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SS Jadhav
B. Tech. Scholar, SWCE, CAET, Dr. BSKKV, Dapoli Maharashtra, India

SD Gayakwad
B. Tech. Scholar, SWCE, CAET, Dr. BSKKV, Dapoli Maharashtra, India

Dr. PR Kolhe
Associate Professor (CAS), SWCE, Dr. BSKKV, Dapoli Maharashtra, India

Dr. HN Bhange
Associate Professor , SWCE, CAET, Dr. BSKKV, Dapoli Maharashtra, India

VD Jadhav
Technical assistant, AKMU, Dr. BSKKV, Dapoli Maharashtra, India

Dr. PB Bansode
Assistant Professor, SWCE, Dr. BSKKV, Dapoli Maharashtra, India

MH Tharkar
Assistant Professor, SWCE, Dr. BSKKV, Dapoli Maharashtra, India

Dr. AR Patil
Senior Research Assistant, AKMU, Dr. BSKKV, Dapoli Maharashtra, India

GG Kadam
Office Assistant, IDE, CAET, Dr. BSKKV, Dapoli Maharashtra, India

Corresponding Author:
SS Jadhav
B. Tech. Scholar, SWCE, CAET, Dr. BSKKV, Dapoli Maharashtra, India

Designing of rooftop rainwater harvesting system by using soft computing technique

SS Jadhav, SD Gayakwad, Dr. PR Kolhe, Dr. HN Bhange, VD Jadhav, Dr. PB Bansode, MH Tharkar, Dr. AR Patil and GG Kadam

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Abstract
Water scarcity is a pressing issue worldwide, and sustainable solutions are crucial for addressing this challenge. This study investigates the potential of a rooftop rainwater harvesting system (RRWHS) for the CAET building at Dapoli, employing soft computing techniques to enhance the system's efficiency and effectiveness. The research involved a detailed analysis of 20 years of rainfall data (1994-2024) collected from the meteorological observatory of the Department of Agronomy, CAET, DBSKKV, Dapoli. Key parameters such as roof catchment area, runoff volume, and time of concentration were meticulously calculated. The findings indicate substantial potential for water collection, with estimated runoff volumes of 3214.20 m^3 for Phase I and 3854.25 m^3 for Phase II. The time of concentration for both phases supports the system's rapid collection capability. Factors such as roof material, rainfall intensity, roof slope, and runoff coefficient were identified as significant influencers of the RRWHS efficiency. The study also included the design of storage tanks with capacities aligned with the runoff estimates and the calculation of optimal transportation pipe diameters to ensure efficient water flow.To manage the collected data and system operations, a robust software solution was developed using ASP.NET with C# language and Microsoft Visual Studio Version 2022, with Microsoft SQL Server 2022 as the backend. This software ensures secure, accurate, and user-friendly data management, enhancing the overall functionality of the RRWHS.
The implementation of RRWHS at the CAET building demonstrates its viability as a sustainable water management practice. The integration of soft computing techniques facilitates precise design and efficient system management, promoting water conservation and reducing dependency on conventional water sources. Future research should focus on further optimizing the system design and integrating other sustainable practices to enhance water resource management.

Keywords: Rooftop rainwater harvesting system, sustainable water management, water conservation solutions, soft computing techniques, rainwater harvesting efficiency, sustainable water practices, water scarcity solutions, runoff volume calculation

Introduction
Water scarcity, particularly in urban and drought-prone areas, is a significant global challenge exacerbated by overpopulation, urbanization, pollution, and climate change. Rooftop rainwater harvesting (RRWH) systems offer a sustainable solution to augment water supply, mitigate water scarcity, and promote water conservation (Bhandari et al., 2023.). These systems have proven effective across various settings, including residential, commercial, and agricultural environments (Mishra et al., 2020; Zabidi et al., 2020) [6, 7]. Key factors influencing the design and efficiency of RRWH systems include rooftop area, rainfall patterns, water demand, and storage capacity.
Advanced software and web application technologies play a crucial role in improving the design and implementation of RRWH systems, providing user-friendly tools for accurate system planning (Dzhangarov et al., 2023) [15]. By leveraging these technologies, the paper aims to enhance the efficiency and accessibility of RRWH systems, contributing to sustainable water management practices. This research seeks to inform and guide decision-makers, planners, and practitioners in developing effective RRWH systems to address water scarcity and promote sustainability.

