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Aquifer Modeling and Rain Water Harvesting: A Review

Mohd. Saleem
University Polytechnics, Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi, India
Shobharam
School of Engineering, Gautam Buddha University, Greater Noida, U.P, India
Gauhar Mahmood
Department of Civil Engineering, Faculty of Engineering & Technology, Jamia Millia Islamia,
NewDelhi, India

ABSTRACT
Shortage of water for industrial and commercial use and even for drinking purpose is a concern throughout the world especially in developing countries. Rainwater harvesting for groundwater recharge is a best and easiest way to solve the groundwater problem. This can be increased in increase in watershed development programs, in which rain water harvesting is an important structural component. Understanding the net effect of these development programs is crucial to ensure that net effect on groundwater is positive both locally and within a watershed. This review article is focused on literature survey of design of rain water harvesting and its aquifer modelling.

KEYWORDS: Aquifer; water; Harvesting; Rain

INTRODUCTION
To collect and store rain water for future various uses, Rain water harvesting (RWH) is a beneficial technique. It is a beneficial technique due to a low- cost solution to water crisis among community, academic, accomplished, system, incompetent and accomplished in the past few years. Underground water is recharged by artificial recharge techniques (RWH). For solving the water problem of present and future generation, Rain water harvesting is a useful tool in water management .Storing runoff to recharge shallow aquifers using miniature structures are achieved by (RWH) in India. To restore aquifers by (RWH), various literatures are highlighted. Various methods, its impacts on groundwater quantity and quality and its modeling are available on (RWH). Initially various issues such as application of RS and GIS in artificial recharge studies, recharge evaluation and groundwater modeling are covered. Basic issues such as (RWH) implementation and its impact are carried out in this review paper. [1].

REVIEW OF LITERATURE
Estimation of recharge
Recharge is defined as the vertical flow of water joining the water table, adding to the groundwater storage. Recharge is normally expressed as the flow volume per unit time such as m^3/day. Rainfall recharge, return flow from surface and ground water irrigation, seepage from tanks and ponds and seepage from canals are various elements of recharge. For efficient management of the groundwater resource, the analysis of the natural recharge of ground water is necessary [2].

To assess the recharge quantitatively many literatures have achieved. Korkmaz (1988) evaluated the groundwater recharge from water level and precipitation data. During the period of 1975 to 1984, the average annual recharge was found to be 180 mm [3]. Chiew et al (1992) [4] predicted the combined surface and groundwater modelling methods for ground water recharge. The researcher explained the model to the Campaspe River Basin in North-Central Victoria and the results determined that the modelling access can estimate satisfactorily the spatial and temporal distribution of local recharge rates resulting from rainfall and irrigation water. He also examined that the integrated model were better than those forecasted when the groundwater and surface models were used separately.

Osterkamp et al (1995) analyzed the groundwater recharge estimation in arid and semi arid areas by examples from Abu Dhabi [5]. In South Africa, Bredenkamp et al (1995) explained the dramatic aquifers by taking the Cumulative Rainfall Departure (CRD) method. They examined the migration of rainfall from the mean rainfall of the preceding time is concerned with the natural ground level fluctuation. If the migration is positive then, the water level will increase and vise versa. [6]. Giambelluca et al (1996) considered the uncertainty in recharge assessment and impact on groundwater susceptibility estimates for Pearl Harbor Basin, O'ahu, Hawai'i, USA. They investigated the recharge uncertainties for agricultural land under pineapple or sugarcane cultivation by taking a combination of first order sensation analysis and ambiguity analysis. By taking unpredictability the recharge was found 58% for pineapple and 49% for sugarcane [7].

Finch (1998) estimated the direct groundwater recharge by taking simple water balance model. He discussed varying the vegetation sunshade parameters for forest in addition to varying the soil moisture model. [8]. Amitha (2000) estimated natural ground recharge by using various techniques such as zero flow plane method, soil water balance method , inverse modelling method and one-dimensional soil water flow model. [9], groundwater level fluctuation method, isotope & solute profile techniques, compound water fluctuation method and ground water balance method.

