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Applications of Google Earth Pro and ArcGIS to estimate the Rainwater Harvesting Potential

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Abstract— Rainwater harvesting is the best method to face the future water shortage in Peshawar because of the water scarcity crisis in many places of Peshawar, KPK province in Pakistan. The rainwater storage system can help to alleviate water scarcity. Rainwater collecting has become a practicable and sustainable solution for lowering potable water usage during the dry season and perhaps mitigating the negative impacts of floods after heavy rains. In our study the techniques of Google Earth Pro and the Geographic Information System (GIS) were used to determine the rainwater harvesting potential of three stadiums in Peshawar city. The average annual runoff and daily discharge from Arbab Niaz Stadium, Peshawar Gymkhana Stadium and Tehmas Khan Football Stadium is calculated with the help of using "Google Earth Pro" and "ArcGIS 10.8". Required size for storage tank is also calculated on the basis of daily discharge from catchment surface of three stadiums. The average annual rainfall in Peshawar city is 403.9 mm according to Pakistan Meteorological Department. Peshawar is the most suitable city for the practice of rainwater harvesting. The estimated average annual quantity of runoff from study area comes out to be 1956769 liters for year 2021.

Index Terms— Rainwater Harvesting, Demand, Storage Tank, Geographic Information System, Google Earth Pro.

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1 Introduction

POTABLE water and basic sanitation should be available, accessible and suitable to people [1]. Water is a basic need for humans and is the basis for socio-economic development [2]. Around 20% of Pakistan's total population has sought clean drinking water. Almost 80% of the population has been supposed to drink contaminated water [3]. Rainwater storage has been performed since 4500 BC, with data spanning until 850 BC, according to sources in Jordan and Israel, accompanied by India and Sri Lanka [4]. Rainwater harvesting may be divided into two categories. Surface water harvesting is the first, while rooftop water harvesting is the second. Rainwater may be obtained from various rooftop surfaces through gutters for rooftop rainwater harvesting. The obtained water is utilized for non-potable activities in our regular lifestyle. Daily life activities like Flushing, cleaning, vehicle washing, gardening, & clothes washing [5]. Rainwater can be collected and store it for later use or discharged into the groundwater. Because of the increasing demand for water in the world, groundwater levels are continuously depleted [6]. Water is an essential need for humans living on Earth. The purpose of collecting rainwater is to help households satisfy their basic water demand [7]. Rainwater can be stored up to dry season by households [8]. Precipitation unpredictability also poses a problem to the water collecting system's performance. Precipitation variability has a significant impact on how much amount of rainwater can be retained by rooftop water harvesting technologies [9].

Rainwater harvesting systems have been shown to be helpful in enhancing the livelihoods of rural communities, particularly those that have incorporated the innovations, partially because they have reduced the time and energy required to get water from alternative sources [10]. Rainwater collecting is the most effective method for increasing the natural filtering of water into underground improvement through a few manmade techniques [11]. Rainwater is being used as the best drinking water source not only in Asia, but as well as in Australia, Europe, the United States, and Africa [12] [13]. The amount of Pb in rainwater has boosted air pollution levels. Some chemical, biological, and physical characteristics of air pollution, such as CO, dust particles, and heavy metals, such as the concentration of Pb, are extremely high. Vehicles, industries, and factories, especially in urban areas, have produced exhaust particles. The findings of several studies in countries such as Palestine and Australia revealed that dust particles, bird faeces, and heavy metals seemed to have an impact on rainwater quality, also including changes in taste and colour [14] [15]. Turbidity in raindrops is caused by suspended solid particles that can be organic or inorganic [16]. Rainwater harvesting systems have met Malaysia's water-saving goals [17]. The results of simulation models and estimations of installing rainwater harvesting systems may not meet actual performance after occupancy for green technology practices [18]. Besides in residential areas, it is extremely difficult to predict individuals' activity and water usage trends [19]. The HI index for chosen metals, for instance, Cd, Cu, Co, and Pb for adults fell inside the safe value. Although in the case of kids, the HI values have surpassed the safe range level of 1.0 for street dust, slime from storm channels, and road dirt is completely examined in urban areas [20]. Rainwater can offer main source of drinking water with appropriate treatment to reduce the levels of contaminants of health concern, such as arsenic and fluoride [21]. The assessment of rainwater harvesting potential is mostly followed by quantifying the runoff volume and all characterization components of the rainwater harvesting system [22].

