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Impact of Temperature Variation & Temperature Duration on Soil Erosion Using Erosion Simulator

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ABSTRACT
In soil erosion, the RUSLE method is well known to calculate soil erosion worldwide, but in this research, the author proved that the given RUSLE is not sufficient to define the erosion. The two new factors i.e., temperature variation and duration of temperature applied on the surface also affect the soil erosion. Guru Shikhar region is chosen as the study area. In the beginning of the thesis, physio-chemical analysis of soil is carried out and it shows that in this region two types of soils i.e., sandy clay loam and clay loam are available. Granite rock is also found in this region. In this paper, the author proves that temperature variation and temperature duration factors in different climates also affect erosion along with the existing RUSLE factors. RUSLE doesn't depend on temperature variation (T factor) and temperature duration (D Factor), but the experiments done using erosion simulators shows that their erosion is different from RUSLE and depends on temperature variation and temperature duration too. Finally, T and D factors equations are derived for clay loam (CL) and sandy clay loam (SCL).
Keywords: *RUSLE, Temperature variation, Temperature Duration, Clay Loam (CL), Sandy Clay Loam (SCL).*

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INTRODUCTION

Soil erosion became an alarming environmental problem in Rajasthan, India. The Major areas under various climatic conditions suffer from these pedological hazards in the Region [1-3]. A few studies have been done on soil erosion. About semi-arid conditions in the Sirohi region and other countries of the world of the ecosystem. So, fill this gap and develop a model of soil erosion loss estimation and its association with the resulting land use pattern. They used USLE (Universal Soil Loss Equation) / RUSLE (Revised Universal Soil Loss Equation) for estimation of soil erosion. There are five factors in the equation such as rainfall-runoff erosivity, soil erodibility, slope length - slope steepness, cover management, & conservation support practices factor [4, 5]. But they did not work on Temperature variation (T) & Temperature Duration (D) factors in different climates. The region thus, the topic problem of soil erosion and strategy for combating it: A case study of the Guru Shikhar in sirohi (Rajasthan) has been selected. Although the Indian departments have not provided necessary data, particularly on soil erosion, by time-to-time duration, an attempt has been made to use limited data to fill the gap by constant values observed. Scientists estimated similar conditions in the sirohi region. Remote Sensing and The GIS are important for soil erosion modelling in the area. Remote Sensing can have many facilitated surveys in the factors enhancing soil erosion. The process such as the soil type, slope length, slope gradient and drainage, geology, and land cover in the Gurushikhar region[16][7-9]. The multiple digital satellite images give valuable information related to seasonal land use in Guru Shikhar [12, 8]. The Satellite data can be utilised for analogies erosion features such as soil interception by vegetation and vegetation cover factor in the Guru Shikhar region [17][5]. The digital elevation model impact and the triangle irregular network are used to find the slope, the slope of the length, the slope of steepness, and the aspect by GIS concept [12]. Interpolate the data of unknown places using known sample data, the prediction of soil erosion, and create a soil erosion map in the Guru Shikhar region in Sirohi (Bhargava, Bhargava, Tanwar, & Narooka, 2016). In the past decades' various researchers worked on the USLE/RUSLE model of soil erosion. They explained various existing USLE/RUSLE factors measures such as erosivity, erodibility, slope steepness, cover management, & control practices up to 2022. Maurya *et al.* [10] reviewed past decades USLE and RUSLE model research for various landforms erosion. They bifurcated the soil erosion research according to major landforms like Plain, Hill, Mountain, Plateau, and Miscellaneous then sub-classified according to model factor's equation [10]. Almouctar *et al.*,[2] Tiruwa *et al.,* [15] Khanchoul *et al.,* [7] & Allafta *et al.* [1] worked on soil erosion estimation of different locations & land forms using RUSLE model with RS & GIS environment. They also predicted the spatial variability of soil loss [1, 7, 14, 5, 1]. Almouctar *et al.* [2] obtained that central & west-southern areas of Maradi zone of south-central Niger are mostly eroded. It's varying from 237.1 to 944.9 t/ac/year. Concluded that high slope gradient & intermediate forest regions are high & severely eroded. Spatial erosion information is useful for deriving land planning and management strategies (Almouctar, Wu, Zhao, & Dossou, 2021). Tiruwa *et al.* [15] saw that highest erosion occurred in hilly forests and lowest erosion occurred in grasslands of Siwalik Hills of Nawalparasi, Nepal. Concluded that hilly forests are high to very severely eroded because of steepness of hills, open forest categories, minimum use of conservation practices. Spatial erosion information is useful for water & soil resource planning and management [15]. Khanchoul K. *et al.* [7] saw that 52 % area of the Chemorah basin covers low erosion and approx. 23 % covers high to very high erosion. Concluded that the greatest risk of soil erosion occurred in the Reboa catchment as compared to Soultez catchment with contributions of 44 % and 32 % of their basin areas respectively [7]. Allafta *et al.* [1] obtained that 16 % extremely high-class soil loss occurred in Shatt Al-Arab basin, Iran and very high, high, medium, & low soil loss class occurred 4, 13, 7, and 60 % respectively. Concluded that heavy rainfall, soil type, steepness of terrains, & intensive farming is associated with high soil loss rates [1]. Maqsoom *et al.* & Getu *et al.* [5] worked on evaluation of soil erosion & created severity map using RUSLE model with RS & GIS tool [9]. Getu *et al.* [5] obtained that low erosion class cover 6.5% in Megech watershed, Ethiopia and moderate, high, very high, severe, very severe, and extremely severe erosion classes covers 11.1%, 8.7%, 22%, 30.9%, 13.4%, and 7.4%, respectively. Severity map classified in seven severity classes. Low class is below 10 ton/ha/yr and moderate, high, very high, severe, very severe, and extremely severe are 10-20, 20-30, 35-40, 40-45, above 45 ton/ha/yr respectively. Concluded that approx. 82% of study area in more than high risk categories of erosion and the northern, north western, and south eastern parts faces more serious soil erosion because of land use, topography, poor conservation, intensive rainfall, free grazing, & human activities [5]. Maqsoom *et al.* saw that Chitral district of Pakistan is highly prone and severely affected by soil erosion, mostly southwestern part of the study region. The very high severity soil erosion class is 8% and other high, moderate, low, & very low are 16, 21, 12, & 13% respectively. Concluded that topography & soil type are major causes of soil erosion in the study area [9]. But the above researcher didn't work on temperature variation (T) temperature duration (D) factors. Soil erosion depends on temperature variation and temperature duration in different climates on the Guru Shikhar. Main objective of this research is evaluating the role of the missing parameters temperature variation and temperature duration on soil erosion in the Guru Shikhar region.

