

RWRE–A WEB BASED OPEN SOURCE GIS TOOL FOR ROOF WATER RUNOFF ESTIMATION

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ABSTRACT

In rural areas of low rainfall, roof top rainwater harvesting is an ideal method for collecting rainwater because it helps not only in meeting at least a part of the water requirement but also prevents storm runoff and flooding during heavy rains. Individual houses and buildings are the best units for collecting the roof water. In this work an interactive web-based GIS tool named RWRE (Roof Water Runoff Estimator) has been developed to estimate the runoff from the rooftops of the buildings. REWE tool was designed using open source geospatial development tools like Geoserver and OpenLayers. The developed tool provides a polygon drawing tool to delineate the rooftop of individual buildings. The area of rooftop of each building is listed. The runoff coefficient for each building is also taken as input. The annual average rainfall is required to calculate the total amount of water available from the rooftops of all the delineated buildings. For the testing and development of RWRE, the municipal area of Bhopal city of Madhya Pradesh was taken. This tool can be configured to be used for any rural or other area and can be of great help in planning and designing of the roof water harvesting structures as it quickly and accurately estimates the volume of water available from the buildings.

Keywords: OpenLayers, Geoserver, Rooftops, Runoff.

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Introduction

Rainwater harvesting is an age old technique of collection of rain water from localised catchments and storing it in reservoirs or tanks or infiltration of surface water to sub-surface water. The process of collecting and storing runoff from rooftops is called roof water harvesting. In residential areas roof top rainwater harvesting is an ideal method for collecting rainwater because it not only helps in meeting some part of water requirement but also reduces storm water runoff and flooding of roads during heavy rainfall. Individual houses and buildings are the best units for collecting the roof water. Rooftop water harvesting has many advantages over the various other techniques of water harvesting. Some of the advantages of rooftop rainwater harvesting are mentioned below:

- a) Rooftop rainwater harvesting is a suitable option for augmenting groundwater recharge/storage in areas, where natural recharge is reduced considerably due to less availability of land for percolation of rainwater.
- b) Rooftop rainwater harvesting can be used to add to the domestic requirements in rural areas.
- c) The water collected from the roof tops use to be soft, bacteriologically safe and free from organic matter, because the roof catchments are usually cleaner as compared to the ground level catchments.
- d) Collecting water from rooftops helps to improve the quality of groundwater by dilution.

- e) The rainwater harnessed from the rooftops can be utilised at the time of water scarcity.
- f) The structures required for harvesting rainwater are simple, economical and eco-friendly.
- g) Losses from roof catchments are much less, when compared to other catchments.

The rooftop rainwater harvesting technique is not a new one, but it has become popular only recently for the collection and storage of water for drinking purposes. Numerous studies have been done in this regard. Liaw and Tsai (2004) found out the optimum storage volume of rooftop rainwater harvesting systems for domestic use in Taiwan. Rooftop rainwater harvesting is only a small part of the large issue of rainwater harvesting. According to Radhakrishna (2007), isolated attempts at rain water harvesting will not produce desired results, but a concrete action plan will be required to be drawn and implemented, making it a mass movement for water harvesting.

In urban and rural settlements where most of the buildings made up of impervious material such as cement concrete, asbestos sheets or galvanised iron sheets, facilitates the large quantities of water to flow as runoff. Collecting this runoff can contribute to substantial amount of water for storage and use. Remote Sensing and GIS can be of great help in calculating the amount of water available from rooftops. Using high resolution satellite images, the foot prints of the buildings from the large area can be quickly mapped and with the help of GIS software

the area of the rooftops of the building can be calculated.

This paper concerns with computation of the runoff volume of water from the rooftops. In this work an interactive web-based GIS tool named RWRE (Roof Water Runoff Estimator) has been developed to estimate the runoff from the rooftops of the buildings. REWE tool was designed using open source geospatial development tools like Geoserver and OpenLayers. This tool uses GoogleEarth imagery as a backdrop for tracing the rooftops of the buildings. RWRE can be of great help in planning and designing of the roof water harvesting structures as it quickly and accurately estimates the volume of runoff water available from the rooftops of the buildings.