Kichurl et al (2001) estimated the groundwater recharge rate for fractured hard rock aquifer, Chojeong area, South Korea. Six different methods were taken to estimate groundwater recharge rate including SCS-CN design, Multi-linear Regression analysis and aquifer modeling techniques. They suggested that SCS-CN and flood formula is more suitable for top unconfined aquifer, which had various hydraulic conductivity including lower fractured hard-rock formation. Using CRD (R-CRD) method the recharge rate values being achieved from those analytical models has been found to be twice than that values obtained from aquifer model [10]. Xu and Van Tonder (2001) evaluated the periodicities and the trends in the rainfall, which was not examined in Bredenkamp formula. Recharge Estimation Model in Excel (REME) was promoted in this study. [11].

Moon et al (2004) evaluated groundwater recharge in South Korea by taking statistical investigation of water-table fluctuation and hydrographs. Groundwater hydrographs were classified into five typical groups by taking water table observation data from the National Groundwater Monitoring Network in Korea. To estimate groundwater recharge, an altered water table fluctuation (WTF) method was developed between the corresponding rain fall reports and cumulative WTF. [12]. Baalousha (2005) examined quantification of groundwater recharge in the Gaza Strip, Palestine by using CRD method. To minimize the (RMSE), the CRD method was carried out between the assumed groundwater head and measured head. The results correlated with the results of other recharge estimation methods from literature. It has also been observed that the results obtained by this method are very close to the results obtained using other methods. [13]. Xianfeng Sun (2005) evaluated groundwater recharge evaluation in Montagu region of the western Klein Karoo, South Africa by water balance technique. The long-term average recharge, runoff model and experimental evapotranspiration were considered. The long-term average recharge was a function of the site conditions such as soil, climate, territory and geology. The definite evapotranspiration, recharge and direct runoff were quantified by using long term physical and climatic data from the various precipitations interval of different gauge stations. [14].

Chand et al (2005) considered neutron moisture probe for ground water recharge in Hayatnagar micro-watershed, India. The data from eight sites of Hayatnagar micro-watershed was cpllected at regular intervals of time and the values were obtained for the soil moisture integrity [15]. It was found that the overall volume of water (recharge) varies from 0.22 to 0.37 m. The storability varies from 6.9 to 10.6% due to rise in water level. Adelana et al (2006) found groundwater recharge in part of the Sokoto basin, Nigeria by using hydrochemical, experimental and vital-hydrological methods. The researcher suggested that for estimation of recharge in most of the basin, the chloride mass balance method was most relevant [16]. Lorenz and Delin (2007) evaluated regional groundwater recharge by Regional Regression Recharge (RRR) model. To evaluate the recharge from, surface water drainage basins, rainfall, average basin and specific yield (SY) (RRR) model was used. The recharge measured by the RRR technique was also the lowest (0 to 5 cm/year) [17].

Delin et al (2007) evaluated the ground-water recharge in Minnesota, USA, using three regional-scale approach Water Table Fluctuations (WTF), unsaturated-zone water balance and age dating of groundwater. It has been observed that the WTF method was the easiest and quietest to apply for recharge calculation [18]. Rasoulzadeh and Moosavi (2007) examined groundwater recharge in the proximity of Tashk Lake by using CRD method Groundwater Recharge Estimation Technique (GRET) was used to reduce the difference between detected water table and simulated elevations. For high volume of groundwater evocation in the study area, the natural recharge is not sufficient. [19]. Bingguo et al (2008) examined groundwater recharge in Hebei Plain, China by tritium and bromide tracers. Tritium and bromide tracing were used for recharge coefficient and Normal recharge rates. It is inferred that this method is useful for evaluation of deep water table. [20]. Sibanda et al (2009) correlated the groundwater recharge estimation methods for the semi-arid Nyamandhlovu area, Zimbabwe by using chloride mass balance method. The flow net estimations and modeling methods provided improved estimates for aerial recharge than the alternative methods. Based on groundwater modeling, a final recharge (from precipitation) was evaluated to be 15–20 mm/year [21].