Rainwater collection is the process of capturing and storing rainwater from rooftop catchments. It entails collecting rainwater in urban areas and utilizing it to raise ground level via artificial recharge. It involves the installation of gutters from the roof's top to the existing tube well [23]. A PC-based mini-computer was introduced to determine tank size based on the monthly precipitation [24]. The size of the capacity tank

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must be evaluated in future research since it may affect the predicted promise of RWH from housetops. The current study also showed that modelling the precipitation overflow design and the potential consequences of environmental changes on Addis Ababa might help with ordering the runoff coefficient of surrounding housetops, which could be a limiting parameter for determining the storage tank capacity [25]. Water kiosks, which were created in health centers in Rwanda developed by large public institutions with a significant capacity for water collection [26]. It was observed that the approach used in the study to determine the area of catchment surfaces with the use of "Google Earth Pro" and QGIS is the most appropriate [27]. To analyze the catchment surfaces, the raster file was converted into a vector file using "Google Earth Pro" and "QGIS" software. "ArcGIS" is a popular tool for calculating the area of any object. "ArcGIS" application allows you to examine, modify, and explore spatial information [28]. Furthermore, the GIS evaluation technique was used to compute the RRWH potential, resulting in an effective appraisal of rooftop rainwater harvesting in Wollert, a Melbourne, Victoria suburb. The total volume of water harvestable at the domestic level could be calculated using "ArcGIS" software [29]. "ArcGIS 10.3" was also utilised to digitise all forms of catchments based on their shape. Finally, the catchment area was estimated in order to evaluate the possibility of rainwater collection [30].

2 METHODOOGY

2.1 Description of Study Area

The selected study areas were Arbab Niaz Stadium (Shahi Bagh Stadium), Peshawar Gymkhana Stadium and Tehmas Khan Football Stadium which are located at 34° 1′ 18″ N, 71° 34′ 42″ E and exist at Peshawar in Khyber Pakhtunkhwa province of Pakistan. Peshawar Gymkhana Ground is a Club cricket ground which is an old British Raj era ground and used to have 2 tennis courts, a pavilion and a cricket ground. It is very popular among Club cricketers and club cricket is regularly played here. Tehmas Khan Football Stadium is popular among footballers and football tournaments are regularly played here. The average annual rainfall in Peshawar city is 403.9 mm according to Pakistan Meteorological Department. The study area map is given in ''Google Earth Pro'' and ''ArcGIS 10.8'' available in Fig 1 and Fig 2.

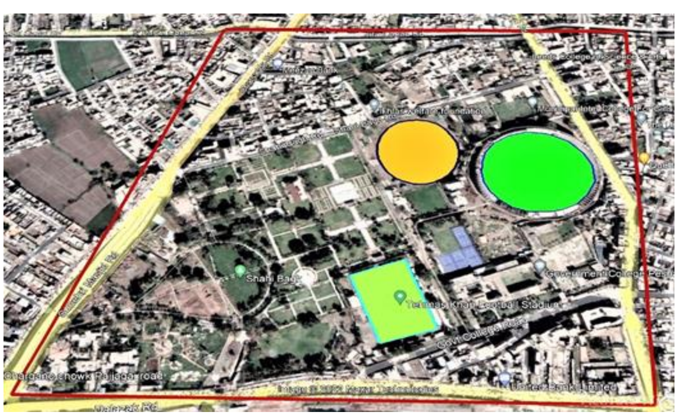

Fig. 1. Study area map (Google Earth Pro)

