RAINWATER HARVESTING POTENTIAL SITES AT MARGALLA HILLS NATIONAL PARK

Bushra Khalid†, Nisbah Mushtaq*, Mubbashra Sial*, Junaid Aziz Khan** and Shahid Imran***

ABSTRACT

Life without water is not possible. Adoption of modern lifestyle and increase in population is leading to a water scarce world. The demand of world population cannot be met with the scarce surface water, which is resulting in increased groundwater abstraction. The world is facing water crisis and Pakistan is no exception. Urban areas of Pakistan are affected badly where extraction is higher while the construction of pavements has disturbed groundwater infiltration. The Federal Capital of Pakistan, Islamabad, is located in Pothohar region of the country and faces severe water shortages, particularly during summers. Extensive drilling by public and private users lowers groundwater table. Satellite imagery of LANDSAT 7 ETM+ and ASTER DEM 30m resolution were used to construct the site suitability map for groundwater recharge of Margalla Hills National Park. Factors considered included land cover, drainage density, elevation and slope. Suitable weightages were assigned to these factors according to their influence on infiltration in the study area. Groundwater recharge at Margalla Hills National Park will be effective in dealing with water crisis in Islamabad as it will raise groundwater table of the adjacent areas.

Keywords: *Water scarcity, Groundwater recharge, Margalla hills, Islamabad, Urban sectors*

1. INTRODUCTION

Water is a vital natural resource. Humans as well as other living things depend on water as the basic need of their lives. Demand for this precious resource is increasing in every part of the world. Water is used in domestic, agricultural and industrial sectors. Rapidly growing world population combined with modern lifestyle, hasty urbanization and industrialization has drastically raised the demand for water and is resulting in a water scarce world [2].

Quality and quantity of surface water is affected due to anthropogenic activities. To meet the increased demand for water, pressure on groundwater is amplifying [6]. Groundwater abstraction is boosting for three major kinds of reasons: technological, hydrological and policy. Technological advancements have provided people with cost-effective and easy means to access water from tube wells through efficient mechanical pumps. Such affordable technologies have increased dependence on groundwater while providing short-term benefits to users. But in the long run, it is causing groundwater depletion [5]. Apart from this technological factor, another significant factor is water scarcity where surface water fails in meeting water needs and people are compelled to use groundwater. On the other hand, some of the government policies also encourage groundwater abstraction by providing loans and subsidies for pumping water from tube-wells [8].

Groundwater is a precious resource, and its tactical significance can be understood by considering the explicit data, which indicates that 25 % of global irrigation is dependent on groundwater, while in arid and semi arid regions this dependence reaches 60 % for agricultural use only [10-14]. About 80 % of the groundwater extraction is carried out in some of the most populated countries of the world, which include China, India, Bangladesh, Pakistan and the United States [4,9]. There is an inverse relation between water resource and population growth. Pakistan is a developing country with rapidly growing population, while its water resource is depleting at the same rate [3]. Groundwater resource is not protected under any legislation in Pakistan. Any person having land and sufficient financial resources can install a tube-well on the land and extract any amount of water at any given time without consideration of safe yields. Groundwater abstraction in 1965 was 10 billion cubic meters (BCM) and in 2002 it reached 68 BCM. Private users are the major exploiters of groundwater, and are involved in about 80 % of its abstraction [7].

Insufficient piped water and reduction in monsoon rains have increased dependence on groundwater. Abstraction of water for non-drinking purposes decreases groundwater level [6,9]. Urban areas are more adversely affected. Water-table statistics of Islamabad show that there has been a 50 feet drop in the water-table from 1986 to 2001 [2]. Reservoirs fall short in meeting the demands of the Federal Capital. A decade ago, groundwater was found at 50-100 feet depth and now it is way after 250-300 feet of drilling [12].