For recharge evaluation based on a water balance approach, Government of India has confined a set of guidelines through a Ground Water Resource Estimation Committee (GWREC 2009). Different values are provided from pumping test analysis. Groundwater storage increase could be estimated by using the variation in specific yield, groundwater level and area of effect [22]. Adnan et al (2010) determined groundwater recharge modeling using WetSpass model for Gaza strip, Palestine. For evaluation of long-term average spatial patterns of absolute Evapotranspiration, surface runoff and ground water recharge, the WetSpass model was developed [23].

Izuka et al (2010) interpreted groundwater recharge on tropical islands by simple equations. Equations were used for recharge estimates from soil intrusion, and infiltration, and preceding soil water- budget studies in Hawai, USA [24]. Subash Chandra et al (2011) evaluated spatio-temporal recharge circulation in crystalline rocks of Bairasagara watershed & Maheshwaram watershed of India by Litho logically Constrained Rainfall (LCR) method. Three input parameters i.e. vadose zone thickness, soil resistivity and rainfall were used in Lithologically Constrained Rainfall (LCR) technique. It was evaluated in the study that the LCR is a generalized, fast method and cost effective also to evaluate natural recharge partially and temporally from rainfall in hard rock region and construct a useful time series of natural recharge in the studied watershed for foretelling studies [25].

Pradeep and Srinivas (2011) determined the stage of groundwater development in Kurmapalli Vagu Basin in Deccan Plateau by exercising remote sensing and geographical information system techniques in conjunction with typical methods. Groundwater recharge from canals, rainfall, minor irrigation tanks recovery flow of irrigation, and water management structures were estimated. The overall groundwater recharge and annual utilizable groundwater resources from different sources were measured. The groundwater balance of the basin achieved 1.95 MCM. The stage of groundwater development achieved to 80.6% which falls in the semi critical category [26]. Mondal et al (2011) delimited prospective groundwater recharge zones in a hard rock area from Southern India by RS and GIS techniques. They achieved the validation of estimated recharge values using the modified WTF method [27].

From the various literature studies, it is inferred that one must understand water resources management in terms of quantification of water recharging the ground water aquifers. Therefore, the GWREC-2009 methodology is observed to be more suitable in Indian context.

APPLICATION OF RS AND GIS TO ARTIFICIAL RECHARGE

Geographic Information System (G.I.S) and Remote sensing (R.S.) is very efficient tool for integrating urban planning and groundwater recharge studies. Satellite data are very useful to controlling the occurrence and movement of groundwater like geomorphology, structural, land use/land cover, soil, features, etc. [28]. Ramasamy and Anbazhagan (1997) identified suitable sites for artificial recharge in Ayyar sub-basin in Cauvery River, India by collecting the data of water lavel variation, omphalic, geology and sub-surface geology. Favorable sites for various artificial recharge structures were differentiated. [29].

Saraf and Choudhury (1998) defined the groundwater exploration and identification of artificial recharge sites in hard rock terrain in the Sironj area of Vidhisha District, India by the potentials of integrated RS and GIS. The study shows reservoir induced artificial recharge downstream of surface water reservoirs. For groundwater recharge in a hard rock region through recharge basins or reservoirs were selected by proper sites [30]. Kshirish and Santhosh (2002) defined the parameters like drainage, surface contour , tendency and groundwater depth by using RS and GIS for Rengareddy District, Andha Pradesh. A clear picture about the recharge areas was concluded by this study [31].

Ravi Shankar and Mohan (2005) considered the site-specific artificial recharge methods in the Deccan Volcanic Province of India by GIS based hydrogeomorphic approach. The hydrogeomorphological characteristics extracted from the IRS-1C LISS-III were adopted for GIS analysis. Check dams and percolation ponds structures were recommended for artificial recharge. [32]. De Winnaar et al (2007) considered the potential runoff harvesting sites in the Thukela River basin, South Africa by GIS technique. Probable runoff harvesting sites were identified by using GIS. [33]. Mbilinyi et al (2007) considered the potential sites for rainwater harvesting in Tanzania by GIS-based Decision Support System (DSS). Maps of rainfall, soil texture, slope, soil depth, and drainage and land use data were collected by DSS [34].