Objectives
To develop a computer-based program by using soft computing techniques for designing the roof water harvesting system for the CAET building.

Method
i) **Volume of Runoff:** Volume of Water Received (m^3) = Area of Catchment (m^2) × Amount of Rainfall (mm) × Runoff Coefficient.

ii) **Time of Concentration:**

$$Tc = 0.0195\,(L)^{0.77} \times (S)^{-0.385}$$

Where, Tc = Time of Concentration, hr, L = Length of Flow of Water, m S = Watershed Gradient, m/m

iii) **Rainfall Data Analysis:**

$$I = \frac{7.9932\,T^{0.1814}}{(t+1.0)^{0.811}}$$

Where,
I = Rainfall Intensity, cm/hr, T = Return Period, year, t = Duration, hr

IV. Rational Method:

Qp = CIA / 36

Where,
C = Runoff coefficient., I = Intensity of runoff, cm/hr, A= Area of Watershed, ha
Qp= Peak Rate of Runoff, m^3/s

V. the capacity of storage tank

Q = (n × q × t) + e

Where,
Q = Capacity , n = no of persons , q = consumption level per capita per day (lpcd)
t = number of days or dry period for which water is needed,
e = evaporation losses from storage, litres

VI. Cost Estimation: the benefit – cost ratio can be calculated:
Cost a: Includes:
A) interest of 10% on working capital
B) Depreciation cost of large items

Cost b: includes cost a + Interest of 10 % on fixed capital with principal value of item of that year
Cost c: includes cost b + supervision charges i.e. 10 % of cost a
Hence,
B.c ratio can be calculated using equation
B.c ratio = cross production cost / cost c

Specifications for the development of Software
Proposed system is developed on
Hardware description

Processor	: Intel core i5
RAM	: 6 GB
Hard disk drive	: 1 TB

Software description

Operating System	: Windows 8
Front- end	: C#. with asp. Net & Visual Studio 2022
Back- end	: MS SQL Server 2022 express and MS SQL Server Management Studio.

Specifications for the debugging of the Software
Proposed system will be Run/debug/used on
Hardware description

Processor	: Intel core i3 or more
RAM	: 4 GB or more
Hard disk drive	: 500 GB or more

Software description

Operating System	: Windows 8 or more
Software	: C# & Visual Studio 2022
Back- end	: MS SQL Server 2022 express and MS SQL management studio.

C# will be used as the programming language and Ms SQL server 2022 express for database.

Source Codes
i. Vol runoff:

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Data.SqlClient;
using System.Drawing;
using System.Linuq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;

namespace Roof_Water_Harv_2024
{
public partial class Volume_Runoff : Form
{
public Volume_Runoff()
{
InitializeComponent();
}

private void button1_Click(object sender, EventArgs e)
{
double volume_rnoff, m2, mm, run_coeffi;
m2 = double.Parse(catcharea.Text);
mm= double.Parse(amt_rainfall.Text);
run_coeffi = double.Parse(runoff_coeff.Text);
volume_rnoff=m2*mm*run_coeffi;

volume_wtr_rcd.Text=volume_rnoff.ToString();

}

private void button2_Click(object sender, EventArgs e)
{
double rnfl, rnfl1;
rnfl=double.Parse(amt_rainfall.Text);
rnfl1 = rnfl * 0.001;
```

```
amt_rainfall.Text=rnfl1.ToString();
}

private void button3_Click(object sender, EventArgs e)
{
//Address of SQL Server and Database
string connectionstring = "Data Source=SAHIL\\SQLEXPRESS;Initial Catalog=Rooftop_project;Integrated Security=True"; //Trust Server Certificate=True";

// Establish Connection
SqlConnection conn = new SqlConnection(connectionstring);

// Open Connection
conn.Open();