Statistics of Capital Development Authority (CDA) of the Federal Capital show alarming trend as 10 tube wells dried up recently and rate of depletion is even faster. Groundwater recharge is a natural process but urbanization and anthropogenic activities affect this process. Therefore, artificial recharge processes are becoming popular at global level [1]. According to the

* Department of Environmental Science, International Islamic University Islamabad, Pakistan. † Email: kh_bushra@yahoo.com.
** Institute of Geographical Information Systems, NUST Islamabad, Pakistan

Table-1: Number of Tube Wells in Different Sectors of Islamabad

Sectors of the City	No. of Tube-wells
I and H Sectors	54
F and G Sectors	67
NPAs series	67
Total	**188**

Table-2: Statistics Showing Tube Wells Water Production in Islamabad

Tubewells Water Production (MGD)	
Design Capacity	36
Production Capacity	29
Actual Capacity	17

CDA statistics, there are a total of 188 public tube-wells supplying water to the capital city apart from private tube wells being installed by the city residents. Despite a large number of tube wells in the city, the gap between actual capacity and production capacity of the tube wells is quite noticeable, as shown in Table-1 and Table-2.

This problem of groundwater depletion could be tackled to a certain extent by artificially recharging the potential aquifers. In areas of hard-rock terrains, groundwater availability is limited to fractured and weathered soil horizons. Efficient planning and management of such areas is of top priority concern [7].

Water resource management is one of the major concerns of policy makers. Rainwater harvesting (RWH) can give significant results for recharging both surface as well as groundwater. RWH is basically to store rainwater for future use; it helps in increasing groundwater table. RWH systems are important in managing scarce rainfall, and success of these systems mainly depends on identification of suitable potential sites and technologies [6,15].

CDA is implementing a pilot project for use of rainwater to recharge groundwater, which can lead to wide spread use in management of groundwater in urban areas of the country. Pilot project of CDA makes Islamabad the first city in the country to establish RWH system. It is expected to play a significant role in water-table recharge. First RWH structure was established at the site of Faisal Mosque and following the success of this project, CDA further identified 20 more potential sites in the city for rainwater harvesting.

Site identification for RWH depends on various factors, applying conventional methods for this task takes long time and there are many chances of oversight. Advanced and efficient techniques like remote sensing (RS) and geographic information system (GIS) are giving momentous results. Generation of thematic maps by the use of Remote Sensing and its integration with GIS can be useful in identifying potential rainwater harvesting sites. The process of decision making in rainwater harvesting can be effectively carried out by using this technique. Margalla Hills are very important from the groundwater recharge point of view as it is responsible for recharging Nullah Lai basin and the Rawal sub-watershed that nourishes Rawal Dam and provides water for both domestic and agricultural use for residents of Islamabad.

2. METHODOLOGY

Methods and materials used to conduct the study were based on:

- Landsat7 ETM+ image of year 2005;
- ASTER digital elevation model (DEM) of 30 meter resolution;
- Similarly a geological map of the Islamabad region on the scale of 1:150,000.

The satellite imagery and ASTER DEM was acquired from U.S. Geological Survey (USGS) website and the geological map was obtained from Geological Survey of Pakistan.

Software used in this study were:

- ERDAS IMAGINE 2013
- ARCGIS 10

Supervised classification was applied on LANDSAT 7 imagery for obtaining the land cover map of the area.

Table-3: Weights and Scores of Different Factors Affecting Directly or Indirectly the Water Recharge

Factors	Score	Maximum Weightage
Land use		
Vegetation	5	
Water body	4	**15**
Scrub land	4	
Built area	1	
Barren land	3	
Drainage density		
0-1.18	5	
1.18-1.99	4	**15**
1.99-2.76	3	
2.76-3.61	2	
3.61-5.39	1	
Elevation		
460-650	5	
650-811	4	**20**
811-989	3	
989-1193	2	
1193-1598	1	
Slope		
0-7	5	
7-15	4	**20**
15-24	3	
24-34	2	
>34	1	

Source: *[Ref. 10-14]*

Furthermore, Raster Attribute Table was used to calculate area of different parts of the map. The processing of ASTER DEM in Arc GIS helped in the generation of maps for different factors controlling the groundwater infiltration (i-e, drainage density, slope, and elevation). Geological map was found to be helpful in finding different soil types in the study area.

