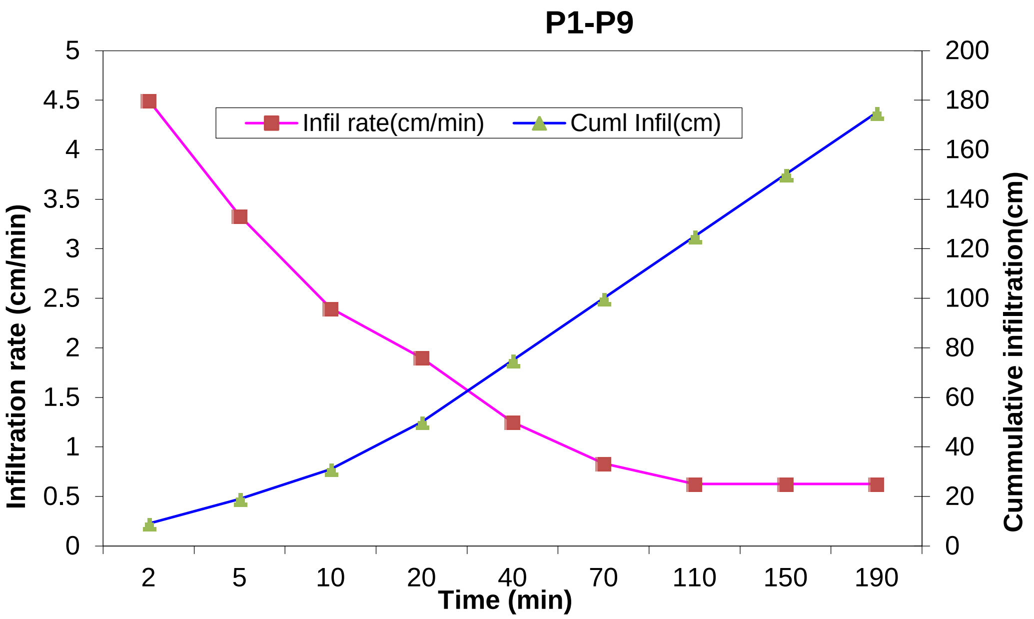

Figure 9. Infiltration in Besease Wetland Site P1-P9.

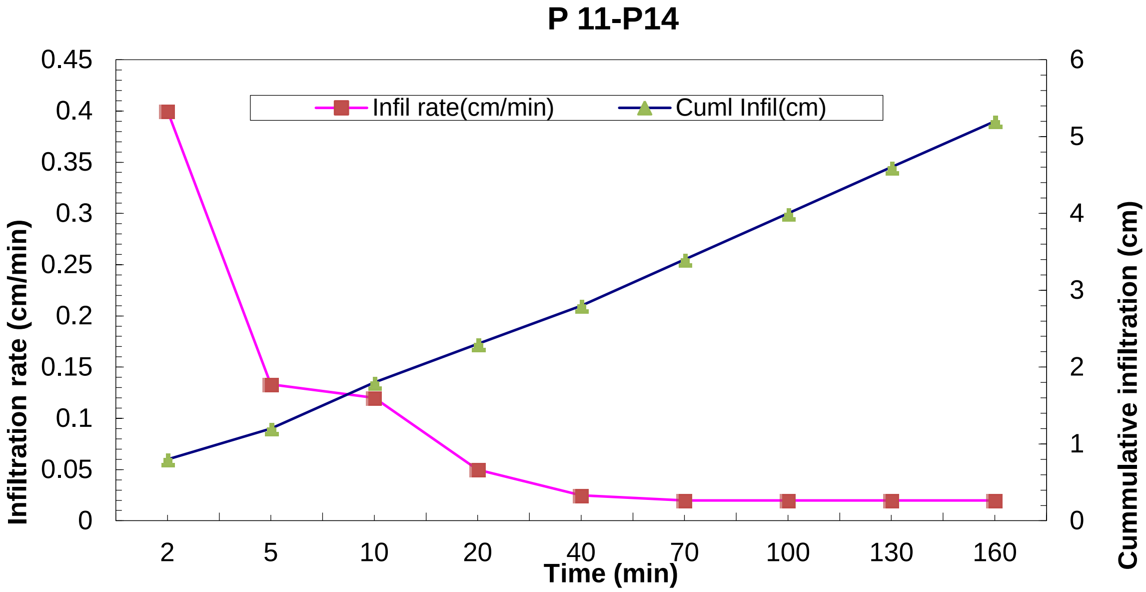

Figure 10. Infiltration in Besease Wetland Site P11-P14.