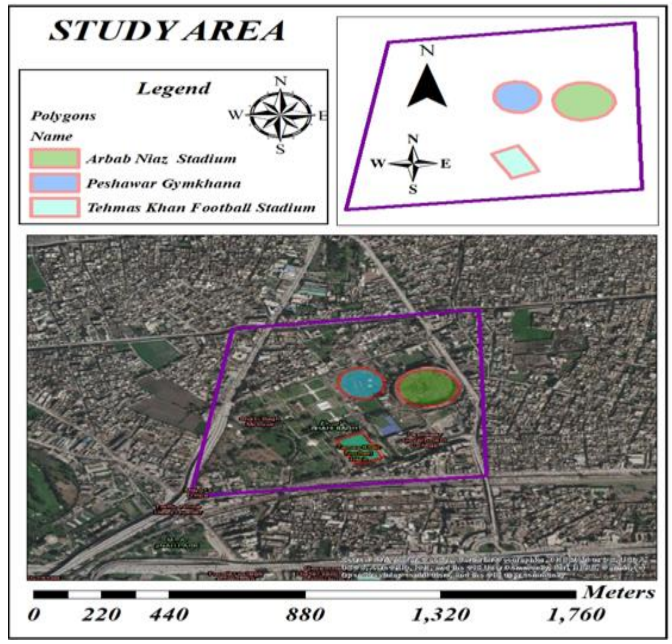

Fig. 2. Study area map (ArcMap 10.8)

2.2 Rainfall Data

Quantity of rainwater is the major component of estimating the rainwater harvesting potential. The rainfall data for year 2021 has been collected from Pakistan Meteorological Department. Fig 3 shows the rainfall data of 2021 in the months (January to December) respectively. Whereas maximum rainfall happened in July which was 79.83 mm and the minimum rainfall happened in January which was 0.01 mm. The average annual rainfall of 2021 is 297.39 mm.

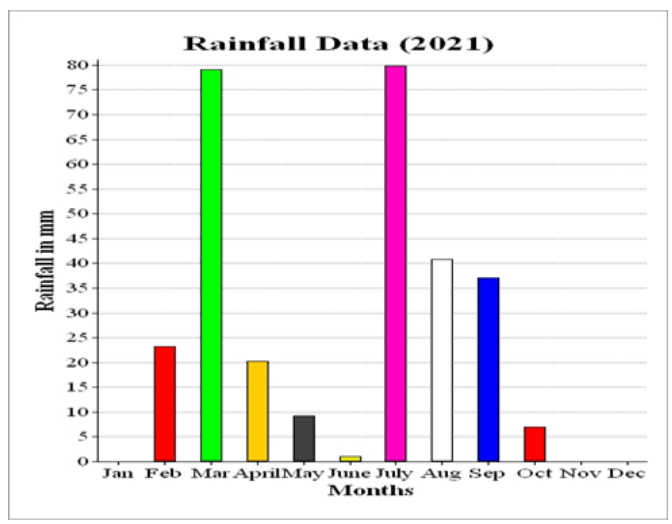

Fig. 3. Rainfall data of Peshawar city (2021)

2.3 Coefficient of Runoff (Cr)

The ratio rate between rainfall and runoff values is called runoff coefficient is dimension less ratio. As the total quantity of runoff is impossible to be stored because there is generally some amount of precipitation water could be lost by the retentive impact of surface. There are also the chances of lost this fresh water by processes of evaporation. The rate of lost rainwater is dependent on the surface of constructed material [31]. As our study catchment surface area is three stadiums of Peshawar city which consists of green area so value of Cr as ''0.15'' is used to estimate the rainwater harvesting potential. The values of runoff coefficients for different catchment surfaces have been given in Table 1.

Table 1. ''Runoff Coefficient'' (Cr) values for different catchment surfaces

Type of Catchment Surface	Runoff Coefficient
Railroad yard	''0.20 to 0.40''
Concrete	''0.80 to 0.95''
Brick	''0.70 to 0.85''
Asphaltic	''0.70 to 0.95''
Playground	''0.20 to 0.35''
Green Park	''0.10 to 0.25''

2.4 Runoff Catchment Surface Area

The type of catchment surface from where rainwater can be collected either it can be rooftop of any building or any plain surface area is called runoff catchment surface area. For calculation of catchment surface area, total area of stadiums was manually digitized from the satellite image with the help of using ArcMap 10.8. Then the area of each polygon was calculated in square meter (m^2), by using area calculation tool.

2.5 Rainwater harvesting potential

Rainwater harvesting potential system is always dependent upon harvestable amount of rainwater. The rainwater harvesting potential has been estimated by using equation (1).

$$S = R \times A \times C_r \qquad (1)$$

Where, S, R, A and Cr are rainwater harvesting potential in cubic meters, average annual precipitation in meters, area of catchment in square meter and coefficient of runoff [32]. Calculating rainwater harvesting potential through equation is the best method for any catchment surface area.

