A PRELIMINARY ASSESSMENT OF SOIL CHARACTERISTICS AND GROUND WATER LEVELS IN KEBBI STATE, NIGERIA

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Abstract

Kebbi State falls within the Sokoto Basin, which is part of an extensive elongated sedimentary basin underlying most of the North-west Nigeria and Eastern part of Niger republic. This basin is characterized by many geological formations which include, Dukamaje, Kalambaina, Taloka, Illo, Gundumi, Dange, Wurno, and Gwandu formations. This area is also situated in semi-arid zone characterised by a short rain season as well as a long lasting dry season, which have consequences on the region’s surface water bodies as well as ground water resources. The aim of this assessment was to highlight variability in soil characteristics and consequently its ground water levels. The study employed onsite soil classification. The data was collected in collaboration with A.G Engineering Nigeria Limited of Jega. About seven samples points were purposively selected and studied. A total of one hundred and forty (140) soil samples were collected at different levels and analysed in the laboratory, from which soil particle density as well as soil porosity percentages were obtained. The points that exhibited high porosity percentages were those with less soil density. However, twenty one variables were further generated from the result of laboratory analysis and regressed against water levels using backward selection. The result of the regression analysis shows that silt (x11, x18) was the most important variables affecting ground water level in the study area. Thus, it was concluded that, ground water underlying the study area, is a product of both the area’s surface and sub-surface soil characteristics.

Key words: Porosity; Sub-surface strata; Water bearing strata; Soil characteristics; and Ground water levels.
Introduction

Ground water refers to water occupying all the voids within a geologic stratum (Todd and Mays, 2005). Wilson (1991), refers to it as rainfall that infiltrates the soil and penetrates to the underlying strata … This is a function of porosity of the sub-surface strata. The water bearing strata, called aquifer can consists of unconsolidated materials like sand, gravels and glacial-drift or consolidated materials like sand stones and lime stones. Ground water is one of the major components of hydrological cycle, including surface and atmospheric (meteoric) waters. Relatively minor amounts of ground water may enter this cycle from other origin. Ground water is a precious and most widely distributed resources of the earth and unlike any other mineral resource, it gets its annual replenishment from meteoric precipitation (Todd and Mays, 2005).

According to Ragthunath (2003), the world’s total water is estimated at 1.37 x 10^8 million ha-m. Of these global water resources, about 97.2% is salt water mainly in oceans, and only 2.8% is available as fresh water at any time on the planet earth. Out of this 2.8%, about 2.2% is available as surface water, and 0.6% as ground water, even out of this 2.2 of surface water, 2.15 is fresh water in glaciers and ice caps and only of the order of 0.01% is available in lakes and reservoirs, and 0.001% in streams as water vapour in atmosphere and 0.002% as soil moisture in top 0.6m. Out of 0.6% of stored ground water, only about 0.3% can be economically extracted with present technology, the remaining been available as it is situated below a depth of 800m.

Ground water occurs in many types of geologic formations; those known as aquifers are of most important. An aquifer may be defined as a formation that contains sufficient saturated permeable materials to yield significant quantities of water to wells and springs (Todd and Larry 2005). The water bearing geologic formations or strata which yield significant quantity of water for economic extraction from wells are called aquifers (Raghunath, 2003).

Rock formation that serves as good aquifers, according to Todd and Larry (2005) include:

- gravel, sand and sand stone, alluvium;
- limestone with cavities formed by action of acid water;
- marble with fissures and cracks;
- granite rocks with fissures and cracks;
- weathered gneisses and schist;
- heavily shattered quartzite;
- vesicular basalts and slate (better than shake owing to its disjointed condition).

