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Original Research

Identification of Groundwater Level by Using Geoelectrical Resistivity Method at Fincha'a Sugar Estate, Blue Nile Basin, Western Ethiopia

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Abstract

Good water management and improved drainage can minimize yield reductions caused by waterlogging and thus increase profitability. Waterlogging became a very severe problem in some of the irrigated fields of Fincha'a Sugar Estate in the Blue Nile Basin of western Ethiopia. As a result many productive agricultural lands were abandoned. A measurement of geoelectrical resistivity at the selected irrigated fields by using Schlumberger array with the space of potential and current electrode was found to be 2 m. The positions of centre sounding measurements to be investigated were at different points along the traverse line (subsurface area). The objective of this study was to identify the depth of the groundwater table in relation to aquifers and subsurface lithology. The shallow ground water was identified at the depth of 1.5, 2.06, 3.18 and 2.49 m with resistivity values of 3.76, 5.42, 49.3, and 29.4 Ω-m at (VES 1), (VES 2), (VES 3) and (VES 4) respectively. While the deep ground water table confined on the course range from the depth of 3.96 to 11.6 m with the resistivity value of 3.96 to 11.6 Ω-m.The variation of resistivity values from each position of ground water shows the variation of variation of crack dimension and variation of medium type. It was identified that the selected irrigated fields are under severe to critically waterlogged conditions. Deeper regolith (3.18-20.7) m was resistive, both above and below the water table, due to low salinities in the groundwater and coarser textures.

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INTRODUCTION

Irrigation alters the surface water balance. Water not used for plant growth or lost to evaporation, drains below the root zone (Jenny *et al*., 2010). There is some evidence, from bore monitoring, of rises in groundwater level in shallower aquifers in the alluvium (DERM groundwater database), likely due to recharge from deep drainage (Murphy, 2008), but many shallower bores have been dry for many years. Diffuse recharge (i.e. through the soil) in the alluvium is considered to be small, with the aquifers mainly recharged by river leakage (Gunawardena *et al.,* 2008). Thus there is a disparity deep drainage below the root zone is seen to be high but recharge from this source is thought to be low. This would be explained, in part, if deep drainage was being stored in an unsaturated zone left dry by the previous native vegetation, creating a time lag between deep drainage and recharge. Little is known about the moisture capacity and status of the regolith (unsaturated zone) or how this has changed as a result of changes in the soil water balance. Soil resistivity is related to soil water content, salinity and clay (content and type). Data can be interpreted qualitatively with the aid of lithology from bore logs and measures of salt and clay content. Contrasts in regolith under native vegetation and under irrigated agriculture were examined, to assess the impacts from land use changes (Jenny *et al*., 2010).

Geophysical techniques are the highly useful for the identification of groundwater potential zones and groundwater level studies, to investigate the nature and status of subsurface saline water contamination. Among various geophysical studies, the Schlumberger configuration was used in determination of depth, thickness and boundary of an aquifer (Omosuyi *et al*., 2007; Ismail Mohameden, 2005 and Olowofela *et al*., 2005 and Oseji *et al.,* 2005) and exploration of geothermal reservoirs (El-Qady, 2006) and estimation of hydraulic conductivity of aquifer (Khalil and Monterio, 2009). Vertical Electrical Sounding method was chosen because, the instrumentation is simple, field logistics are easy and straight forward while the analysis of data is less tedious and economical (Selvam and Sivasubramanian, 2012**)**. Using this method, depth and thickness of various subsurface layers and their water yielding capabilities can be inferred. Aquifer resistivity is controlled by water content, water quality and grain matrix (Tahmasbinejad, 2009; Yusuf *et al*., 2011). When the distance between the current electrodes is increased the depth to which the current penetrates is increased (Bobachev and Igor, 2000, Amadi *et al*., 2011). The current electrodes spacing (AB) increases after each reading while the potential electrodes spacing (MN) increases only when deemed necessary and controlled by the relation AB/2≥5MN/2 as required by the Schlumberger array (Patra *et al*., 1999).

The waterlogging in some sugar plantation irrigation fields of Fincha'a sugar estate have an effect on yield of sugar cane and the productivity of the estate. To ensure its negative impact, a combined hydrological and hydrogeological study was needed in place. The main objective of the present study was to identify the groundwater level condition and the nature of subsurface layers within the selected waterlogged irrigated fields of Fincha'a sugar estate. Vertical Electrical Sounding (VES) was used to carry out groundwater level identification in the present study area. The results of the study could be used to locate the positions and dimensions of the drainage ditch in order to carbe the existing waterlogging problems and increase the productivity of the Sugar cane.

MATERIALS AND METHODS

Geographical Environment

The study was conducted in FSE in the Fincha'a valley, Abay cowman district, Horo Guduru zone (HGZ), Oromia Regional State (ORS), Blue Nile basin (BNB), Ethiopia (Figure 1) lying between 9°30' to 10°00'N latitude and 37° 15' to 37°30'E longitude a distance of 340 km from Addis Ababa, the capital of Ethiopia with altitude variation from1350 to1600 m above sea level and bounded by the Amhara National Regional state in the North, Guduru Woreda in the East, Horro Woreda in the West and Jarte and Amuru Woreda in the South respectively. The total command area of the valley is 65,000 ha. The thirty years (1979-2012) climatic data from FSE Meteorological Station recorded the yearly average annual rainfall 1315.5 mm which is characterized by unimodal rainfall pattern. About 80 % of the annual rain falls between May to September its mean annual maximum and minimum temperatures lies between 30.5 and 14.85^0 C (Figure 3) Average pan evaporation was 153.1mm and the average annual reference evapo-transpiration (based on Penman-Monteith) is 1320 mm, with monthly low variation (Ambachew and Girma, 2005). The average annual relative humidity is about 83.8% (Baissa, 2007). Fincha'a valley has alternate wet (during May to October) and dry (during the rest of the months) seasons Wind speed in Fincha'a Valley is low as the surrounding escarpments hinder wind movement. However, wind speed is high between the months of March to June (Worku, 1995, Ademe, 2001).The study area falls in the humid agro-climatic zonation (MOA, 1998) on the basis of altitudinal and annual rainfall variations.