2.6 Volume of storage tank

The volume of the storage tank has been assumed based on the quantity of daily discharge expected. The discharge per day is based on the catchment area and quantity of daily rainfall. Daily rainfall is calculated by dividing average annual rainfall by 365. For some safety rules, the size of storage tank must be bigger than the required size [5].

3 RESULTS AND DISCUSSION

3.1 Digitization of catchment area using Google Earth Pro

The catchment surfaces of study area have been digitized in ''Google Earth Pro'' with the advantage of available ''Polygon tool''. This process resulted in digitized catchment surfaces of Arbab Niaz Stadium, Peshawar Gymkhana and Tehmas Khan Football Stadium that are saved as KML file and shown in Fig 4 respectively.

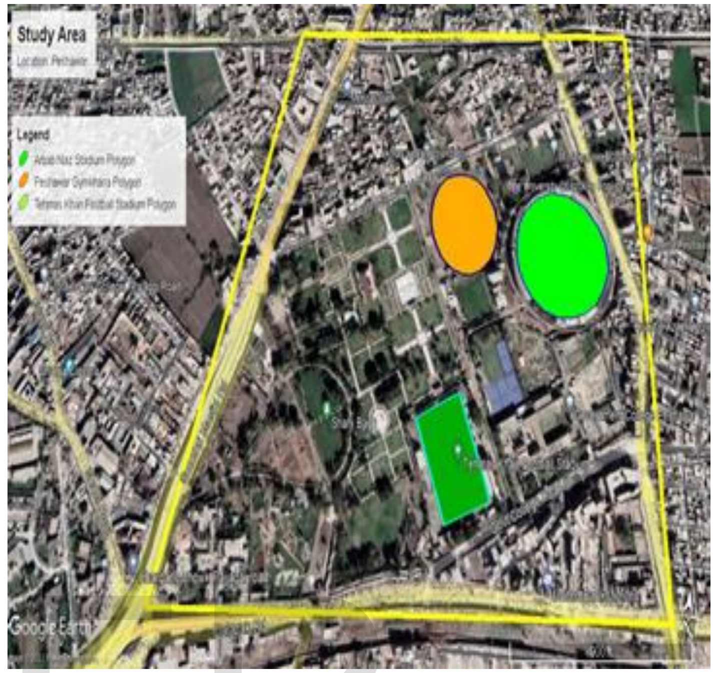

Fig. 4. Study area digitized using Google Earth Pro

3.2 Calculation of catchment area with the advantage of ArcGIS Software

Digitized catchment areas in the ''Google Earth Pro'' which were saved as a KML file. The KML files of digitized catchment surfaces were changed from ''KML files to layer form'' in ''ArcGIS 10.8''. After converting from KML to layer, all layered forms were converted to Shapefiles. After changing from layered form to shapefiles, the coordinate system of each shapefile was changed to a projected coordinate system that is different for every region i.e. EPSG: 32644 - WGS 84 / UTM zone 43 N is used for Pakistan. For calculating digitized catchment surfaces with the advantage of geometry calculation tool in the Arctic. Fig 5 represents shapefiles of study area projected in ''ArcGIS 10.8'' and Fig 6 represent digitized catchment study area calculated in ''ArcGIS 10.8'' through attribute table.