// Prepare Query
string query = "INSERT INTO volume_of_runoff (catchment_area, Rainfall_Amount, Runoff_Coefficient, Volume_Water_Received) VALUES ('" + catcharea.Text + "','" + amt_rainfall.Text + "','" + runoff_coeff.Text + "','"+ volume_wtr_rcd.Text + "')";

// Execute Query
SqlCommand cmd = new SqlCommand(query, conn);
cmd.ExecuteNonQuery();

// Close Connection

conn.Close();
MessageBox.Show("Data Saved Successfully");
}
}
}
```

ii. Time of concentration

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Data.SqlClient;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;

namespace Roof_Water_Harv_2024
{
 public partial class Time_of_Concentration : Form
{
public Time_of_Concentration()
{
InitializeComponent();
}

private void button1_Click(object sender, EventArgs e)
{
Double l, s, Tc;
// Double lp, sp;
l = Double.Parse(length.Text);
s= Double.Parse(gradient.Text);
// lp = Math.Pow(l, 0.77);
// sp = Math.Pow(s, 0.385);

Tc = l / s;
time.Text = Tc.ToString();

}

private void button2_Click(object sender, EventArgs e)
{
//Address of SQL Server and Database
string connectionstring = "Data Source=SAHIL\\SQLEXPRESS;Initial Catalog=Rooftop_project;Integrated Security=True"; //Trust Server Certificate=True";

// Establish Connection
SqlConnection conn = new SqlConnection(connectionstring);

// Open Connection
conn.Open();

// Prepare Query
string query = "INSERT INTO Time_of_Concentration_tb (Length_Flow_of_Water, Watershed_Gradient, Time_of_Concentration) VALUES ('" + length.Text + "','" + gradient.Text + "','" + time.Text + "')";

// Execute Query
SqlCommand cmd = new SqlCommand(query, conn);
cmd.ExecuteNonQuery();

// Close Connection

conn.Close();
MessageBox.Show("Data Saved Successfully");
}
}
}
```

iii. Rational Methods

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;
using System.Data.SqlClient;

namespace Roof_Water_Harv_2024
{
public partial class rational : Form
{
public rational()
{
InitializeComponent();
}

private void button1_Click(object sender, EventArgs e)
{
```

```
float c, i, a, qp;
c = float.Parse(peak_rate.Text);
i = float.Parse(intensity.Text);
a = float.Parse(area_watershed.Text);
qp = c * i * a;
float qp2 = qp / 36;
qp_txt.Text = qp2.ToString();
}

private void button2_Click(object sender, EventArgs e)
{
//Address of SQL Server and Database
string connectionstring = "Data Source=SAHIL\\SQLEXPRESS;Initial Catalog=Rooftop_project;Integrated Security=True"; //Trust Server Certificate=True";

// Establish Connection
SqlConnection conn = new SqlConnection (connection string);

// Open Connection
conn.Open();

// Prepare Query
string query="INSERT INTO Peakrunoff (PeakRunoff, Intensity, AreaofWaterShed, QP) VALUES ('"+ peak_rate.Text + "','"+ intensity.Text + "','"+ area_watershed.Text + "','"+qp_txt.Text+"')";

// Execute Query
SqlCommand cmd = new SqlCommand(query,conn);
cmd.ExecuteNonQuery();