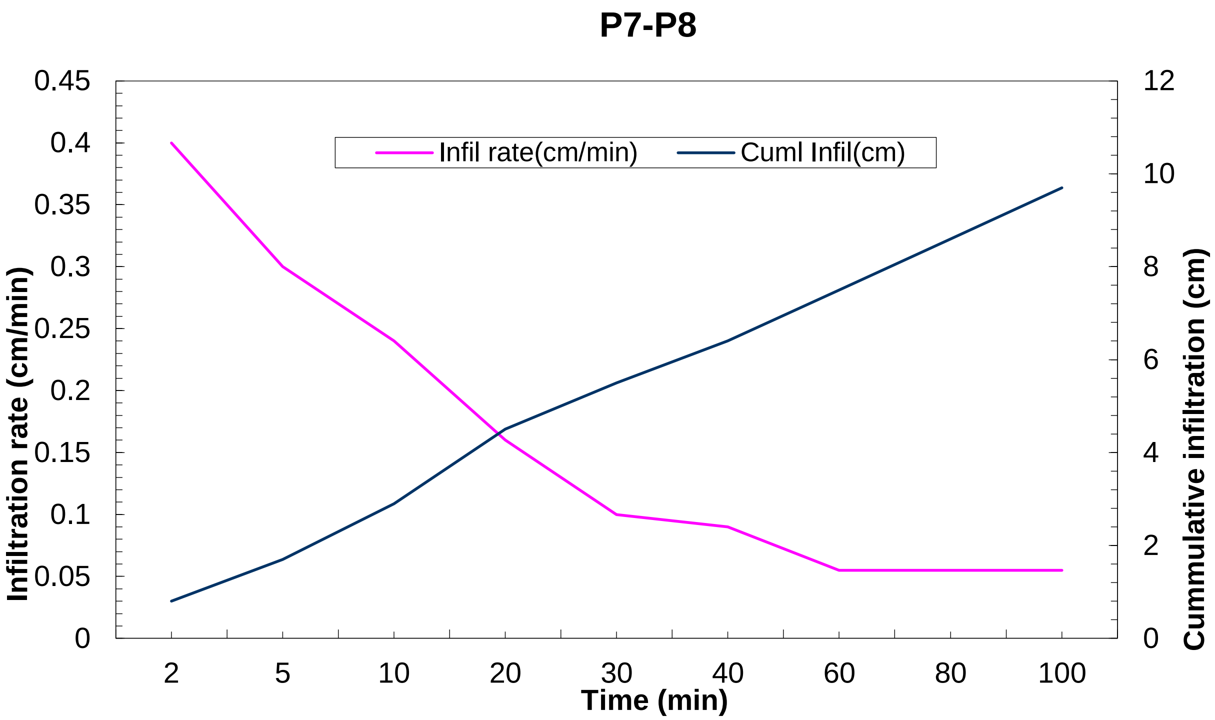

Figure 11. Infiltration in Besease Wetland Site P7-P8.