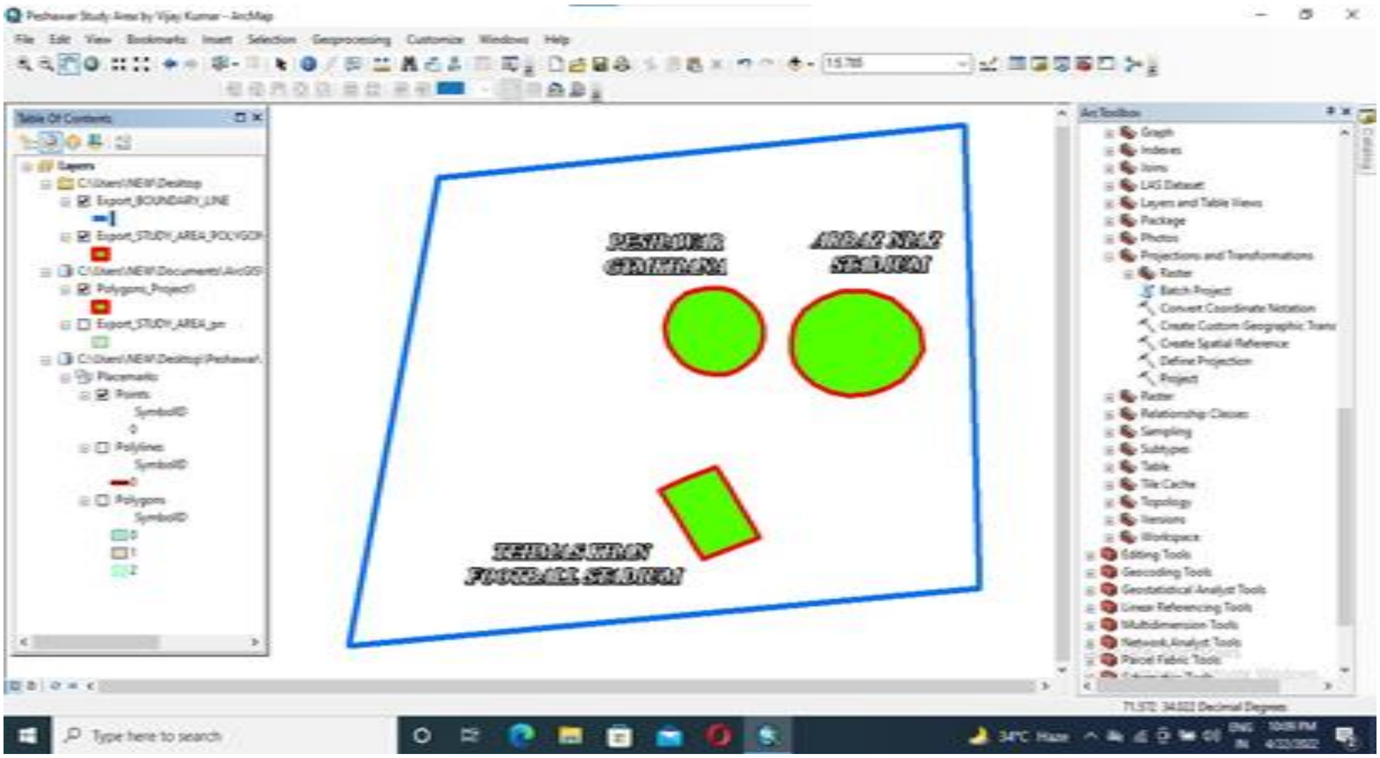

Fig. 5. Projected shape files of study area

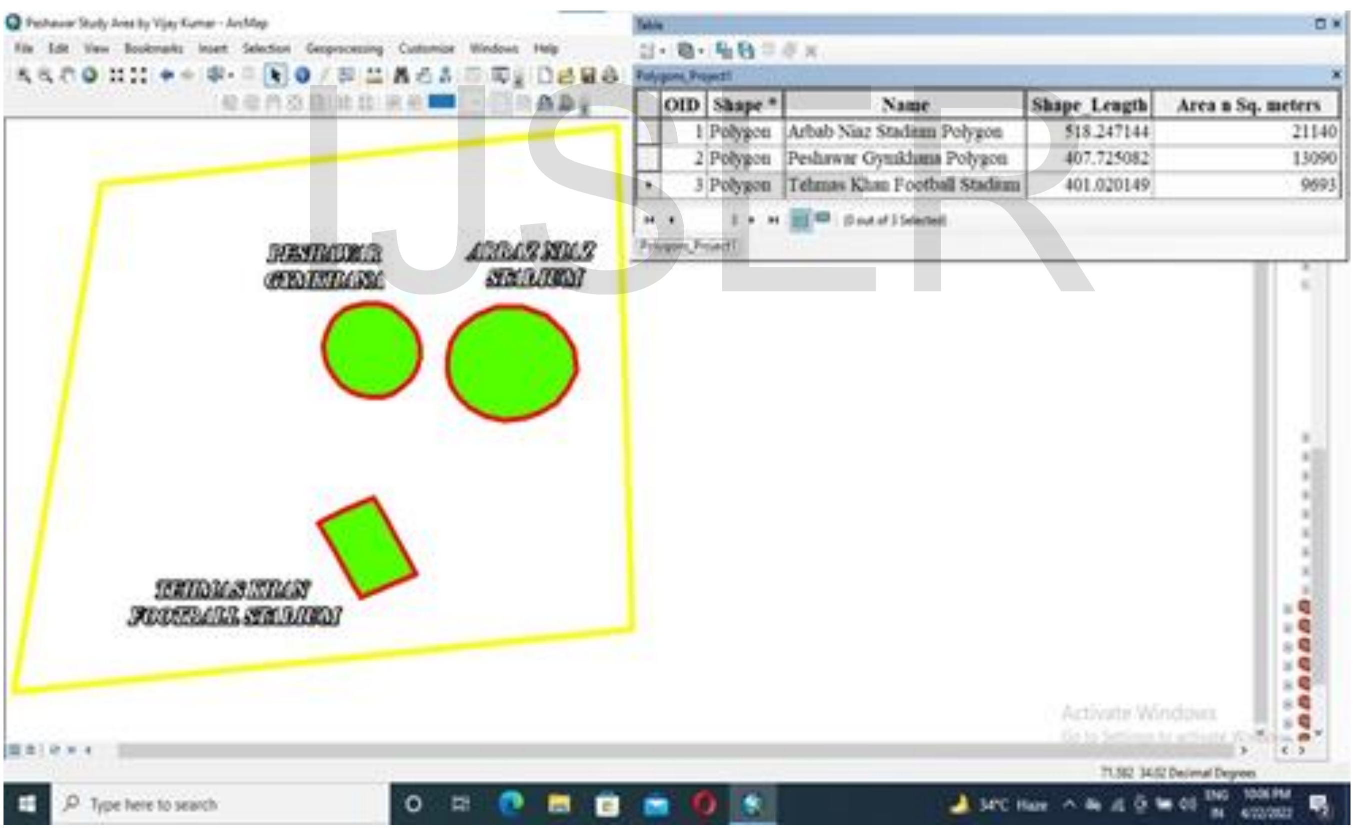

Fig. 6. Digitized shape files with calculated areas in attribute table in ArcGIS

3.3 Estimated rooftop rainwater harvesting potential

Fig 7 shows the estimated average annual rainwater harvesting potential runoff from catchment surfaces of three stadiums as 1956.769 cubic meters for year 2021. The maximum quantity of rainwater can be obtained from our study area. Our study area is divided into three catchment surface areas which are Arbab Niaz Stadium, Peshawar Gymkhana stadium and Tehmas Khan Football Stadium. The maximum amount of rainwater can be obtained from catchment surface of Arbab Niaz Stadium is 941.787 cubic meters and minimum amount of rainwater can be obtained from catchment surface of Tehmas Khan Football Stadium is 431.823 cubic meters. Fig 8 represents the amount of runoff map in ArcMap.