Ghayoumian et al (2007) determined most suitable regions for artificial groundwater recharge in a coastal aquifer in Southern Iran by GIS technique. Infiltration rate, confined layers for slope, quality of alluvial sediments, depth to groundwater, and land use were examined for completed and integrated in a GIS environment [35]. Lin et al (2009) determined groundwater recharge and discharge evaluation by PRO-GRADE GIS toolkits. The mass balance technique such as water table, hydraulic conductivity and ground elevation data were used for GRADE-GIS. [36]. Maggirwar and Umrikar (2009) established the possibility of artificial recharge in overdeveloped small watersheds by RS-GIS technique. Village map, drainage map, geomorphology, soil map and land used were prepared for confined aquifers. [37].

Sukumar and Sankar (2010) delineated the possible zones for artificial recharge in Theni district, Tamilnadu by using GIS technique. Moderate, high and least favorable zones were prepared for artificial recharge. Soil depth, permeability, drainage intensity, soil texture and water holding capacity maps were prepared for different confined layers. [38]. Balachandar et al (2010) examined the artificial recharge regions in Sivaganga District, Tamilnadu by using the RS and GIS techniques. Various confined maps such as drainage, lineament, drainage density, lineament density, land use, geomorphology, land cover and Land sat satellite data were prepared. For updating the confined maps the Normalized Difference Vegetation Index (NDVI) methods were prepared to all integrated and confined maps. [39].

Alivia et al (2010) described the RS, GIS and Multi Criteria Decision Making (MCDM) methods for groundwater recharge zones and to identify the artificial recharge sites in West Medinipur district, West Bengal. Conventional and IRS-1D imagery data were prepared for confined layers. Based on the available field information Check dams were proposed for artificial recharge structures. [41].RS and GIS are very useful technique for groundwater recharge studies. To define the potential groundwater recharge zones artificial groundwater recharge must be implemented.

GROUNDWATER MODELING

To predict recharge of groundwater, the practical management of groundwater is very necessary. For estimating flow and recharge in groundwater systems the deterministic, assigned-parameter, computer simulation models a very popular tool. Equations, constants or coefficients of physical properties in the equations and amplitudes of state are performed by mathematical models (Delleur 1999) [42]. Conservation of mass, energy & momentum, are based on Mathematical groundwater models. To determine the necessity of artificial recharge, mathematical model can be used as a design tool. Many researchers around the world have attempted to carry out groundwater recharge modeling. Bekesia and McConchie (1999) used Monte Carlo technique for Manawatu region of New Zealand for ground water recharge modelling. In this study a regional rainfall recharge model was developed .For the basic variability of soils Randomized soil moisture parameters were used. Good agreement between the modeled and actual groundwater levels was obtained. [43].

Gnanasundar and Elango (2000) carried out the groundwater flow modeling of a marginal aquifer near Chennai city, India using MODFLOW. The model was measured under steady and transient conditions. The structural distribution of groundwater head and well hydrograph was differentiated with the historic data. They achieved that rapid urbanization would lead to further lowering of water table at few locations along the Northern coast of the aquifer system. They also indicated that their model is delicate even for 5% reduction in recharge [44].

Gogu et al (2001) performed groundwater modeling of Belgium for the Walloon region by using GIS-based hydro-geological database. Different hydro-geological characteristics of five river pool were chosen in the data base. A “loose-coupling” device was estimated between the groundwater numerical model interface GMS (Groundwater Modeling System) and the structural-data base plan. Stored data in the database of hydro-geological data can be used easily for structural queries and following time within different groundwater numerical models [45]. Pliakas et al (2005) examined the groundwater recharge of Bedin Xanthi plain, Greece by reactivating an old stream. MODFLOW was used to copy the aquifer system of the study area. [46].