According to the extracted BNB digital soil (1974) data obtained from Ministry of Water and Energy of Ethiopia (MWEE, 2011), the soil classes of the study area are Cambisols, Luvisols, Leptosols, Alisols, Marsh, Vertisols and water associated with the geomorphology and the geology of the area (Figure 4) and topographically surrounded by escarpments and steep side sloping landscape. The steep side slopes and escarpments of mountain plateau and gorges have very shallow soils. (Dereje, 1995) reported that Luvisols are relatively good in drainage and mineral composition and are largely (75%) distributed and the Vertisols are characterized with poor drainage and high water holding capacity and the distribution is (23%). Most of the Luvisols are situated in the middle of the interfluves. Nineteen percent of the Luvisols are moderately deep. Vertisols are found mostly in the lower areas near The Agul River and at the upper ends of the interfluves (Worku, 1995). Sugarcane mono cropping based on irrigation agriculture is the main agricultural activity taking over. The area is mainly drained by the Fincha'a river. Fincha'a Valley has quite diversified physical landscape with Topography ranging from 892 to 2520 (Figure 2). Slope for the study varies from, flat (0-2 %), moderately steep (16-30 %), Gently Undulating (2-8 %), Rolling (8 - 16%) and to steep (> 30 %), (Figure 5). Geologically, the Adigrat sandstone formation, which is composed of alternating beds of sandstones and shales and have been deposited unconformable upon the eroded surfaces of the Basement Complex is commonly is commonly distributed. The study area is surrounded by

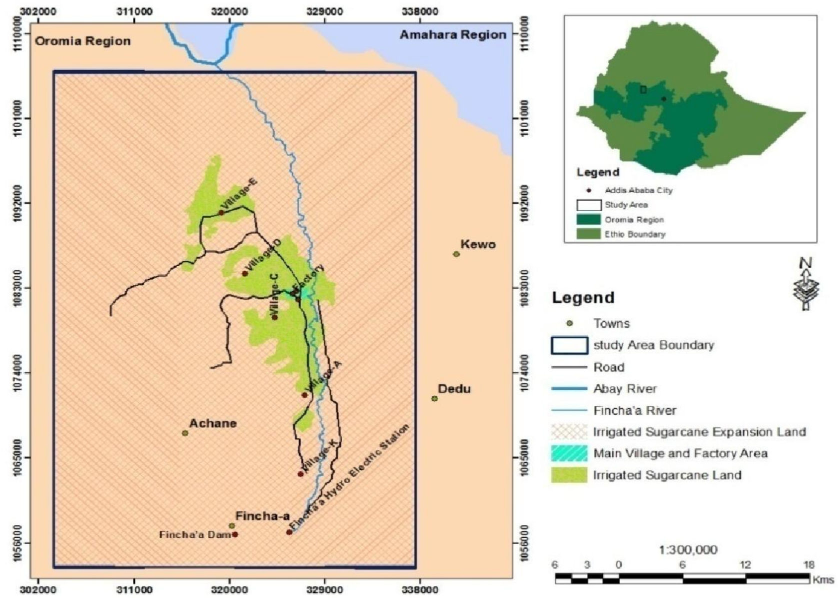

Figure 1: Location map of the study area.

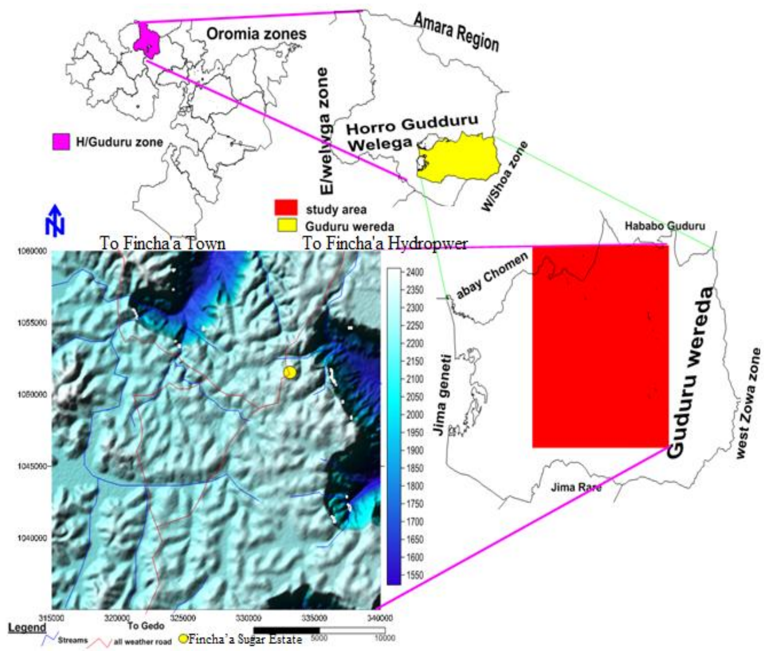

Figure 2: accessibility, drainage and location map of study Area.

escarpment along its southern, eastern and western sides, which rise approximately 700-850 m above the valley floor. The floor of the valley is dominated by a gently undulating slope (1- 8 %) surface northwards Ahmed (2007). The width of the valley, generally, increases from south to north with an average size ranging from 25 to 30 km.