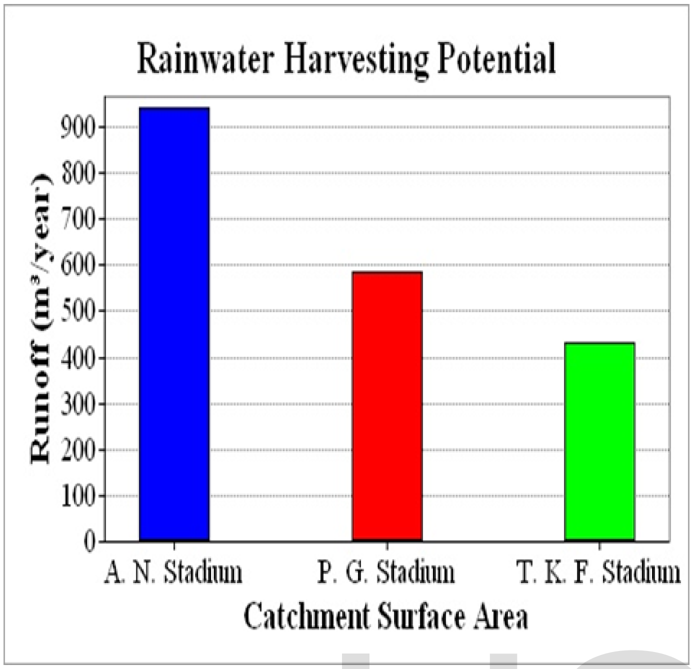

Fig. 7. Estimated potential of rainwater harvesting for year 2021

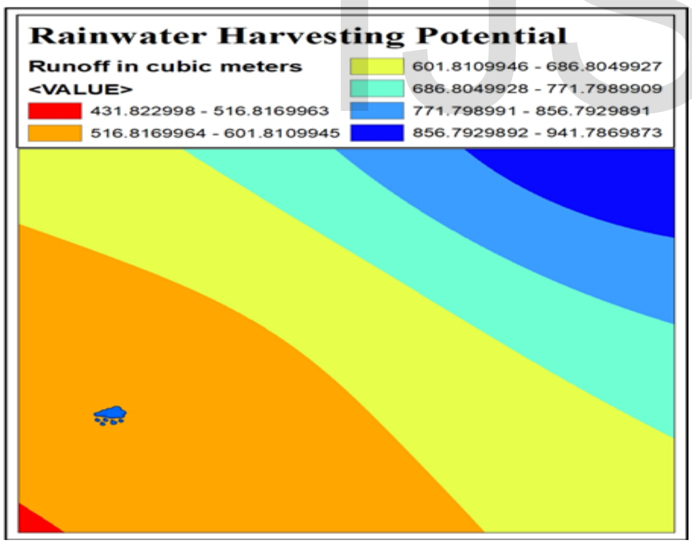

Fig. 8. GIS mapping of rainwater harvesting potential in the year 2021

3.4 Estimated daily discharge and required volume of storage tank

Fig 9 shows the daily discharge of 17.186 cubic meters can be obtained from catchment surface of Arbab Niaz Stadium, daily discharge of 10.642 cubic meters can be obtained from catchment surface of Peshawar Gymkhana and daily discharge of 7.880 cubic meters can be obtained from catchment surface of Tehmas Khan Football Stadium. Fig 10 shows the required storage tank volume of 40 m³ is assumed for the daily discharge of 17.186 cubic meters from Arbab Niaz Stadium, storage tank volume of 27 m³ is assumed for the daily discharge of 10.642 cubic meters from Peshawar Gymkhana and storage tank volume 24 m³ is assumed for the daily discharge of 7.880 cubic meters from Tehmas Khan Football Stadium.