3. RESULTS AND DISCUSSION

Geological studies show that areas lying at the foothill of Margalla Hills are generally covered by alluvium, which consists of surficial deposits of mainly clay with sand and semi-consolidated gravels with average thickness between 5-20 m [13].

Five classes were identified: forest, scrub land, water body, barren land and urban land, where forest cover was found to cover maximum area (i.e., 39 % of the total area). Since land cover plays a significant role in groundwater infiltration, therefore, the overall weight given to this factor was 15.

The elevation of study area ranges between 495 m to1,598 m. On the other hand, about 70 % of the area was recorded to have gentle to moderate slopes, which favors the water infiltration. As in relation to groundwater infiltration, the flat/level and gentle slopes hold more rainfall, which is the primary source of groundwater recharge since level and gentle slopes allow more time for water to infiltrate [14]. Similarly the drainage network observed in the study area follows dendritric pattern, which is the characteristic of areas with moderate slope while it changed into parallel drainage network pattern at much higher sloppy area.

Suitable weightages were assigned to different factors in the study area, since these factors (slope, elevation, drainage density, and land use) control the water flow and directly or indirectly influences the water infiltration into the ground as are shown in Table-3.

For identifying such zones, the weighted overlay analysis of the above mentioned layers was done by using 1 by 3 by 1 scale. The resultant layer was then classified into 3 classes based upon suitability scale, i.e., least suitable, slightly suitable and highly suitable as shown in Figure-1.

The importance of groundwater recharge in the Margalla Hills can be understood through the effect it will have on the water-table situation of the areas lying

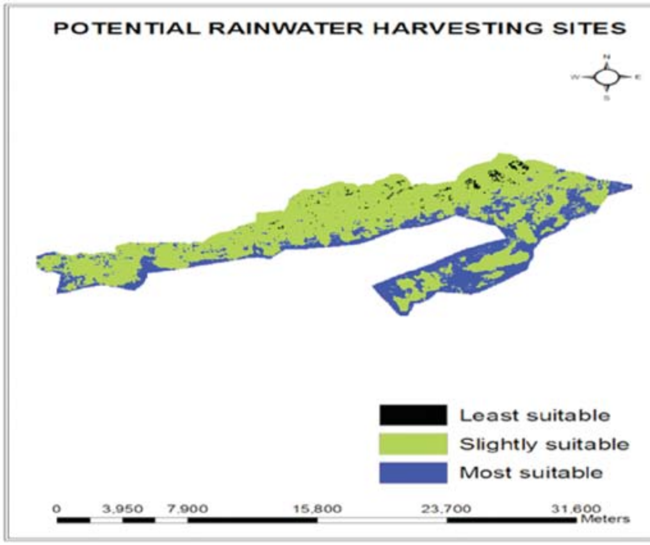

Figure-1: Map Showing Potential Suitable RWH Sites at Margalla Hills National Park

at its foothills. Since streams originating from these hills are the main source of groundwater recharge for the areas lying at foothills and also are a source of surface water for the residents of capital city, as all the streams ultimately drain into Rawal Lake. The water recharge at Margalla Hills will help in raising the water-table level of the surrounding areas through increasing stream water flow, and the resultant increased runoff could be utilized effectively through harnessing of runoff by installing water harvesting structures at areas which are worst hit by climate change, like I-8, I-9, I-10, G-7, G-8, G-10 and G-11 sectors of Islamabad.