Objective

The main objective of this work was to develop an easy to use web based GIS tool for rooftop runoff estimation, which can be used by the rural community without having any knowledge of GIS software. Another objective was to demonstrate the simplified use of the emerging web based GIS using the popular open source web GIS software tools like GeoServer and OpenLayers.

Runoff Calculation

The volume of water available from the rooftop harvesting can be calculated by following formula:

$$W = T \times A \times R$$

Where, **W** is the volume of water available from rooftop water in liters, **T** is total area of the roof in Sq. m., **A** is the annual rainfall in mm and **R** is the coefficient of runoff. Roof area should be measured on the map i.e. the area projected on a horizontal surface.

Runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface (Rainwater Harvesting and Utilisation Book 2). It accounts for the fact that all the rainfall falling on a catchment cannot be collected. The nature of roofing material can greatly affect the quality and quantity of runoff water. Impervious roofing materials with smoother and cleaner surfaces contribute to better quality and quantity of water. The runoff coefficient of untreated ground sloping less than 10 per cent will be in range of 0 to 0.3 and with rocky natural pavement will be in range of 0.2 to 0.5 (Pacey, 1989). The coefficient of runoff depends on the type of roof. Table 1 shows the runoff coefficients for common types of roofs.

Table 1: Runoff Coefficients of Common Types of Roofs

S.No.	Type of Material	Runoff Coefficient
1	GI Sheet	0.9
2	Asbestos	0.8
3	Tiled	0.75
4	Concrete	0.7

Source: Manual on Artificial Recharge of Ground Water, CGWB, 2007.

Tools Used

The application development for this work was done using following open source software tools and scripting languages:

- 1) GeoServer 2.4.3
- 2) Apache Tomcat 7.0
- 3) OpenLayers 2
- 4) HTML and CSS

The framework of application using the above mentioned tools is given in Figure 1. RWRE is based on Client-Server architecture. The logical tier of the web application consists of Apache Tomcat server and GeoServer, while data tier is composed of shapefiles. The client can communicate with the Apache Tomcat server by sending it HTTP request and then Apache Tomcat sends the request to GeoServer that can access shapefiles. The HTTP response is then sent back to the client.