// Close Connection

conn.Close();
MessageBox.Show("Data Saved Successfully");
}
}
}
```

Results and Discussions

Fig 1: Home page of rooftop harvesting software.

Above figure no 1. shows the homepage of rooftop rainwater harvesting software. It is developed using visual studio 2022 by c# language. It includes various menu options such as volume of runoff, time of concentration, rainfall data analysis, capacity of storage tank and cost estimation page etc.

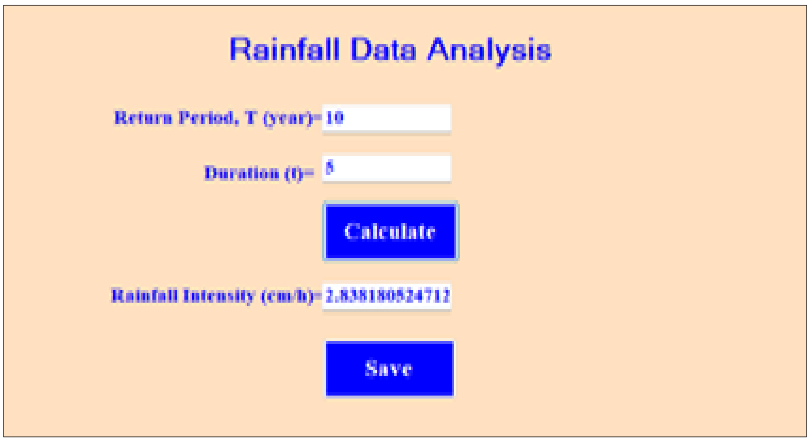
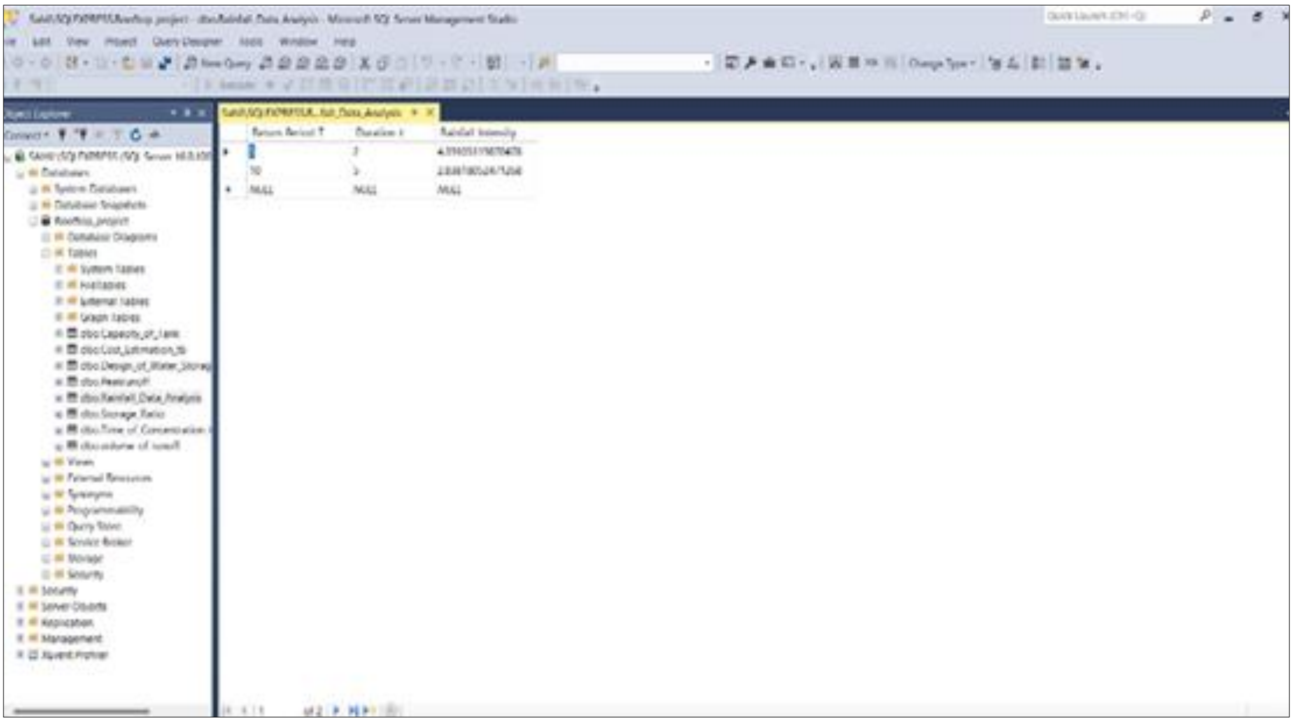


Fig 2: Home page of rainfall data analysis option.

Above figure no. 2. shows the home page of rainfall data analysis option. It is developed using visual studio 2022 by c# programming language. It helps to do accurate calculations. Necessary information required to use this option are return period (T) in years and duration (t) in hours.



