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Groundwater Recharge Estimation Models and Ethiopian Groundwater Potential

Kasye Shitu*

Department of Soil Resource and Watershed Management, Assosa University, Assosa, Ethiopia, P.O. Box 18, Assosa, Ethiopia

***Corresponding author:** Kasye Shitu, Department of Soil Resource and Watershed Management, Assosa University, Assosa, Ethiopia, P.O. Box 18, Assosa, Ethiopia, E-Mail: kasye6@gmail.com

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Abstract

In Ethiopia ground water shares 70% of rural water supply. Even there are models like WetSpas and WetSpass that used to estimate groundwater potential and recharge but, in Ethiopia there has been a general misunderstanding about groundwater, where it comes from and where it is going to. Likewise the ground water potential of the country is under quoted. So, this seminar is conducted to receive some information about the groundwater recharge estimation models and Ethiopian groundwater potential from different literature. Based on the information of many literatures the occurrence of groundwater in Ethiopia is mainly influenced by the country's geology, geomorphology, tectonics and climate. With the understanding of the nature, distribution and the recharge classification of the country the groundwater potential distribution is not uniform throughout the country. 185 Bcm total groundwater reserve of the country is distributed in an area of 924,140km2. Most literatures show previous ground water usage potential of the country with value of 2.6Bcm3. This valve is underestimated relative to the present literature values and some regional area groundwater potential. As example literatures in one year different (2013 and 2014) shows different value (26Bcm and 30Bcm) respectively. Since different studies show different result about the total groundwater potential of the country through time to time, the result is under quoted. So, to study the ground water potential of Ethiopia proper investigation and organized groundwater study committee is required in the country starting from the lower to the highest governmental level.

Keywords: Ethiopia; Groundwater; Models and Water Resource

Introduction

Water has always been a precious commodity for human life. It is a precious natural resource, vital for life, development and the environment. It can be a matter of life and death, depending on how it occurs and how it is managed [1]. When, too much or too little, it can bring destruction, misery or death. It is the most widely distributed substance on our planet earth. It covers three-quarter of the earth's surface and occupy a special place among other natural resource. Water is available everywhere and plays a vital role in both the environment and human life. Of most importance is fresh water. But in reality, we have a limited amount of usable fresh water. From the World's total water resources of 1.36 × 108 M ha-mover, 97 percent is found in the oceans as salt water. Two percent of the earth's water is stored as fresh water in glaciers, ice caps, and snowy mountain ranges. That leaves only one percent of the earth's water available to us for our daily water supply needs.

According to Candela et al. and Connor, Africa has about 9% of the world's freshwater resources and 11% of the world's population. Our fresh water supplies are stored either in the soil (aquifers) or bedrock fractures beneath the ground (ground water) or in lakes, rivers, and streams on the earth's surface (surface water).Surface water is renewable, usually within few months or a year, while groundwater is completely renewable, as it takes several months or a year.

Many reasons make groundwater a good choice for a water supply. At present world, groundwater is the main source of water supply to both urban and rural populations as well as to industry and agriculture [2]. It is also one of the most valuable natural resources supporting human health and economic development. Because of its continuous availability and excellent natural quality, it becomes an important source of water supply in both urban and rural areas of many countries. It is an important natural resource for living things which exist on the earth and backbone of civilization for our world. The resource is used for irrigation, industries, and domestic purpose. Even if consideration is further limited to only the most active and accessible groundwater bodies that estimated by Lvovich, at 4 × 106 km3and constitute 95 per cent of total freshwater. It is also one of major source, which contributed a lot to the world water demand and at the present condition one fifth of all water used in the world is obtained from the ground resource.

Most of the time groundwater storage is estimated by combining the saturated thickness and effective porosity of aquifers. Study that was conducted by this point in Africa by AM MacDonad et al. shows that large sedimentary aquifers in North Africa contain a considerable proportion of Africa's groundwater [3]. In line with this he was reported countries like Libya, Algeria, Sudan, Egypt and Chad grouped under high groundwater reserves in Africa.