In addition, an aquifer may be aquiclude, aquifuge or aquitard. Porosity, permeability, soil textural classes, and specific surface are other properties that influence ground water. Porosity of a rock or soil is a measure of the contained interstices or voids expressed as the ratio of the volume of interstices to the total volume (Todd and Larry, 2005). Porosity is the ratio of the volume of voids or pores in a soil mass to its total volume. Shape, size and packing of the grain affect the porosity of granular materials (Raghunath, 2003). However, the terms primary and secondary porosity are associated with primary and secondary interstices, respectively. While the term effective porosity refers to the amount of interconnected pore space available for fluid and is expressed as a ration of interconnected interstices to total volume. In sedimentary rocks subject to compaction, measurements show that porosity decreases with depth of burial.

The sub-surface occurrence of ground water according to Todd and Larry (2005), may be divided into zones of aeration and saturation. In the zone of aeration, vadose
water occurs. This general zone may be further sub-divided into the soil water zone, the intermediate vadose zone, and the capillary zone. The saturated zone extends from upper surface of saturation down to underlying impermeable rock. In the absence of overlying impermeable strata, the water tables, or phreatic surface, forms the upper surface of the zone of saturation. This is defined as the level at which water stands in a well penetrating the aquifer.

However, a study by Offodile (2002), reveals that, the bore holes drilled in many parts of Kebbi state, gave high heads of 7.6m in Argungu, 3m at Birnin-kebbi and 4m at Yeldu. The higher heads associated with the artesian aquifers make it an even more important assets to cheap rural water supply schemes and small scale irrigation projects. The major problem is how to harnessed these resources in order to provide for the increasing demand for water in the study area. This call for a research on the ground water availability. Thus, in this study attempt was made to investigate some the effects of soil characteristics on ground water levels in Kebbi state.

The Study Area

Kebbi state is situated between latitude 10° 8’ and 13° 15’ North of the Equator; and n longitude 3° 30’ E. Kebbi State shares boundary with Sokoto state on the North Eastern axis, Zamfara State in the Eastern part, Niger state in the Southern part and Republic of Niger on the Western part (Figure 1). The state occupies a total land area of about 36,800 km². (Yakubu 2006)

The climate of Kebbi state is hot, semi-arid tropical (Aw) in Koppen’s classification (Yakubu, 2006). The climate is characterised by a long dry season lasting between the months of October and May with a short but intensive wet season between the months of May/June and September. The dry season results from a hot continental air mass blowing from the North-west through the Sahara desert. The rainy season is caused by a humid equatorial maritime air mass blowing from the South-west over the Gulf of Guinea (Yakubu, 2006). Owing to the position of the state in the extreme North-west of the country and over 1000 km away from the sea, Kebbi state remains largely under the influence of the hamattan, which is frequently dust carrying for long period. (Yakubu, 2006)

Kebbi state is located within the Sudan savannah zone with the natural vegetation type of open scrub savannah. It consists of shrubs of various densities with the trees rarely exceeding 6 metres in height. Man, through farming activities and the search for fire wood has tremendously influenced the native vegetation. The main shrub species are *combretum Nigerians varelloctic*, *combretum uira semicranthum* and *Gnevalensis* (Yakubu, 2006)

Kebbi state falls within the Sokoto basin which is part of an extensive elongated sedimentary basin underlying most of the North-western Nigeria and eastern part of Niger Republic. Geologically, the Sokoto basin is divided into two groups, Sokoto group and Rima group. The later consist of Dukamaje formation, Kalambaina formation, Taloka formation, Illo formation and Gundumi formation, while the former group, consist of Gwandu formation, Dange formation and Wurno formation. Among the later group, only Dange formation is characterised by poor water storage. Specifically, the geology of present Kebbi state, though part of Rima basin, is dominated by Gwandu and Illo formations (Figure 1). However, Illo and Gwandu formation show a lot of features in common as such they are treated together in most literature (Mathew, 2002).
Materials and Methods

A total of seven boreholes were purposively selected and studied across the state in collaboration with A.G. Engineering Nigeria Limited. The sub-soil samples were collected after every three metres. The study employed onsite soil classification from which the various soil categories were identified. All the one hundred and forty (140) soil samples were analysed in the laboratory for soil particle density, bulk density as well as soil porosity per cent.