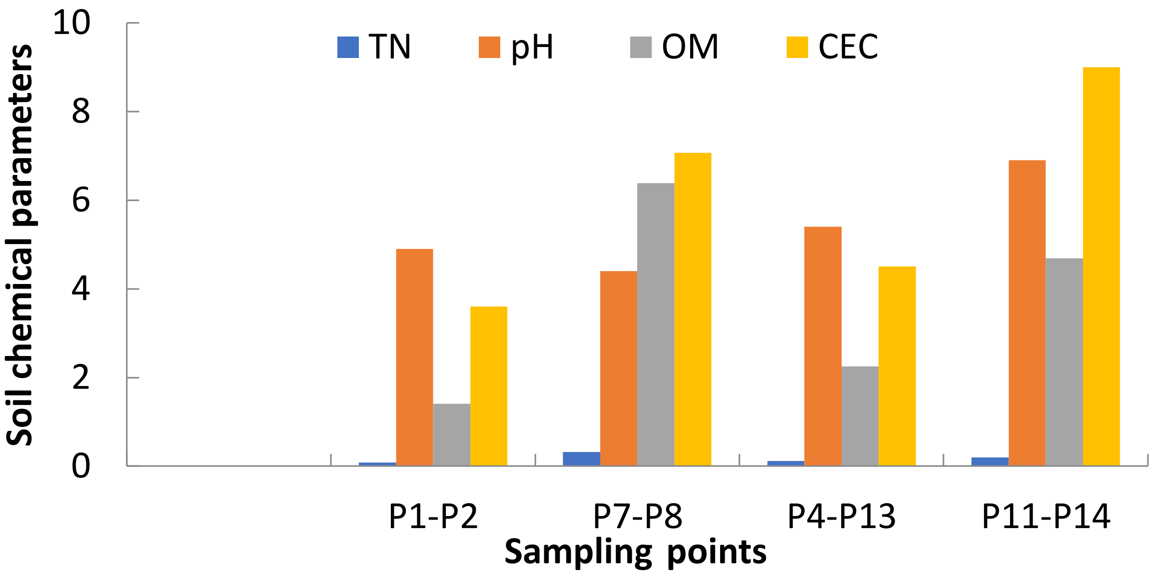

Figure 12. Soil pH, Organic Matter (OM), Total Nitrogen (TN) and ECEC of the Wetland.

reduced forms of N, particularly NH_4^+, are nitrified to NO_3^- (Sanchez, 1976). After soil flooding, NO_3^- may be lost by leaching or by denitrification to N gasses. To ameliorate the losses of N, efficient use of fertiliser application must be employed. The higher eCEC at site P11-P14 and P7-P8 was as a result of higher clay content (Table 1) and organic matter coupled with sedimentation and less leaching. The higher EC observed at P11-P14 may be due to possible groundwater discharge and evaporation associated with the area. The SAR observed from the four sampling points (Figure 14) shows the valley systems suitability for crop production.

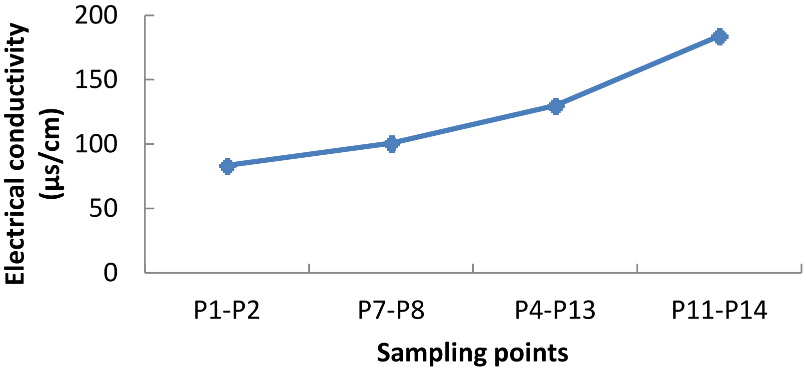

Figure 13. Electrical conductivity for the different sampling points.