Methodology

Electrical prospecting makes use of a variety of principles, each based on some electrical properties or characteristics of the materials within the earth (Singh *et.al.,* 2002). In this study, Vertical Electrical Sounding (VES) method has been applied. VES survey was carried out in 4 locations (Figure 2) using Schulumberger electrode configuration. The Schlumberger method was adopted for this study because of the fieldwork is faster, easier and economically save the money and software's are readily available for its interpretation (Todd 1980, Fetter 1994, Patra and Nath 1999). The resistivity values of the layers were measured using the Syscal Junior Resistivity meter model). For Schlumberger soundings (Figure 6), soundings were carried with maximum current electrode spacing (AB) 1500 m (AB/2 = 750 m). The distance used for potential electrode spacing (MN) ranged from 0.3m to 10m (MN/2=0.15m to 5m). At each VES station electrodes were placed in a straight line and the inter-electrode spreads were gradually increased about a fixed center. The current was sent into the ground and the potential difference (**V**) due to this current was measured and recorded against the electrode spacing. With these values of currents (**I**) and potential (**V**) of the electrode configuration adopted one can get the apparent resistivities (ρa). The apparent resistivity values were plotted against AB/2 on double – log graph sheets. The manner in which apparent resistivity values increase or decrease with electrode separation forms the basis for choosing the shape of the field curve that can perform quantitative interpretation of the sub surface resistivity distribution (Singh *et al.*, 2002). IPI2WIN software and inversion technique were implemented for data interpretation. Aerial photographs and topographic maps at a scale of 1:50,000) were used to identify the geological structures and trace them on to the topographic sheet of 1:50,000 scale. The topographic sheet

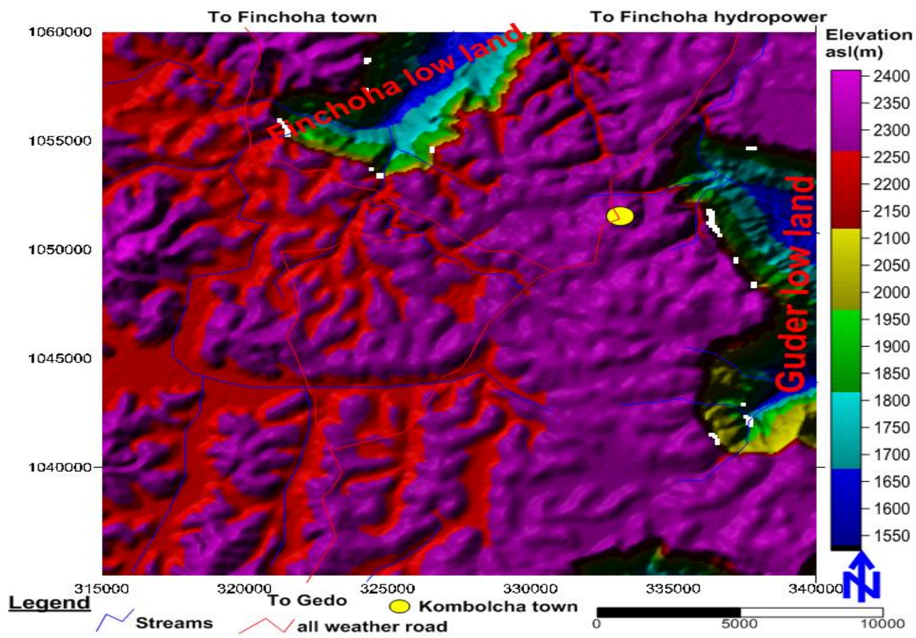

Figure 3: Physiography and drainage system of Fincha'a Sugar Estae.

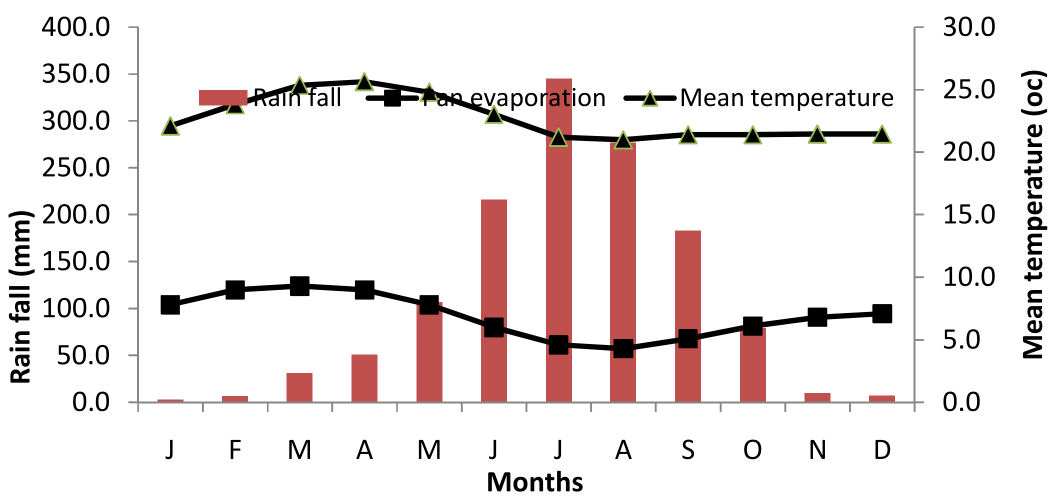

Figure 4: Mean monthly rain fall (RF), mean maximum and minimum temperatures (Temp.) and pan evaporation of the Fincha'a Sugar Estate, Blue Nile Basin, western Ethiopia based on records at the Fincha'a Sugar Estate research station methodological station (1979-2012).