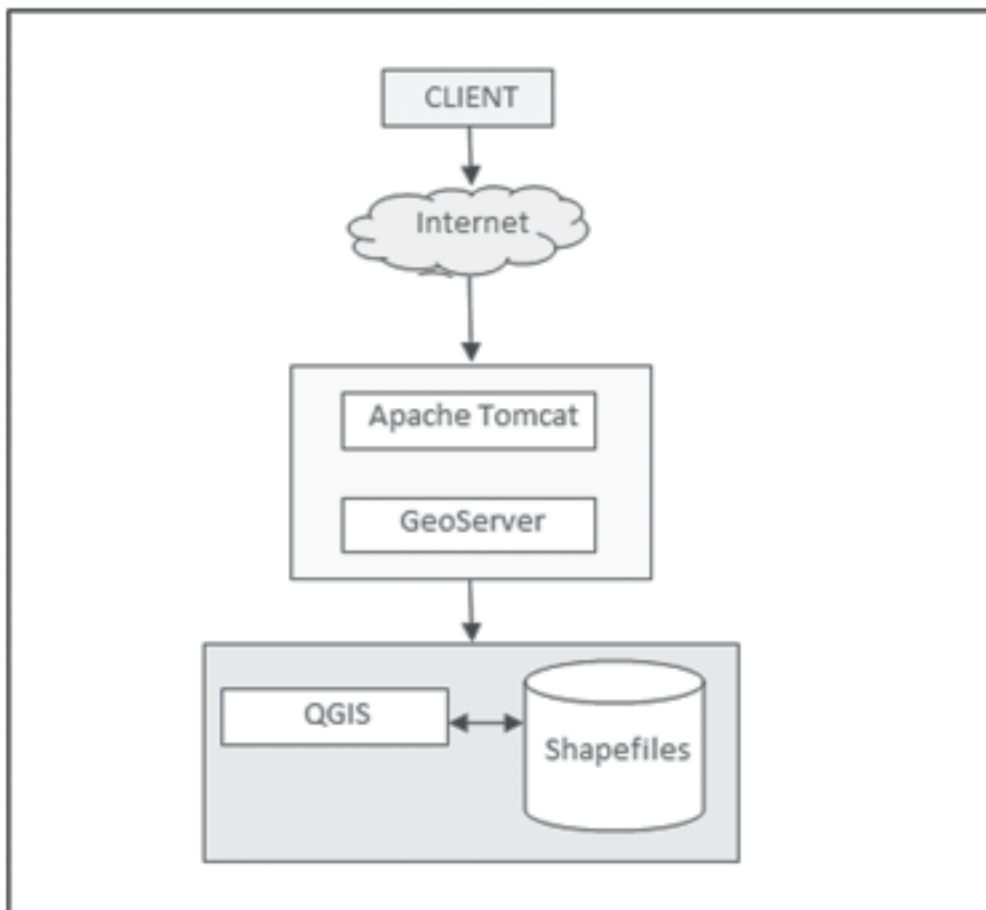


Figure 1: Framework of Application

GeoServer is an open source software server written in Java. GeoServer allows users to share and edit geospatial data. It is designed for inter-operability and it can publish data from any major spatial data source using open standards. GeoServer allows users to view and edit geospatial data as Web Map Service (WMS) and Web Feature Service (WFS). In this application both WMS and WFS were used.

Apache Tomcat is an open source Java-based web and servlet container, used to host Java-based applications (Khare, 2012). Its major function is to respond to the requests from the clients i.e. web browsers. Apache Tomcat can easily link to GeoServer.

OpenLayers is one of the most important components of RWRE. OpenLayers is an open source client side JavaScript library for making web maps, viewable in nearly any web browser (Hazzard, 2011). It is based on AJAX (Asynchronous Java Script and XML) technology. OpenLayers is a client side library and it does not require any special server side software or settings. It can be used even without downloading anything. OpenLayers makes it easy to put a dynamic map in any web page (Openlayers.org). OpenLayers was used in this application to write all the map related functions.

Scope of the Work

The scope of our work is aimed at developing an easy to use web based GIS tool, which can be used as to compute the volume of runoff from the rooftops of the buildings delineated from the GoogleEarth image. The

entire development was done using open source tools, hence it is available for the community to use. The application can be easily modified to fulfill other related requirements like runoff estimations from the land surfaces. Since it is an open source application it can be redistributed with or without any modifications.

Methodology

Web application requires the configuration of the above mentioned software tools. The following steps were followed to develop the web-GIS application:

- 1) Installation of Apache Tomcat.
- 2) Installation of GeoServer web archive (.war file) using Apache Tomcat.
- 3) Configuration of GeoServer by creating workspace and adding polygon shapefile of municipal wards polygons to a new vector data source.
- 4) Creation of a style descriptor file (.sld) for display of ward polygons with ward number and hollow fill.
- 5) Development of client by writing script of html, OpenLayer and CSS.

The development and testing of the application was done on a localhost machine, for actual use this application can be deployed on a website for giving access to the public.

For development and testing of this application the municipal area of Bhopal city of Madhya Pradesh, India was taken. The municipal

area of Bhopal is divided into 14 zones and 70 wards.

The ward boundaries of all the 70 wards was stored in shapefiles were used in this application. Using RWRE the rooftops of 2367 buildings of municipal ward number 30 were digitized. The total area of the ward number 30 is 14,18,979 Sq. m. and the area occupied by buildings is 295949 Sq. m. The average annual rainfall of Bhopal is 1200 mm. The value of runoff coefficient of runoff was taken 0.7 as most of the buildings are having concrete roofs. Total 248597160 liters of runoff volume can be made available from the ward number 30, which can make the aquifer more sustainable or can be stored in tanks.