Determination of groundwater recharge has shifted from a basic problem to an urgent and fundamental issue in hydro geologic research for sustainable development of groundwater. It's worth noting that the majority approaches for quantifying groundwater recharge measure it directly or indirectly over a limited area (point or small basin scale) and for brief periods of time [4]. However, Kahsay et al. reported that direct groundwater recharge from precipitation in semi-arid areas is usually small, but about 5% of the common annual precipitation, with a high temporal and spatial variability. According to Yeh et al. recharge happens when geological formation infiltrates into the saturated zone.

Always, the occurrence of groundwater is mainly influenced by the geophysical and climatic conditions of the area. The difficulty in obtaining productive aquifers is a peculiar feature of Ethiopia, which is characterized by the wide heterogeneity of geology, topography, and environmental conditions. Actually, the geology of the country provides usable groundwater and provides good transmission of rainfall to recharge aquifers, which produce springs and feed perennial rivers. In many parts of the country, groundwater is an important source of domestic and industrial water use especially in rural areas and towns [5]. It takes shares at present of 70% rural water supply and plays a major role in several largest cities (Addis Ababa, Dire Dawa, Mekelle, Harar), a number of medium-sized towns and contributes significantly to irrigation, in some region of the country.

Hydrologic models frequently used for groundwater investigation. Groundwater modeling techniques may be accustomed to estimate the water balance components supported by the biophysical characteristics of the watershed and climatic time-series data. However, for a long time in Ethiopia there has been a general misunderstanding about, where groundwater comes from and where it is going to. Likewise, proper and accurate knowledge on the place and role of ground water in every aspect of the country has been lacking. In the country groundwater potentials are still poorly assessed, hardly managed, underestimated and under used [6]. So, the general objective of this seminar paper is to receive some information about the groundwater recharge estimation models and Ethiopian groundwater potential from different literature in order to identify the major gape between the different scholars about the groundwater potential of the country.

Literature Review

Water resource of Ethiopia

Ethiopia is kind of rich in water resources and its drainage pattern is of great importance for its neighboring countries. The country is a dome-shaped with high mountains and plateaux at the center, surrounded by lowlands, often dissected by deep ravines. Because of its proximity to the equator and high altitude, the Ethiopian highlands receive relatively high rainfall. The run-off flows in different directions to the surrounding lowlands, in many cases crossing international boundaries; this makes Ethiopia the 'Water Tower of East Africa'. No rivers flow into Ethiopia from neighboring countries [7].

Ethiopia has 12 river basins with a complete annual water resources estimated at 111 Billion m3 of which 75.5 Billion m3 is within the Nile basin. Additionally, the country release an annual runoff volume of 122 Billion m3 of water, the Abay, Baro-Akobo, Omo-Gibe and Tekeze being the most river basins contributing runoff to the neighboring countries.

Ethiopia is taken into account as a reservoir of Africa groundwater next to Zaire, due its lots of water resources available on the surface and groundwater beyond the erratic rainfall [8]. The full exploitable groundwater potential of Ethiopia is high as compared to other countries in Africa. However, Awulachew et al., have indicated that as compared to its surface water resources, Ethiopia has lower Groundwater potential.

The occurrence of groundwater in Ethiopia is mainly influenced by the country's geology, geomorphology, tectonics and climate. The variability of these factors strongly influences the quantity and quality of groundwater in different parts of the country. There is usable groundwater in many areas, offering good transmission of rainfall to recharge aquifers, sustaining springs and maintaining flows in perennial rivers. In other areas, however, groundwater is only found at depth (e.g. lowland regions such as Somali), in only limited quantities (with limited storage), or quality poses a risk to health. Also, knowledge available on groundwater resources of Ethiopia is scanty [9]. There's also an outlined agreement among the authors on the available groundwater potentials and therefore, the like. It must have an awfully detailed study on this issue so enough information is accessible.

Groundwater recharge estimation models

The entry of water into the saturated zone, varies spatially and temporally, and depends on a decent reasonably factors (e.g. Vegetation, precipitation, topography, geology, and soil type), making it one in all the foremost difficult, complex, and unsure hydro logic parameter to quantify within the water budget. Recharge will be classified as direct (diffuse), indirect (non-diffuse) and localized (focused). In step with Haile, Bhattacharya, and Ghouili et al. groundwater recharge may be defined as water that enters into the groundwater system from any directions (up, down or laterally).