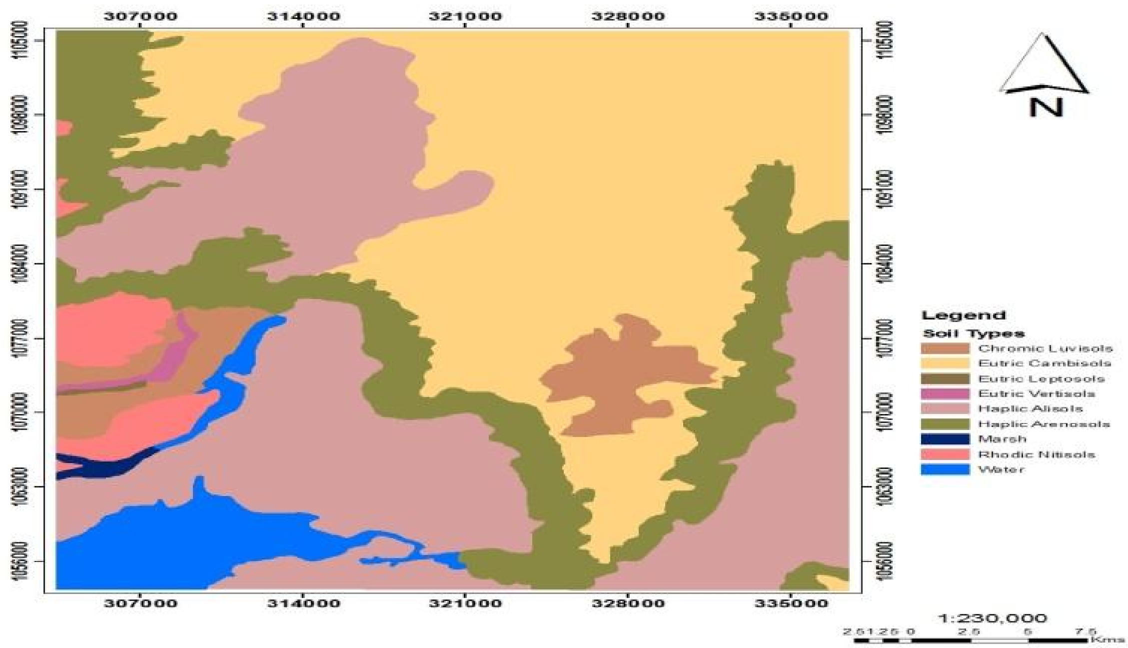

Figure 5: Soil map of Fincha'a watershed: modified from Soil Map of East Africa (1997).

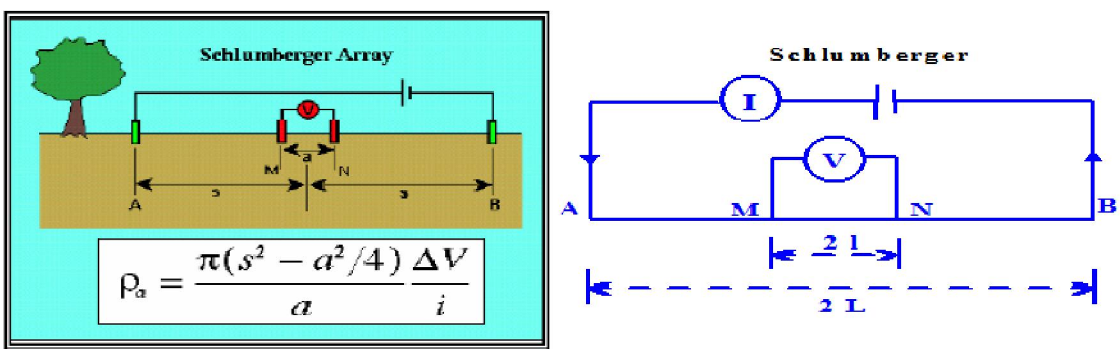

Figure 6: VES geoelectric sounding and Schlumberger array.

was used as base map in the field to mark the lithologies, their contacts and trends and to develop detailed geological and hydrogeological maps of the area. Primary geological and hydrogeological data were collected in the field after having the secondary data. Aquifers in the area of investigation were classified based on two factors: qualitative and quantitative classifications.

Data Interpretations

An iteration software (WIN RESIST) was used to iterate curves of VES. The smooth curves taken through the set of data points were interpreted quantitatively by the method of partial curve matching. Layer resistivity and thickness were got from VES1 to VES4 diagram.These curves were interpreted using the partial curve matching technique (Orellana and Mooney, 1966) and corresponding auxiliary curves to obtain the resistivity, thickness and depth of water table of each of the layers delineated. The quasi-computed resistivity values were then analyzed by the application of IPI2Win Program for inverting the 1 D dimension. This inversion results in a 1 D curve showing the distribution of underground electrical resistivity values. The VES was conducted in the Southwestern Eastern direction for VES1 at GPs Location of 37P, 0325839mE, UTM, 10^0 71736mN an elevation of 1586 m. a.s.l. East direction for VES 2 at GPs Location of 37P, 0325318mE, UTM, 10^0 74134mN and elevation 1560 m.a.s.l. East-North direction for VES 3 at GPS Location of 37p, 0325355mE UTM, $10^{0,}$78960 and elevation 1515 m.a.s.l. for VES 4 at GPs Location of 37P, 0321457mE UTM, 10^0 84325 an elevation of 1506 m.a.s.l. Figure 7.

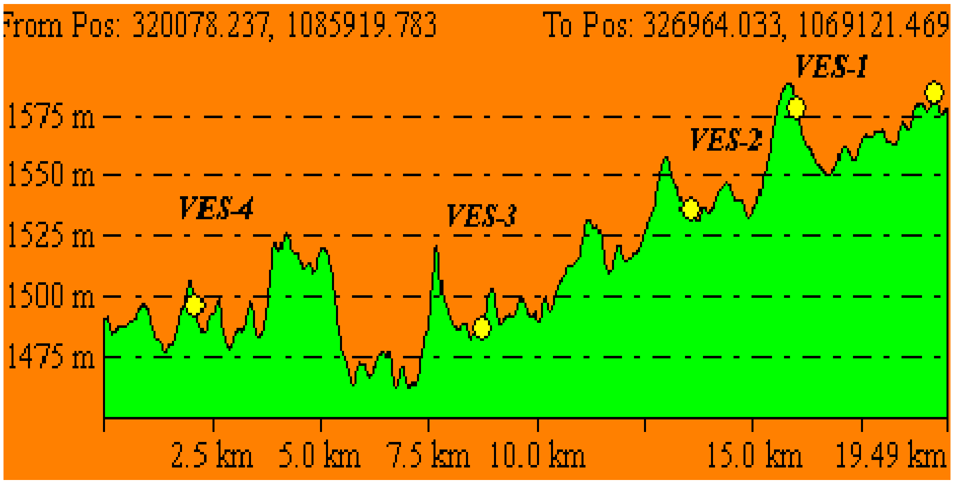

Figure 7: Location of Vertical Electrical Soundings for selected irrigation fields of FES