The soil porosity per cent was derived as:

\[ \text{Bd/Pd} \times 100 = \text{porosity}. \]

The result of the laboratory analyses were further organised into twenty one variables. These variables were also imported in to MINITAB (mtb13) statistical soft ware and regressed using backward selection, against water level.

The regression equation is written thus:

\[ Y = a + b_1x_1 + b_2x_2 + b_3x_3 \ldots \ldots + b_nx_n + e \]

\[ Y = \text{ground water levels} \]

This explained how much of Y is explained by the X variables.

Where:

- \(a = \text{Intercept}\)
- \(e = \text{error terms}\)
- \(b_{x_1} - b_{x_n} = \text{regression co-efficient}\)

\[ y(f) = x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{18}, x_{19}, x_{20}, x_{21}, x_{22} \]

The twenty one (21) variables comprise the soil density and porosity per cent of different soil categories across the seven bore holes. In the same vein, the water levels were measured by the use of marine rope, in place of water level indicator. The water level was obtained by subtracting water level (WL) from well depth (WD), from which the difference (D) was obtained. This is written, thus;

\[ WD - WL = D. \]
**Result and Discussion**

The results of the analysis are presented in Table 1 and Figures 1 and 2 as well as Figure 3 respectively. The overall mean porosity per centage shows a pattern of variation both between the soil types and across the studied bore holes. The mean porosity image of Figure 1(a) shows that coarse sand and very coarse sand appears to have highest porosity per cent among the identified soil types. The mean image of Figure 1(b) shows that fine sand appears to have highest porosity per cent. In the same vein, the mean porosity image (c) also shows that very coarse sand has the highest porosity per cent. Contrary to this, the mean porosity images of (d), (e) and (g) showed clay to be with the highest in (f) where coarse sand appeared highest per centage, clay has the highest porosity per cent. This strange situation could be as a result of the fact that this analysis was based on a disturb or packed soil samples. In addition, the findings of this analysis, compared with that of Morris and Johnson, (1959), cited by Todd D. K. and Larry M. (2005), it appears that the per centage porosity figures in this analysis are greater. Possible reasons for this disparity may include differences in geographical back ground. Figure 2, shows both the soil particle density as well as soil bulk density. Figures 2(a) – (g) show clearly, that there is close relationship between soil particle density and soil bulk density.

However, comparing the results of density analysis with that of porosity per centage, it can be observed that, the less dense is the soil, the more prose it becomes. Therefore, the more dense is the soil material, the less porous it becomes in the study area.

However, the results of the analysis of soil density and soil porosity per centage were employed in MINITAB (mtb13) statistical soft ware. Twenty one (21) variables were generated and regressed against water level using backward selection. The result shows that, silt was the most important soil property influencing ground water levels in the study area. The result of the analysis gives 63.6% and 87.6% explanation.

Overall, the result showed that sandy formation appears to be the most important soil property affecting water levels in the study area. This is clearly manifested in the homogeneity of the sub-soil properties across the studied bore holes. This findings further confirms the findings of Mathew O.(2006), who argues that the geological formations in Sokoto Basin are similar in their lithological characteristics only that Gwandu formation is a lateral equivalent of Gumdumi formation.
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Figure 1. Soil density of the study area. (a) – (g) show the mean soil particle density and mean soil bulk density of the study area.
Figure 2. Soil porosity percentage of the study area. (a) – (g) show the mean soil porosity per cent of the different soil categories in the study area.

Figure 3. Water levels, Well depth and difference.
Source field work (2010)
Conclusion
Although, this study is not broad in nature, covering only seven areas within Kebbi state, it was able to analyse the effect of soil on ground water levels in the study area. Though, the results showed that, porosity percentage is strongly influenced by the soil density and the overall result of the analyses has shown that, silt particle was the most important soil property which influences ground water levels in the study area. Therefore, ground water underlying the study area is a product of both sub-surface and surface soil properties.
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