Recharge estimates are made specifically difficult in arid and semi-arid lands by the vast variability of hydrological events in time and space. Different scientists have used different methods to estimate groundwater recharge [10]. The groundwater recharge estimation methods are may be classified as physical techniques, tracers, and numerical modeling. There are some models which are important for the estimation of ground water recharge potential of a given watershed. From the total of those the two most relevant models which are used by different scholars are WetSpa and WetSpass Model.

WetSpas Model

WetSpa is an acronym for Water and Energy Transfer between Soil, Plants and Atmosphere. It is a physically based and distributed hydrological model for predicting the Water and Energy Transfer between Soil, Plants and Atmosphere on regional or basin scale and daily time step. It was developed in the Vrije Universiteit Brussels, Belgium. The model is physically based and simulates hydrological processes of precipitation, interception, depression, surface runoff, evapotranspiration, infiltration, percolation, interflow, groundwater flow.

Historical climate and physical data such as precipitation and potential evapotranspiration, minimum and maximum temperatures and discharge data and grid maps of elevation, land use and soil type of higher resolution are used as an input for this model on each pixel. During simulation a simple linear reservoir method will be employed for determination of the groundwater flow. According to Liu and De Smedt and Nyenje and Batelaan river flow hydrographs, soil moisture, infiltration rates, groundwater recharge, surface water retention and runoff are the main outputs of the WetSpa model.

Data inputs to the model are digital maps prepared with the help of GIS and remote sensing packages and parameter files from spreadsheet tables with their specific extensions. The digital maps are seasonal or daily records of meteorological parameters such as precipitation, potential evapotranspiration, temperature and wind speed, groundwater level, land-use, soil, slope and topography. The parameter tables are time series data that have an attribute data for the model which contains land-use type as rooting depth, leaf area index, vegetation height; soil parameter for each textural soil class as field capacity, wilting point, permeability and runoff for all combinations of land-uses, slope, and soil type.

WetSpass model

WetSpass stands for Water and Energy Transfer between Soil, Plants and Atmosphere under quasi-Steady State. It was built upon the foundations of the time dependent spatial distributed water balance model WetSpas. WetSpass is a physically based model for estimation of the long-term average spatial patterns of surface runoff, actual evapotranspiration and groundwater recharge which is suitable for studying long-term effects of land-use changes on the water regime in a watershed. The application of this model is compatible and integrated with the GIS ArcView software during simulation process.

WetSpass is developed as to regional groundwater models are quasi-steady state used to simulate infiltration–discharge relations based on long-term average recharge input data. This model simulates water balance components, surface runoff, actual evapotranspiration and groundwater recharge based on distributed data. WetSpass estimates spatial groundwater recharge at seasonal and annual scales. It was successfully applied in Belgium and other environments as in Gaza Strip, Palestine and Geba catchment in Ethiopia. In addition to Gebreyohannes et al. in Ethiopia WetSpass was used to estimate groundwater recharges in several studies like, Dereje and Nedaw; Armanuos et al. and Zeleke and Merkel.

Groundwater Potential of Ethiopia

The topographic features and general surface gradient, regional structure, porosity, permeability and special geological structure like; sink hole, alluvial fan, dykes, joint, lineaments, buried channel, weak zone and fractures and climatic condition have great role on the occurrence of ground water.

The rainfall that percolates below the ground surface passes through voids of rock, fracture and joints to reach water table. These voids are generally interconnected permitting the movement of ground water. The mode of occurrence of ground water largely depends on the topographic formation and geologic structure. Weathered layer, fracture and other structure are a source of ground water. The geology of Ethiopia provides usable groundwater and provides good transmission of rainfall to recharge aquifers, which produce springs and feed perennial rivers. However, the occurrence of groundwater is not uniform because it depends on various environmental and geological factors.

Geologically, the country can be characterized with generalized classifications, such as 18 % of the Precambrian basement, 25 % of the Paleozoic and Mesozoic sedimentary rocks, 40 % of the Tertiary sedimentary and volcanic rocks, and 17 % of the Quaternary sediments and volcanic rocks.With the understanding of the nature of the distribution of these rocks and the recharge classification of the country, Alemayehu estimated the total groundwater reserve of the country as 185 BCM, which is distributed in an area of 924,140 km2 made of Sedimentary, Volcanic, and Quaternary rocks and sediments, including the highlands and the Rift Valley. In this estimation, the mean groundwater recharge for the entire country is assumed as 200 mm.