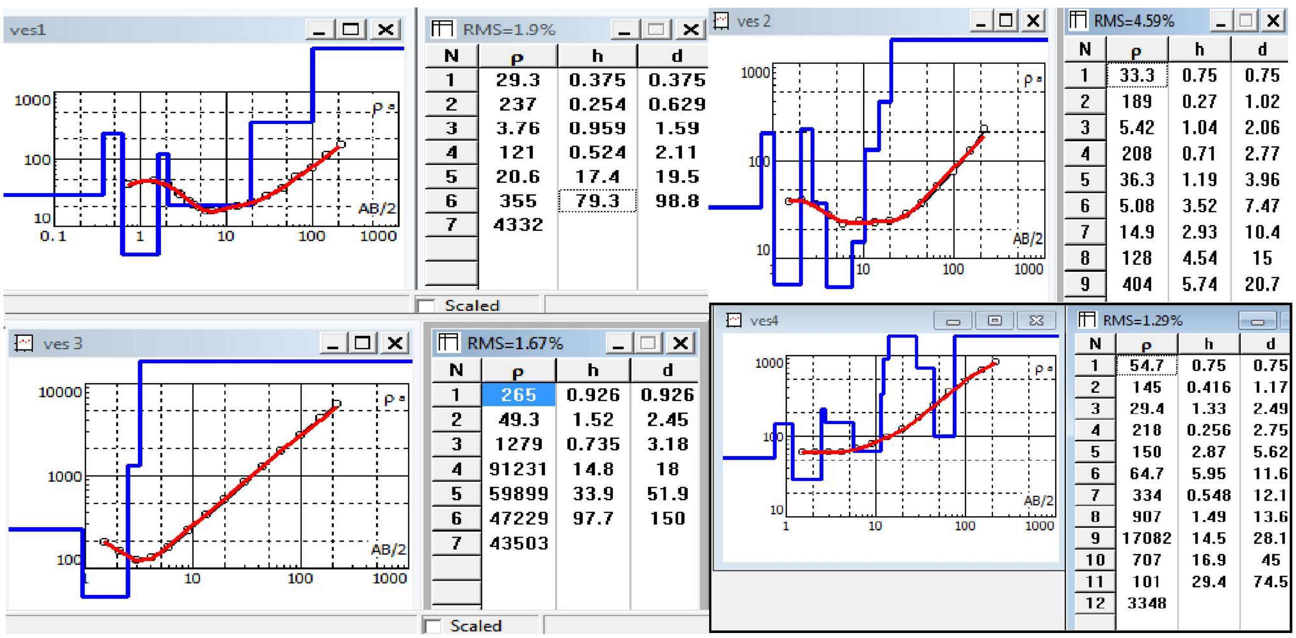

Figure 8: Interpretations of Vertical Electrical Sounding Field Curves.

RESULTS

Morphology & Soils of Selected Irrigation Site

The topography of the site is dominated by the flat to moderately steep landscape and areas of (0 – 30 %. This site is basically part of the low land with the altitude of 28-2828 m. The most dominant soil types in the study site are Luvisols and Vertisols. These together with topography, nature of basement rock are an indication for the selected fields to be waterlogged.

Geology of the selected Irrigation site

In terms of its geological characteristics, the site's natural condition and distribution of aquifer, aquiclud and aquitard are mainly dominated by rocks, layers and structures of geological content and formation (Ibrahim, 2008). The lithological component shows the physical structure and geological content. They consist of mineral compositions, and grain packing formed from sedimentation. Stratigraphic structure explains the age of layers, their kinds and formation. Cleavages, fractures, folds and faults show the geometric characteristics of a geological system resulting from deformation, deposition and crystallization of the rocks. For unconsolidated deposits, the lithological and stratigrafic processes play an important role to maintain a balanced structure. Plateau basalt and Adigrat sand stone were identified as highly dominant geological formations (Figure 10) with highly weathered and fractured trachyte at quarry site and recent deposit (Figure 11), alluvial deposit (Figure 12) and highly weathered and fractured basalt at local faulting (Figure 13). These are indicators of the groundwater potential of the site.

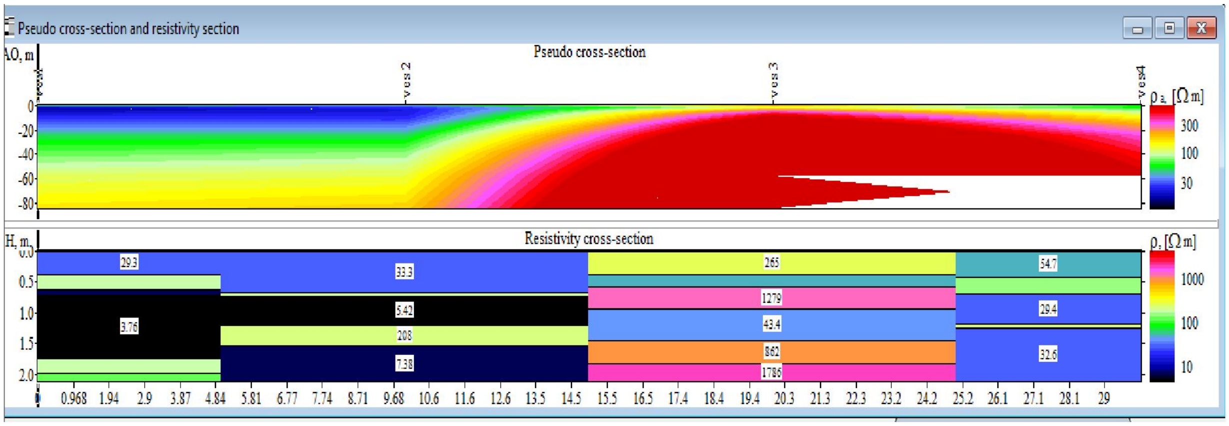

Figure 9: Pseudo cross –section and resistivity section of the study area.