Fayez and Tamer (2006) examined groundwater flow for Mujib aquifer of Jordan by using MODFLOW technique. The affect of the flow system under various stresses were examined and MODFLOW model was used to build a groundwater flow technique. The steady state condition of initial head contour lines were measured by MODFLOW model. The affect of drawdown of a well were examined and used this data to calibrate the temporary model. To predict aquifer system response under different environment various scenarios were forecasting. [47]. Shammas and Jacks (2007) determined the movement of the freshwater/saltwater interface by using the codes MODFLOW and MT3DMS for solute transport. The protection of the groundwater in Salalah plain aquifer in Oman from further intrusion by artificial recharge with reclaimed water along the Salalah coastal agricultural strip were recommended.[48].

Rejani et al (2008) estimated the efficient groundwater management in Balasore Coastal Basin, India by Visual MODFLOW technique. It was found that the recharge from rainfall, river seepage and inflow than to horizontal and vertical hydraulic conductivities and definite storage is very easy in the Balasore aquifer system. [49]. Some and Tarhule (2008) used MODFLOW technique for the impacts of groundwater pumping on stream–aquifer dynamics in semiarid Oklahoma, USA. Pumping-induced changes in base flow, stream flow total package and stream leakage were evaluated by MODFLOW to estimate stream flow depletion in the Beaver-North Canadian river system. [50].

ANALYSIS AND OBSERVATION

Different techniques of RWH along with its impact, various methods of recharge, use of RS, GIS and models in artificial recharge were reviewed. It helped to learn the past RWH implementation experiences around the world and the different way that are likely to provide the most quantitative estimates of recharge. From the various literatures, it has been identified that various researchers handled different objectives with different methodologies and identified that all the works done are at initial levels .so there is a need to handle the different issues of ground water recharging by applying the rain water harvesting techniques which is major challenges these days.

Table 1: Objectives and methods for ground water recharge

S. No.	Objective	Method	Reference
1	Storing Run off to recharge shallow aquifers.	By RS and GIS in artificial recharge studies and ground water modeling	[1]
2	Evaluated ground water deposit.	By seepage from canals, Rain fall recharge, ground water irrigation, return flow from surface, seepage from tanks and ponds.	[2]
3	Evaluated ground water recharge.	Using precipitation and water table data.	[3]
4	Predicted ground water recharge.	Using ground water and combined surface modelling approach measuring against stream flow and potentiometric head data.	[4]
5	Techniques of ground water recharge evaluate-On in arid and semi arid areas.	By distributed transmission-loss model for ephemeral stream flow in arid/semi-arid areas	[5]
6	Evaluated recharge of acquittal of an aquifer.	Examining the percolation of rain fall into the ground.	[6]
7	Investigated the uncertainty in ground water estimation and its impact.	Using first order sensation analysis and ambiguity analysis.	[7]
8	Estimated the direct ground water recharge.	Using vegetation sunshade Parameters as input for simple water balance model.	[8]
9	Estimated natural ground recharge.	Using soil water balance method, one dimensional soil water flow model and inverse modelling techniques.	[9]
10	Estimated the ground water rate for fractured hard rock aquifer.	Using multi -linear regression analysis, SCS-CN design and aquifer modelling techniques.	[10]
11	Estimated ground water recharge.	Using a user - affectionate Excel program termed as recharge estimation model in Excel (REME).	[11]
12	Investigated the ground water recharge taking hydro graphs and water table fluctuation.	Using water table observation data from the national ground water monitoring net work in Korea.	[12]
13	Quantified ground water recharge.	Using CRD and Root Mean Square Error (RMSE).	[13]
14	Techniques of ground water recharge evaluation	Using water balance technique.	[14]
15	Estimated ground water recharge.	Using neutron moisture probe.	[15]
16	Predicted ground water recharge.	Using experimental, hydro chemical and vital hydrological methods.	[16]
17	Evaluated regional ground water recharge.	Using Regional Regression Recharge (RRR) model.	[17]
18	Evaluated of ground water recharge.	Using (RORA) and water table fluctuations (WTF).	[18]
19	Examined ground water recharge.	Using ground water recharge estimation and CRD method.	[19]
20	To estimate ground water recharge in Hebei Plain	Using tritium and bromide tracing.	[20]
21	Correlated the ground water recharge estimation for semi -arid area.	Using by chloride mass balance method and water table fluctuation method.	[21]
22	Estimated storage of ground water recharge.	Using by the guidelines through a ground water Resource Estimation Committee (GWREC 2009).	[22]
23	Distributed recharge estimation for groundwater modelling	Using by Wets pass model and a water balance in GIS.	[23]
24	Estimated ground water recharge on tropical island.	Using equations depict recharge estimates from preceding soil water budget studies in Hwai, USA.	[24]
25	Evaluated spatiotemporal recharge circulation in crystalline rocks.	By using LCR technique taking three input parameters soil resistivity, vadose zone thickness and rainfall.	[25]
26	Determined the stage of ground water development.	By exercising RS and GIS techniques in conjunction with typical methods.	[26]