Figure1 indicate an estimate on best available knowledge of the areas with potential for more intensive groundwater development area of Ethiopia. There are several large areas with potential for groundwater development in all regions especially, in Amhara, Oromia, SNNPR and Gambela. In some areas such as Afar and South Omo the constraints to the potential are not so much available and the present ground water also characterized by salinity nature.

According to Kobo Girana Development Project Office report, the Kobo sub-basin groundwater resource safe yield was estimated using analytical method and is found around 309,942.00 m 3/day (186,514.00 m3 /day for Hormat Golina well field and 123,428.00 m3 /day for Waja Golesha Well field). On the basis of the water balance model, the mean annual rechargeable water into the Ada’a-Becho plains groundwater aquifers is more than 965 Mm3 with 67% contributed by upper Abay Basin and the groundwater recharge of the Alaidege valley is about 112 MCM.

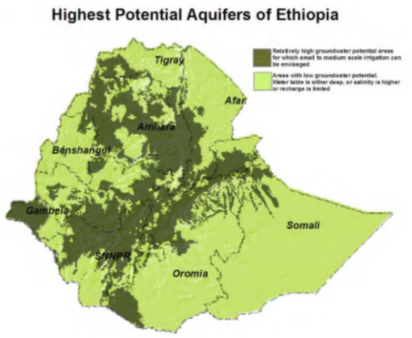

Figure 1: Highest potential aquifers of Ethiopia.

The total ground water storage potential in Ethiopia is estimated 1 trillion m3 (Kebede, 2013). But, the amount of yearly groundwater recharge of the country is estimated about 28 000 mm3.Previous studies including Awulachew et al. and minster of water resource report show groundwater usage potential of the country was estimated at 2.6 BCm3 and this figure is still often quoted. Following the results of recently completed assessment for parts of the country like Kobo Girana, Alaidege and Raya show that there is consensus that the 2.6 BCm3 figure is an underestimate and that it needs to be considerably revised upwards.

According to MoWR, the best guess in this respect range between 12-30 Bcm3 or even more if all aquifers in the low lands are assessed. In addition to this MoWR was estimated the ground Water Resources of the country with a value of 26 Bm3. After one year even although it needs further detailed investigation according to the current knowledge Berhanu et al. was reported the country groundwater resources with a value of 30 BCM. These all indicates that there is no common agreement about the groundwater potential of the country. The estimated value is increased time to time. These variations may be occurred due to model and data uncertainty, nature of sample watershed where the study is conducted etc.

Conclusion and Recommendation

For every aspect of our live and the environment we live water is very important. However, how much it is more interesting and distributed all over the world we have limited and finite fresh water in our world. Relative to other continent Africa has small amount of fresh water.

Our fresh water supplies are stored either in the soil (aquifers) or bedrock fractures beneath the ground (ground water) or in lakes, rivers, and streams on the earth’s surface (surface water). In Ethiopia the surface water resource of the country includes water that found in Rivers, Lakes, Wetlands Swamps and natural and manmade reservoirs.

The occurrence of groundwater in Ethiopia is mainly influenced by the country’s geology, geomorphology, tectonics and climate. In the country there are several large areas with potential for groundwater development in all regions especially, in Amhara, Oromia, SNNPR and Gambela. This indicates that there is usable ground water in Ethiopia. But in some areas like low land region such as Somali has only limited quantities or quality poses a risk to health. Most studies that were conducted previously about groundwater potential of Ethiopia indicate the occurrences of 2.6bcm3 of groundwater in the country.

Based on different evidence this figure is still under quoted. For example, recently completed assessment for some part of the country like Kobo valley and Alaidge valley gives 1530 and 112 Mcm groundwater potential. This is very large relative to the groundwater potential of the contrary. In addition to this some study that was conducted by governmental office and individuals in one year time interval shows that the country's ground water potential with a value of 26bm3 and 30bm3. This is a clear indicator that the country has huge amount of ground water. But, the occurrences are not uniform throughout the country and not evaluate properly because of various environmental and geological factors. So, as a recommendation proper investigation is required for understanding and estimation of groundwater potential in the country. For this, well developed and organized groundwater study committee should be organized in the country starting from the lower level up to the highest government level.

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