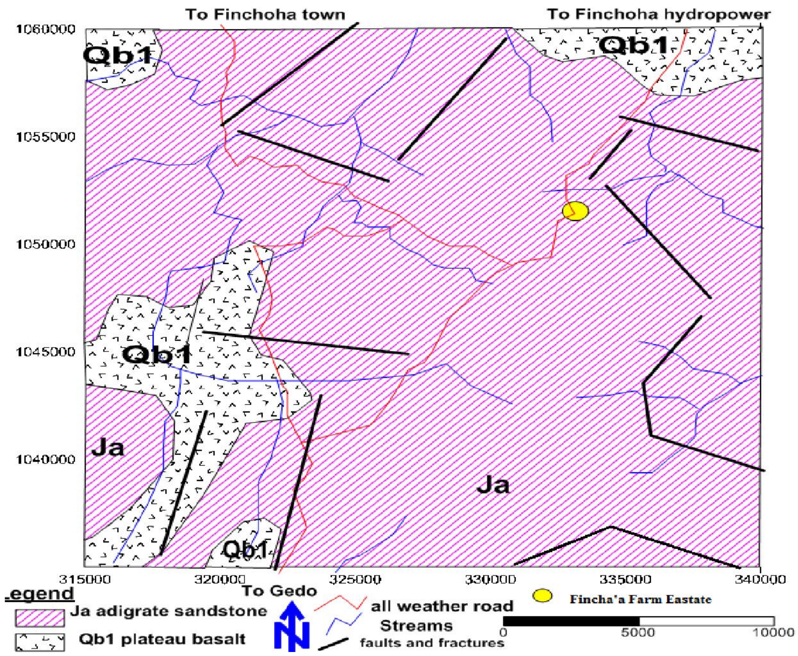

Figure 10: Geological map of Study area, (modified from geologic map of Ethiopia ,1996)

Figure 11: Highly weathered and fractured trachyte at south and west of the study (quarry site).

Figure 12: Alluvial deposits of the selected irrigation fields in the study area.

Figure 13: Highly weathered and fractured basalt at local faulting of the selected irrigation fields in the study area.

Aquifers in the Selected Irrigation Site

In the Fincha'a Sugar Estate irrigation fields, aquifers are generally of two kinds: the shallow or free and the compacted ones. Their conditions show all of the specific characteristics: their total quantity, spread, hydraulic status, potential and groundwater quality. The shallow aquifers in the Fincha'a Sugar Estate irrigation fields varies between 1.59 and 2.49 m depth and the compact(deep) ones varies between 10.4 and 19.98 m. The shallow aquifers basically consist of wet top and clay soil and the compacted aquifers consist of saturated sand stone and sandy soil.

Geoelectrical Resistivity Measurement

The field data were interpreted and processed qualitatively and quantitatively by using partial curve matching techniques and computer to obtain the resistivity values of different subsurface layers and their corresponding thickness (Table 1). From the interpretation of VES curves, 6 to 12 subsurface layer where identified within the study area. The curves are prominently of different type indicating the presence of six to twelve layers and sub-surface layers (Figure 8).

Locations VES 1, VES 2, VES 3 and VES 4 can be explained by ($\rho_a 6 > \rho_{a2} > \rho_{a4} > \rho_{a1} > \rho_{a5} > \rho_{a3}$), ($\rho_{a9} > \rho_{a4} > \rho_{a2} > \rho_{a8} > \rho_{a5} > \rho_{a1}\ \rho_{a3} > \rho_{a6}$), ($\rho_{a4} > \rho_{a5} > \rho_{a6} > \rho_{a7} > \rho_{a3} > \rho_{a1}\ \rho_{a2}$) and ($\rho_{a12} > \rho_{a9} > \rho_{a8} > \rho_{a10} > \rho_{a7} > \rho_{a4} > \rho_{a5} > \rho_{a2} > \rho_{a11} > \rho_{a6} > \rho_{a1} > \rho_{a3}$) six, nine, seven and twelve layer models respectively (Figure 8).

VES1: The resistivity of the first layer (top soil) was 29.3 Ω-m and a thickness was 0.37 m. In the second layer, hard and compact sand was inferred with the high resistivity value of 237 Ω-m and thickness 0.254m and can be mapped relatively as fresh bed rock of basalt and dry and fresh top soil which are not so affected by fractures and joints. The Third layer has resistivity of 3.76 Ω-m and a thickness 0.959 m. This layer acts as the shallow aquifer in these places because this layer consists of fracture or weathered zone which constitutes an aquifer of very good quality of groundwater resulted from the in situ weathering of the basalt rocks interpreted as zone of wet aquifer soil, clay soil, and weathered soil accumulates as a result shallow ground table was identified at depth of 1.5m.The basement had resistivity and thickness of 121ohm-m and 0.52 respectively. The basement resistivity data indicates the rock type is hard and massive. The fiftieth layer was identified as highly weathered wet clay soil and fractured bed rock in which the discontinuities were filled with water had resistivity of 20.6 Ω-m and a thickness 0.95 m. The resistivity and thickness of the last (six) layer were 355 Ω-m and a 79.3m respectively which might considered as basement rock of driest zone.