27	Evaluated prospective ground water recharges zones in a hard rock area.	By using RS and GIS techniques adopting the (GWREC-2009) methodology.	[27]
28	Evaluated integrating urban planning and ground water recharge study.	By using RS and GIS Techniques in artificial recharge modelling.	[28]
29	Identified suitable sites for artificial recharge.	By taking four parameters sites, water table variations and hydrogeology and artificial recharge structures.	[29]
30	Defined the potentials of ground water exploration and identification of artificial recharge sites in hard rock terrain.	By using RS and GIS techniques.	[30]
31	Find out the recharge suitability of the area.	By using RS and GIS techniques.	[31]
32	Identified the site -specific artificial recharge methods.	By using GIS based hydro geomorphic approach extracted from theIRS-ICLISS-111 data from Indian Remote Sensing (IRS) satellite.	[32]
33	Identified potential run off harvesting sites.	By using GIS based approach for probable run off harvesting sites.	[33]
34	Identified potential sites for rain water harvesting.	By using GIS based Decision Support System (DSS) for maps of rain fall, slope, soil texture, soil depth, drainage and land use.	[34]
35	Determined most suitable regions for artificial ground water recharge in a coastal aquifer.	By using GIS techniques for Confined layers for slope, infiltration rate depth to ground water, quality of alluvial sediments and land used were arranged.	[35]
36	Determined ground water recharges and discharge evaluation.	By using PRO-GRADE GIS toolkits by measuring mass balance technique.	[36]
37	Evaluated the possibility of artificial recharge in over developed mini watersheds.	By using RS- GIS approach for the confined layer of drainage map, village map, soil map, geomorphology and land use.	[37]
38	Determined the possible zones for artificial recharge	By using GIS approach for various confined maps.	[38]
39	Determined the artificial recharge regions in Sivaganga district, Tamilnadu	By using RS and GIS approach for confined maps.	[39]
40	Evaluated the ground water recharge zone and the artificial recharge sites in West Bengal.	By using RS, GIS and MCDM methods for confined layers such as geomor phology, geology, drainage density, and slope and aquifer transmissivity.	[40]
41	Determined the ground water recharge zone mapping	By using GIS based multi criteria analysis for the thematic layers of hydr ological , lithological and hydro dynamic conditions of the aquifer.	[41]
42	Predicted the recharge in ground water system.	By using mathematical models performing process as equations, Constant and amplitudes of state.	[42]
43	Evaluated the ground water recharge modeling.	By using a regional rain fall recharge model.	[43]
44	Determined the ground water flow modelling of a marginal aquifer near Chennai city.	By using MODFLOW for study and transient conditions.	[44]
45	Evaluated ground water modeling of Belgium for the Walloon region.	By creating Ground water modeling system (GMS) based on hydro-geological data.	[45]
46	Determined the ground water recharge.	By using MODFLOW and model calibration to forecasting of the aquifer system.	[46]
47	Evaluated the modeling of ground water flow.	By using mode flow to simulate the behavior of the flow system under different stress.	[47]
48	Determined the movement of the fresh water inters face.	By using the codes MODFLOW and MT3DMS.	[48]
49	Evaluated the imitation modeling for efficient ground water management.	By using visual MODFLOW for analyzing the aquifer response to different pumping strategies.	[49]
50	Derived the impacts of ground water pumping on stream aquifer dynamics.	By using USA visual MODFLOW.	[50]

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