Functioning of Application

The application runs in a web browser and is quite easy to use. The developed application RWRE provides the following functionalities:

- 1) Display of high resolution GoogleEarth image for identification and delineation of rooftops of the buildings.
- 2) Selection of the area of interest based on administrative or any other boundary polygon
- 3) Option for drawing and deletion of the rooftop polygons.
- 4) Option for entering the average annual rainfall and coefficient of runoff for each building.
- 5) Saving the drawn rooftop polygons along with the attributes (coefficient of runoff, area and volume) as GeoJsonfile.

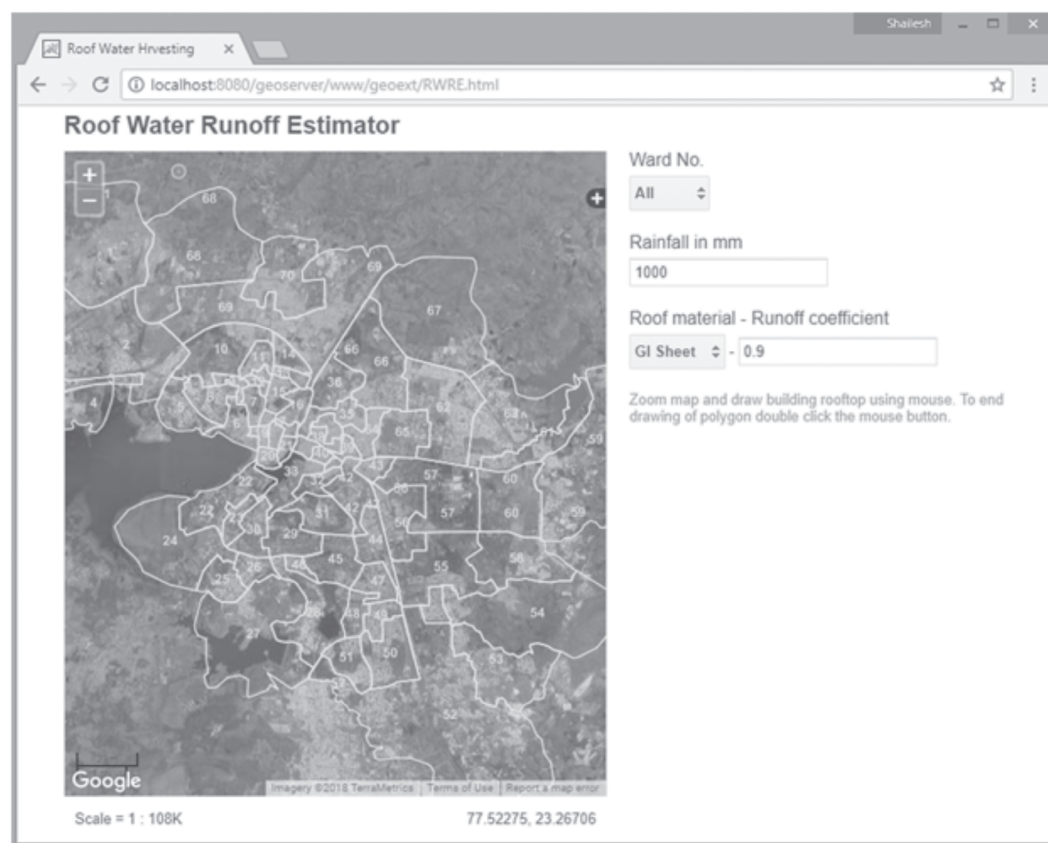


Figure 2: User Interface of Web Application REWE with Google Eath Image and Ward Boundaries

In this application, user will be initially provided with a web client displaying Google Earth image with the administrative polygons (Figure 2). The names of the administrative polygons are displayed in a dropdown box on the right side of the map. User can select any administrative polygon to easily locate his area of interest. Once the polygon is selected from

the drop down box, the selected polygon is centered and zoomed to fit the map along with the background Google image. Standard navigation and zooming options are available for further zooming and planning. Annual rainfall or the rainfall per spell in mm is required as an input and can be entered in the input box provided for this purpose on the right side of the map.