Table 1: Summary of VES data interpretations with positions and Lithology.

layer	ρa (Ωm)	T(m)	D(m)	Inferred lithology
VES 1				
1	29.3	0.37	0.37	wet top soil,
2	237	0.25	0.62	dry and fresh topsoil
3	3.76	0.95	1.59	Wet, aquifer soil ,clay soil, weathered soil
4	121	0.52	2.11	sandy soil and basement hard rock
5	20.6	17.4	19.98	Wet ,clay soil, weathered soil
6	355	79.3	Inf.	
VES 2				
1	33.3	0.75	0.75	wet and weathered topsoil,
2	189	0.27	1.02	Dry soil and ,fresh sandstone
3	5.42	1.04	2.06	Wet, aquifer soil and clay soil
4	208	0.71	2.77	hard sandstone
5	36.3	1.19	3.96	Wet sandy soil
6	5.08	3.52	7.47	Wet sandy soil
7	14.9	2.93	10.4	Wet sandy soil
8	128	4.54	15	Dry massive sand stone
9	404	5.74	20.7	Hard basement rocks
VES 3				
1	265	0.92	0.926	dry and topsoil
2	49.3	1.52	2.45	wet top soil
3	1279	0.73	3.18	Hard and massive basement rocks
4	91231	14.8	18	Hard ,not fractured massive basement rocks
5	58998	33.8	51.9	Hard ,not fractured massive basement rocks
6	47229	97.7	150	Hard ,not fractured massive basement rocks
7	43503	Inf.	Inf.	Hard ,not fractured massive basement rocks
VES 4				
1	54.7	0.75	0.75	wet top soil and weathered topsoil
2	145	0.41	1.17	dry and topsoil,
3	29.4	1.33	2.49	Wet Laterite soil
4	218	0.25	2.75	Dry and massive sand stone
5	150	2.87	5.62	Dry sandy soil
6	64.7	5.95	11.6	Wet sand stone
7	334	0.54	12.1	Dry and massive basement rocks
8	907	1.49	13.6	Dry and massive basement rocks
9	17082	14.5	28.1	Dry and massive basement rocks
10	707	16.9	45	Dry and massive basement rocks
11	101	29.4	74.5	Fractured volcanic rocks
12	3348	Inf.	Inf.	Dry and massive basement rocks

Table 2: Qualitative analysis of curve types where ρ represents resistivity of the layer.

VES	Curve type	Curve Characteristics	Number of layers
1	KH	$\rho_{a1} < \rho_{a2} > \rho_{a3} < \rho_{a4} > \rho_{a5} < \rho_{a6}$	6
2	KH	$\rho_{a1} < \rho_{a2} > \rho_{a3} < \rho_{a4} > \rho_{a5} > \rho_{a6} < \rho_{a7} < \rho_{a8} < \rho_{a9}$	9
3	HAK	$\rho_{a1} > \rho_{a2} < \rho_{a3} < \rho_{a4} > \rho_{a5} > \rho_{a6} > \rho_{a7}$	7
4	KH	$\rho_{a1} < \rho_{a2} > \rho_{a3} < \rho_{a4} > \rho_{a5} > \rho_{a6} < \rho_{a7} > \rho_{a8} < \rho_{a9} > \rho_{a10} > \rho_{a11} < \rho_{a12}$	12

VES 2*:* The resistivity of the first layer (top soil) was 33.3 Ω-m and a thickness was 0.75 m. In the second layer, dry and fresh top soil was inferred with the high resistivity value of 189 ohm-m and thickness 0.27m.The Third layer has resistivity of 5.42 Ω-m and a thickness 1.04 m. This layer acts as the shallow aquifer in these places because this layer consists of fracture or weathered zone which constitutes an aquifer of very good quality of groundwater resulted from the in situ weathering of the basalt rocks interpreted as zone of wet aquifer soil, clay soil, and weathered soil accumulates as a result shallow ground table was identified at depth of 2.06 m. The basement rock had resistivity and

thickness of 208 Ω-m and 0.71 m. The basement resistivity data indicates the rock type is hard and massive sand stone. The fifth, the six and the seventh layer with resistivity of 36.35, 5.08 and 14.9 Ω-m respectively was interpreted as wet sandy soil which were filled with water, this might be attributed to basalt and trachitic rocks of the aquifer bearing zone.

VES3: The resistivity of the first layer (dry top soil) was 265 Ω-m and a thickness 0.92m. In the second layer, wet top soil of the resistivity value of 49.3 Ω-m and thickness 1.52 m and affected by fractures and joints identified and ground water table depth was identified at 3.18m. The Third, fourth, fivith, six and seventh layer had resistivity of 1279, 91231, 58998, 47229 and 43503 Ω-m and a thickness 0.73, 14.8, 33.8 and 97,7 m were represented as hard, not fractured and massive basement rocks.

VES 4: The resistivity of the first layer (top soil) was 54.7 Ω-m and a thickness was 0.75 m. In the second layer, dry and fresh top soil was inferred with the high resistivity value of 145 Ω-m and thickness 0.27m.The Third layer has resistivity of 29.4 Ω-m and a thickness 1.33m. This layer acts as the shallow aquifer in these places because this layer consists of fracture or weathered zone which constitutes an aquifer of very good quality of groundwater resulted from the in situ weathering of the basalt rocks interpreted as zone of wet aquifer soil, clay soil, and weathered soil accumulates as a result shallow ground table was identified at depth of 2.5 m. The basement rock had resistivity and thickness of 218 Ω-m and 2.75m respectively. The basement resistivity data indicates the rock type is hard and massive dry sand stone. The fifth layer with resistivity of 150Ω-m and thickness 2.87m was interpreted as dry sandy soil the six with resistivity of 64.7 Ω-m and thickness 5.95m represented, wet sand stone was filled with water, this might be attributed to basalt and trachitic rocks of the aquifer bearing zone. The dry massive basement rock of resistivity and thickness of 334 , 907, 179082, and 707 Ω-m and 0.548, 1.49, 14.5 and 16.9 m was identified at seventh, eighth, ninth and tenth layers respectively. The eleventh layer of resistivity and thickness 101Ω-m and 29.4m showed fractured volcanic rock. The twelve layer of resistivity and thickness 3348Ω-m and very large represented dry and massive basement rocks.