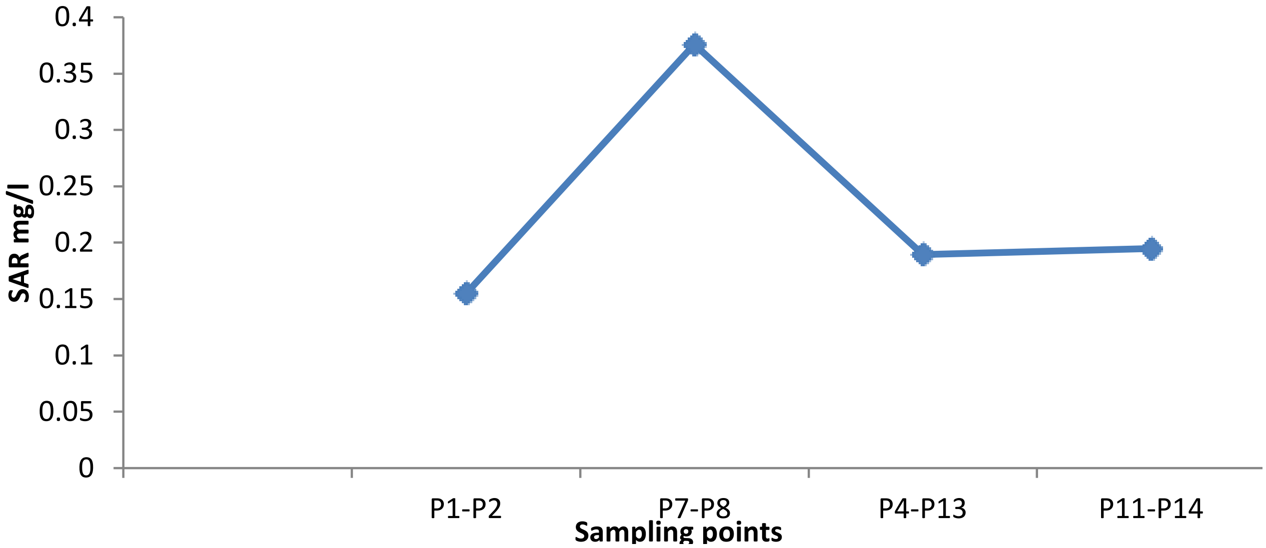

Figure 14. SAR for the different sampling points.

Table 6. Chemical properties of soils.

Horizon	pH	Org. C %	Total N %	Org. M %	Exchangeable cations me/100 g				C.E.C me/100 g
					Ca	Mg	K	Na	
0-10	6.9	2.72	0.2	4.69	4.81	3.20	0.50	0.39	9.00
10-20	6.5	0.60	0.05	1.03	2.94	1.87	0.45	0.24	5.85
20-30	5.6	0.41	0.03	0.70	1.87	1.34	0.28	0.18	4.22
30-40	5.3	0.21	0.03	0.36	1.34	0.94	0.24	0.15	3.32
+40-50	5.5	0.18	0.03	0.31	1.60	1.20	0.31	0.15	3.76
50-60	4.7	0.14	0.01	0.25	0.80	0.27	0.20	0.10	2.27
60-70	5.1	0.11	0.01	0.19	1.07	0.53	0.15	0.08	2.58
70-80	4.6	0.11	0.01	0.19	0.80	0.53	0.15	0.07	2.60

Conclusion

The assessment of wetlands fertility and water holding capacity is a prerequisite for the development of wetlands for crop production. The saturated hydraulic conductivity was high at the soil profile pit P1-P2 which was at a higher elevation. However, a lower saturated hydraulic conductivity which was experienced at profile pit P11-P14 at a lower elevation with characteristic fine textured soils indicated a small water intake. Also possible elongation of water level ponding at P7-P8 and P11-P14 with low infiltration rates of 0.06 cm/min and 0.02 cm/min showed an increase in water storage that is ideal for rice production. The higher EC observed at P11-P14 may be due to possible groundwater discharge and evaporation associated with the area. The SAR observed from the four sampling points showed the valley system suitability for crop production. There is the possibility of sustained plant nutrient and elongation of water level ponding which will result in an increased water storage under rice cultivation in the studied wetland.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors appreciate the Ministry of Food and Agriculture (MoFA), Ghana for funding this research work and the Soil Research Institute of the Center for Scientific and Industrial Research (CSIR), Ghana for assisting in conducting the Physico-chemical soil test.

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