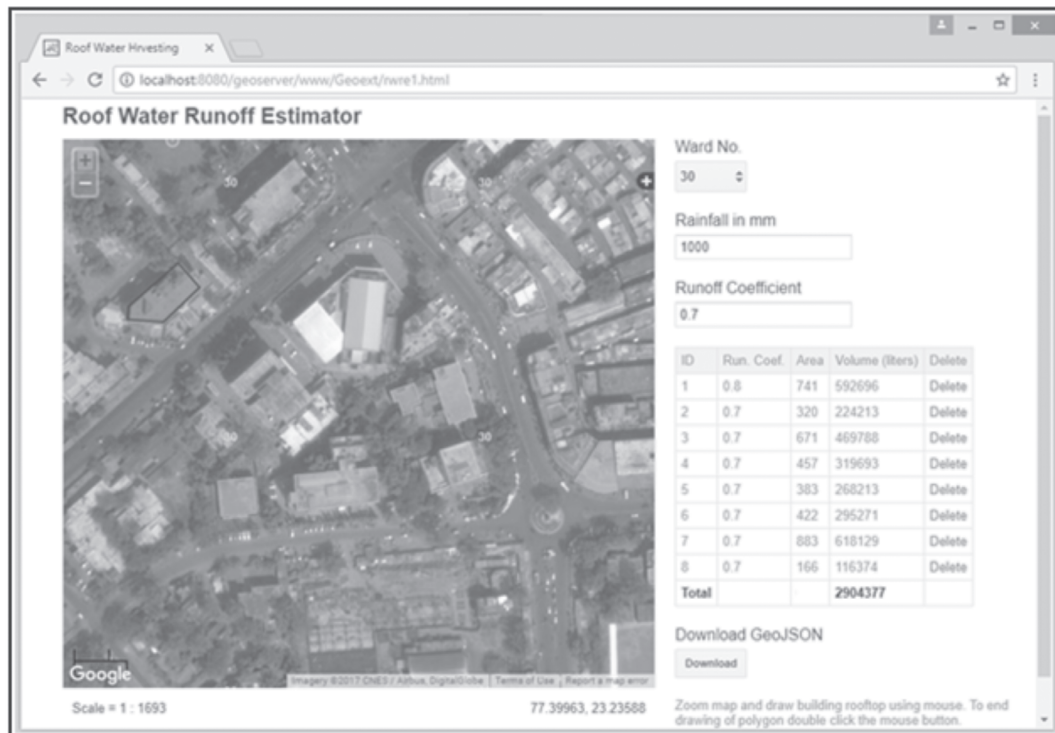


Figure 3: Polygons of Rooftops of the Buildings and Volume of Water Available as Runoff

Using the navigation controls the user can locate the buildings and can draw the rooftops using mouse. The runoff coefficient is required to be entered for each polygon before drawing. The area and volume of runoff for polygon is added in the table on the right hand side of the map. The value of runoff coefficient depends upon type of material used for the construction of roof and may usually range from 0.7 to 0.9 (Manual on Artificial Recharge of Ground Water, CGWB, 2007).

User can draw any number of rooftop polygons. The area and volume of the runoff for each polygon is added in the table and the total volume of runoff in liters is shown in the table

(Figure 3). By just putting mouse cursor on the table, the corresponding rooftop polygon is highlighted in blue colour. There is also an option to delete the polygon. All the polygons drawn for the rooftops can be saved as a GeoJson file for further use. In GeoJson the attribute information of each polygon such as area, coefficient of runoff for polygon and runoff volume from polygon is also stored.

Conclusion

The developed application can be used for the runoff estimation from the rooftops of the buildings of a residential or commercial area. It can be used in rural areas to estimate the roof water runoff from the large buildings like cold

storage, school buildings and poultry farms, etc. The application can be of great help in the planning of the roof water collection and storage structures for urban and rural areas. Even runoff volume from individual buildings can also be calculated to meet the domestic requirement. The cost of material used for collection of water and its storage is an important limiting factor in popularising the roof water harvesting practices. RWRE can also be used for runoff volume estimation of other land surface catchments. The idea presented here can further be extended to address the various other issues of rural development, planning and management.

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