Table 3: Resistivity value for water and rock. Source (Ibrahim, 2006).

Resistivity (ohm-m)	Sediment Rock	Interpretation
0.5- 2.0	Very porous sand	Seawater, very saline water TDS = 20,000mg L^{-1}
2.0–4.5	Porous sand, or saturated clay	saline water TDS = 10,000mg L^{-1}
4.5–10	Sandy saturated or sandy clay	Salty Brackish water, TDS = 10,000mg L^{-1}
10.0–15	Sandy clay, sandy gravel	Brackish water, TDS = 5000 -1500 mg/l
15.0–30	Sand, gravel, some clay	Poor quality fresh groundwater, TDS = 1500- 700mg L^{-1}
30.0–70	Sand, gravel, minor clay	Intimidate quality fresh groundwater, TDS = 1500- 700mg L^{-1}
70.0–100	Sand, gravel, no clay	Good quality fresh groundwater, TDS small
> 100	Coarse Sand, gravel, no clay	Very good quality fresh groundwater, TDS very small

DISCUSSION

The detected lithological layer of top soil, clay, laterite, sandy clay, sandy soil, loose sand and clean sand were all aquifer or water bearing layers. Therefore, the study area was rich in groundwater and this might be the cause for the groundwater table rise in the selected irrigated fields of the study area. Low moisture contents were found by the increase in depth. The reason for the existence of fresh groundwater in the sub-soil was that the strata contained a mixture of dry sand and Adigrat sand stone (Figure 10).

The shallow aquifers within the first, second, third and fourth layers were at depth of about 1.59, 2.06, 2.45 and 2.49 m with resistivity value of 3.76, 5.42, 49.3 and 29.4 Ω-m respectively indicated the irrigation fields where all of VES were under sever waterlogging condition and it was identified the severity was maximum for the first two VES (Figure 9). This in consistent with the value obtained with GIS environment from pizometer data analysis for the same fields (which the second paper of this work done for comparison). The second aquifer in the fivith layer at a depth of 19.8 m and resistivity value of 20 ohm-m is not a confined layer. It was clearly identified from this study that the plateau basalts are the major causes of waterlogging in the selected irrigation fields of the study area (Figure 10) in addition to in addition to poor irrigation water management, soil type, slope and drainage.

The study revealed that the quality of groundwater increased with increase in resistivity but the existence of water decreased with increased value of resistivity and the variation of resistivity values of water locations showed that the variation of water flow was affected by the medium type. The results showed that there were significant different resistivity values of sounding points (Table 1) this is good evident that soil compaction affects apparent resistivity of rock materials. The study, indicated that the water quality was good at VES 3 when compared to VES 1, VES2 and VES4 (Table 3) as it was more compacted irrigated field than others . This also showed that the geological structure affected the quality of groundwater in the irrigated fields (Figure 10). Theoretically, every kind of rock transmits electric current and has its own resistivity but the rock of the same kind may not necessarily have the resistance. Conversely, the same resistivity value may point to a different kind of rock. Other factors such as lithological composition, rock condition, mineral composition, and liquid content influence the values of electrical currents and material resistivity and so do other external factors. Rocks resulted from loose sedimentation show a low resistivity value when compared to compact rocks, dry rocks have a high resistivity and Wet rocks contain in a lot of water and have low resistivity value. Mineral content in the surrounding area of a pack of rock, wires thickness, electrode rods, and topographic condition are among the factors that influence the resistivity of rock. The most part of the study area consists of good quality of groundwater because the study area is dominated by the H type curve (Table 2) this result is in consistent with that of (Selvam and Sivasubramanian, 2012).The above data was compared to the other finding values (Table 3) that indicate that shallow water was found in the depth of approximately 1.5 m with the resistivity values of 3.76 Ωm (VES1), 2.06 m in depth and with the resistivity value of 5.42 Ωm (VES 2), 3.18 m with the resistivity value of 49.3 Ωm (VES 3) and 2.49 m with the resistivity value of 29.4 Ωm (VES4) respectively. In addition to poor farm water management, soil type, slope and drainage, the nature of the basement was identified as the cause for the waterlogging problem of the irrigated fields of the study area. The observed irrigated fields were under critical to sever conditions of waterlogging. Thus storage of considerable deep drainage in the irrigation fields in regolith to keep the waterlogged irrigated fields dry by native vegetation, preventing it from contributing to recharge is one of the solutions to minimize the problem. It is not possible to determine from resistivity imaging whether deeper layers (e.g. >15m) are also wet because they are resistive in the unsaturated zone and below the water table, due to low salinity of the groundwater. Deeper coring is required to determine the moisture status and confirm the salinity of these deeper materials.

CONCLUSIONS

Present work has shown that in a hard rock environment, Vertical Electrical Sounding (VES) has proved to be very reliable for underground water studies and therefore the method can excellently be used for shallow and deep underground water geophysical Resistivity investigation. The most part of the study area consists of good quality of groundwater because the study area is dominated by the H type curve. The top layer is the black cotton soil and it is followed by a weathered zone which is underlain by basement rock.

Fractured basalt and nature of the basement in the study area was identified as major cause for the study site to have maximum average relative humidity, unique under Ethiopian condition and for most of irrigated Vertisols to be waterlogged within 10-25 years of irrigation in addition to other natural and human induced factors

The observed irrigated fields were under critical to sever conditions of waterlogging. Thus considerable deep drainage from irrigation has been stored in regolith previously kept dry by native vegetation, preventing it from contributing to recharge. It is not possible to determine from resistivity imaging whether deeper layers (e.g. >15m) are also wet because they are resistive in the unsaturated zone and below the water Table, due to low salinity of the groundwater. Deeper coring is required to determine the moisture status and confirm the salinity of these deeper materials.

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