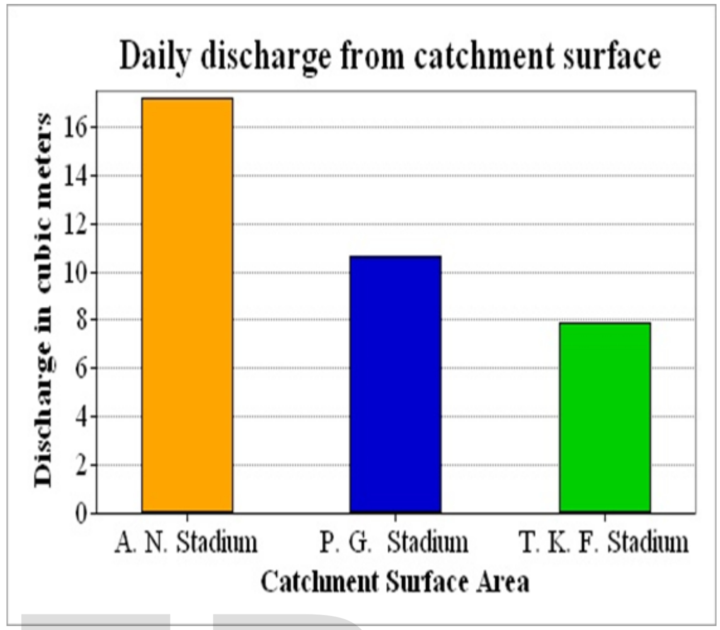

Fig. 9. Estimated daily discharge from catchment surface area

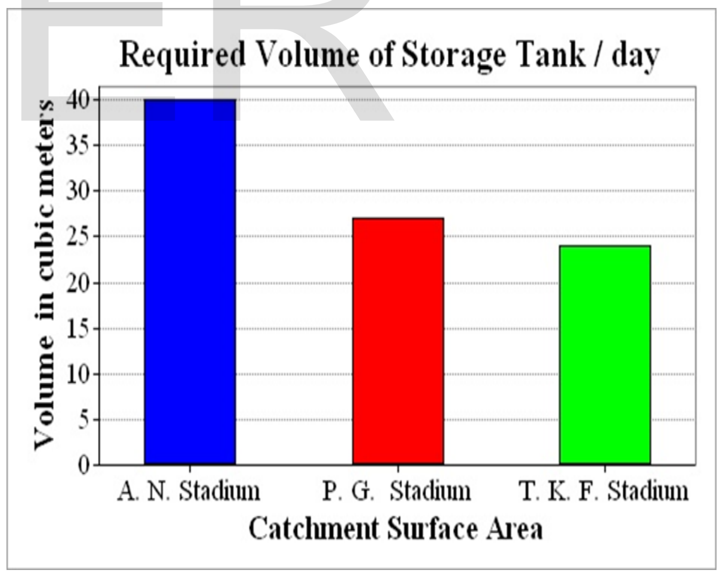

Fig. 10. Required volume of storage tank for daily discharge

3.5 Estimated demand of water

The obtained runoff from Arbab Niaz Stadium, Peshawar Gymkhana Stadium and Tehmas Khan Football Stadium will be used by players and public. It has been assumed that 5 liters quantity of water per person is sufficient in stadium for hand washing and hygiene practices per day. It is supposed that there are total 7000 persons present in all three stadiums.

Total demand of water per day for a person in stadium is

5 × 7000 = 35000 liters

Total annual demand of water for a person in stadium is
5 × 7000 × 365 = 12775000 liters

Our estimated daily discharge from Arbab Niaz Stadium, Peshawar Gymkhana and Tehmas Khan Football Stadium is 35708 liters which is more than 35000 liters and our estimated annual discharge from catchment area is 12775000 liters which is even more than 13033420 liters. Practice of rainwater havesting technique is the best alternative way to meet the demand of water for players, coaches, management staff and all the public come in huge amount.

4 Conclusion

The water demand is increasing as population is growing rapidly. To meet all water demands, the technology of rain water harvesting is the best solution. In highly populated country like Pakistan crisis of water is a serious problem and resources of water should be managed carefully. Rainwater harvesting helps us to meet water demands, replenish groundwater, reduce water bills and improves environmental health. The Environment experts suggested that 70 mm (minimum) rainfall is required for doing rainwater harvesting. Peshawar is most suitable for rainwater harvesting as average annual rainfall in Peshawar city is 403.9 mm. Our study is carried out to calculate the potential of rainwater harvesting from catchment surfaces of Arbab Niaz Stadium (Shahi Bagh Stadium), Peshawar Gymkhana and Tehmas Khan Football Stadium in Peshawar. The amount of rainwater can be obtained from catchment surface of Arbab Niaz Stadium is 941.787 cubic meters, amount of rainwater can be obtained from catchment surface of Gymkhana Peshawar is 583.159 and amount of rainwater can be obtained from catchment surface of Tehmas Khan Football Stadium is 431.823 cubic meters. Harvested rainwater is freely available for every person because rainwater is a natural cost free source. The best solution is rainwater harvesting for people living not only in Peshawar but all cities of Pakistan who face water problems in their daily life. Rainwater can be captured from rooftop of any building, roads and open spaces which are available everywhere. Our research study has proved that any domestic house, school, college, office and universities can easily adopt RWH technique to face future water problems. Government should take interest to promote the RWH technique in every part of the country. Celebrities of every country must promote RWH technology on social media as pubic take interest and apply at domestic level. The population of every region of Pakistan can easily install rainwater harvesting system as every house has large catchment surface area (rooftop, roads, and open plain surface area) available for rainwater harvesting. Promoting and installing rainwater harvesting technologies systems is an alternative solution in many cities and villages of urban or rural areas of Pakistan. New methodology should be used for collecting rainwater for our future demand.

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