4. CONCLUSIONS

In this water scarce world, trend towards groundwater recharge is increasing rapidly. Suitability of groundwater recharge site is dependent on various factors and conventional methods cannot give significant results. This study was based on time and cost effective methods of remote sensing and GIS. The study was based at Margalla Hills national park and focused on many factors like land cover, drainage, elevation, slope, aspect and rainfall. Combined results of satellite image classification and GIS analysis of ASTER DEM produced final site suitability map for groundwater recharge in the study area. Areas on the map were categorized as suitable, slightly suitable and highly suitable, depending upon their suitability for recharge. Installation of recharge structures at suitable sites will increase the level of water-table and reduce the threat of water shortage during the coming years. Following similar approaches for other parts of the country will help in managing water crisis at national scale.

REFERENCES

1. Ashraf, M., and Majeed, A., 2006. Water requirements of major crops for different agro-climatic zones of Balochistan, IUCN. Water Programme, Baluchistan Programme Office. 7, pp 139
2. Ali, M., 2011. Rain water Harvesting potentials [online] available from <http://apniinews.com/en/2011/08/15/rainwater-harvesting-potentials> [02 September 2012]
3. Bigas, H., 2012. The Global Water Crisis: Addressing an Urgent Security Issue. Papers for the InterAction Council, 2011-2012. UNU-INWEH, 2012
4. Brisco, J., Qamar , U., Contijoch , M., Amir, P., and Blackmore, D., 2005. Pakistan's Water Economy Running Dry. Pakistan Water Strategy, The World Bank. pp. 1-140
5. Gunn, E., and Llamas, M., 2008. Rethinking water scarcity: Can science and technology solve the global water crisis, National Resource Forum. 32(3), pp. 228-238
6. Isioye, O. A., Shebe, M. W., Momoh, U.O., and Bako, C. N., 2012. A Multi Criteria Decision Support System (MDSS) for Identifying Rainwater Harvesting Site(s) In Zaria, Kaduna State, Nigeria. 1(1), pp. 1-19
7. Kumar, G. M., Agarwal, A. K., and Bali, R., 2008. Delineation of potential sites for rainwater harvesting structures using remote sensing and GIS. Indian Society of Remote Sensing 36(34), pp. 323-334.

8. Mohtadullah, K., 2004. Integrated water resource management in Pakistan. International Symposium on Community Based Approaches for IWRM. February, 16-17, 2004, UNDP, Islamabad
9. Sakthivadivel, R., 2007. The Groundwater Recharge Movement in India. The Agricultural Groundwater Revolution: Opportunities and Threats to Development. 3, pp. 195-210.
10. Sener, E. Darvaz, A., and Ozcelik, M., 2005. An integration of GIS and remote sensing in groundwater investigations: A case study in Burdur, Turkey. *Hydrogeology Journal.* 13(5-6), pp. 826–834.
11. Shah, T., Singh, O.P., and Mukherji, A., 2006. Some aspects of South Asia's groundwater economy: Analyses of a survey in India, Pakistan, Nepal Terai and Bangladesh. *Hydrogeology Journal*, 14(3): 286–304.
12. Sheikh, S., and Tunio, S., 2012. Islamabad's taps dry up as water shortages worsen [online] available from <http://www.trust.org/alertnet/news/islamabads-taps-dry-up-as-water-shortages-worsen> [December, 2012]
13. Sheikh, I. M., et al., 2007. Environmental Geology of Islamabad-Rawalpindi Area, Northern Pakistan. Regional Studies of the Potwar Plateau Area, Northern Pakistan: U.S. Geological Survey Bulletin 2078 G, pp. 1-32.
14. Teixeira, J., et al., 2008. Integrated approach of hydro-geomorphology and GIS mapping and evaluation of ground water resources: An example from the hydro-mineral system of CALDAS DA CAVACA, NW Portugal. The 33rd International Geological Congress, General Symposium: Hydrogeology, Oslo (Norway). pp. 227-249.
15. UNESCO-WWAP, 2006. Water-A shared responsibility. UN World Water Development Report 2, New York: UN.