Above figure no. 3 shows the data stored of rainfall data analysis in SQL server. Ms sql 2022 is used to store and manage this data. All the calculation we do is saved successfully in the ms sql 2022. We successfully created the database as “Rooftop_project” and created the tables for all the formulaes.

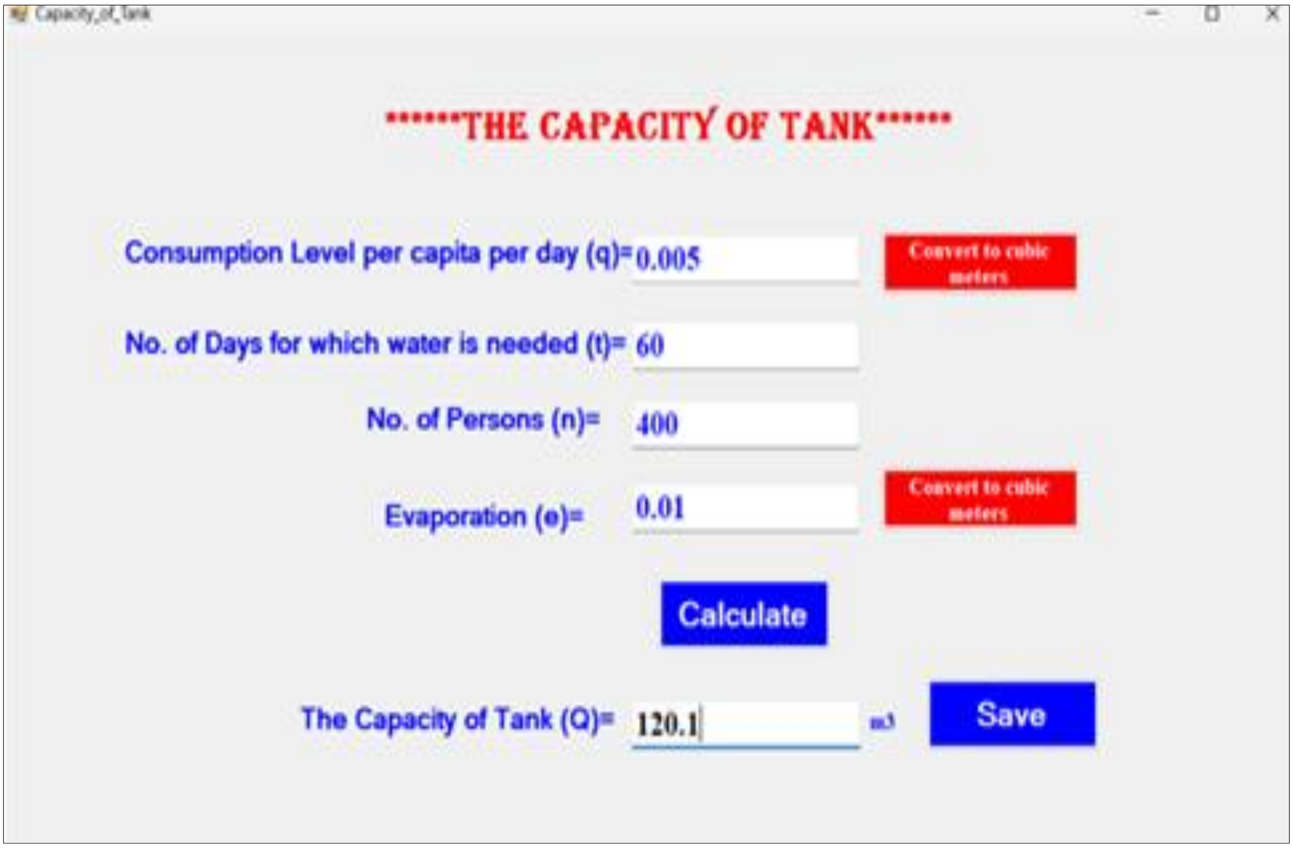


Fig 4: Homepage of the capacity of storage tank option.

Above figure shows the homepage of the capacity of storage tank option, it is developed using visual studio 2022. We have used double data type for the formulae. It contains all types of data (e.g. float, int, double etc.). It helps to do accurate calculations.

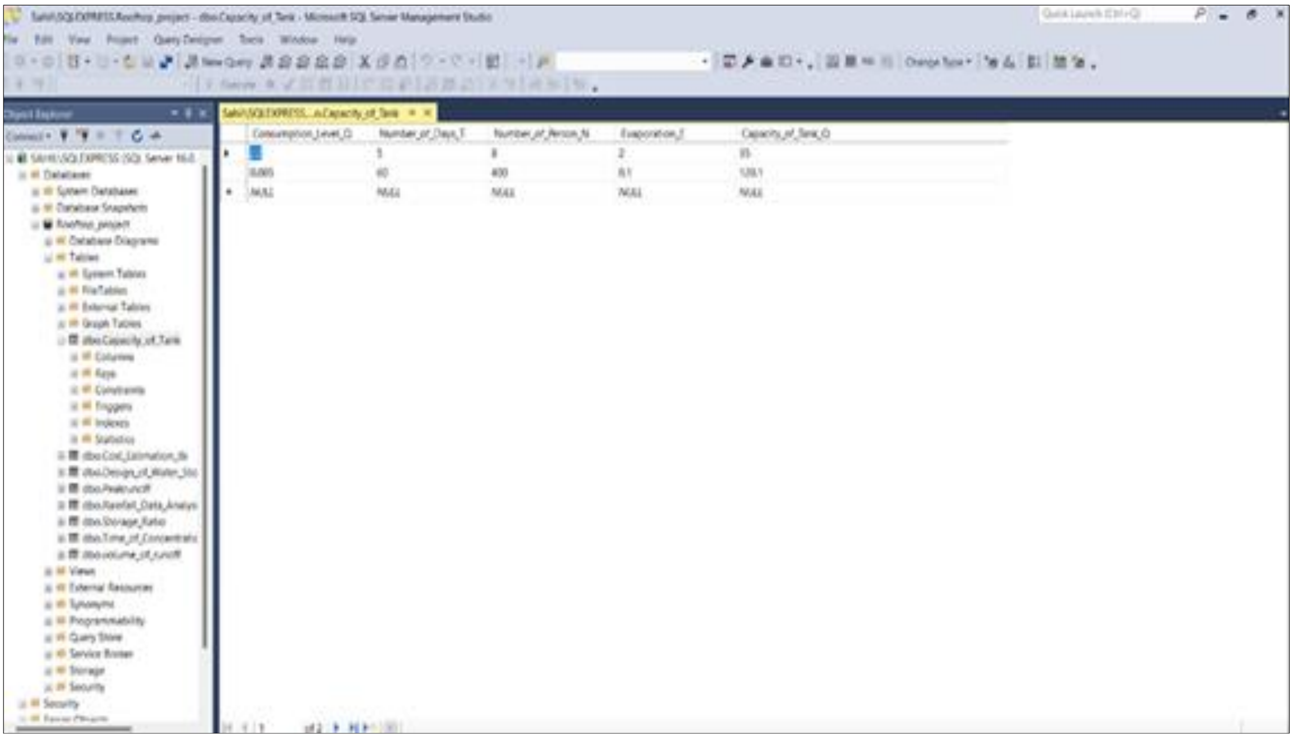


Fig 5: Data stored of capacity of storage tank in SQL server.

Above figure no 5 shows the data stored of capacity of storage tank in SQL server. Ms sql 2022 is used to store and manage this data. All the calculation we do is saved successfully in the ms sql 2022. We successfully created the database as “Rooftop_project” and created the tables for all the formulaes.

Conclusion

- RRWHS at CAET, Dapoli, effectively mitigates water scarcity.
- Study highlights RRWHS's high runoff volumes and efficient water collection.
- Proper design and maintenance promote sustainable water management and conservation.
- ASP.NET software with C# and Microsoft SQL Server 2022 enhances system efficiency and reliability.
- Future research should optimize design and integrate other sustainable practices

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