MATERIAL AND METHODS

There are following methodology steps used in the study.
(i) Sample of soils has been collected by stratified random sampling method in Guru Shikhar region.
(ii) Evaluated the texture of soil samples by Bottle test with Textural Triangle method.
(iii) Established the erosion simulator setup, it consists of three major parts
(a) Water supply system
(b) Artificial land surface
(c) Temperature simulator
(iv) Collected huge amounts of soil type from study area for erosion simulator experiment on various parameter basis.
(v) Due to the help of a simulator, we evaluated the role of Temperature variation & Temperature duration on soil & implemented the new factors Temperature variation (T) & Temperature duration (D) equations.

IMPLEMENTATION

Data Collection:

Soil samples are collected from the study area Gurushikhar, Sirohi(Rajasthan) to study the impact of temperature variation and temperature duration on the soil erosion. Eighty-one soil samples from various locations of Guru Shikhar region are collected. In soil belongs to Achalgadh, Akhi, Block No. 2, Boki Derli, Burari Khera, Gurushikhar, Jawai, Oriya, Oriya jheel, Ratan villas, Shergaon, Shergaon path, Udwariya, Uttaraj, Uttaraj Path, WildLife Sanctuary [10].

Soil Test Experiment:

A) Bottle Test with Textural Triangle Method

Bottle test with textural triangle method was used to analyse the soil samples texture. According to this test in the study area it has been observed that these samples have either clay loam or sandy clay loam soil.

B) Simulation of erosion:

Experimental Setup

Erosion simulation setup is established as shown in fig. 1. This system can be divided into three parts. First part contains a water supply system for artificial rainfall, the second part is an artificial land surface that contains compressed soil collected from various sites. and the third part contains the temperature simulator that is used to provide temperature on the soil surface.

a) Water Supply System
b) Artificial Land Surface
c) Temperature Simulator

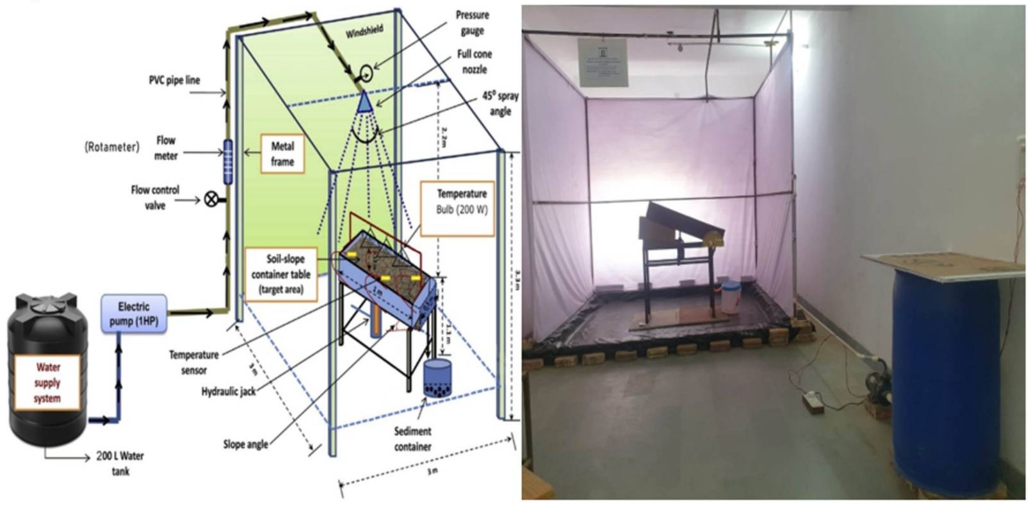


Fig. 1: Soil Erosion Simulator [11]

(a) Water Supply System

Water supply system is used to provide artificial rainfall on the artificial land surface. Water supply system contains 200 ltr water tank, 1 inch PVC pipe, spray nozzle having 2.2 mm diameter size hole with 45-degree spray angle, 1HP electric pump, rotameter and water pressure gauge as shown in fig. 1 and fig. 2. A supporting metal frame is used to support and fix the water flow system. Water flow starts from the water tank using 1 HP electric pump through the PVC pipe towards the nozzle attached at the end point. Nozzle is fixed in such a way that the rain falls on the artificial land surface. Flow control valve and flow meter is fixed in between the electric pump and nozzle to control the flow of water [9, 11].

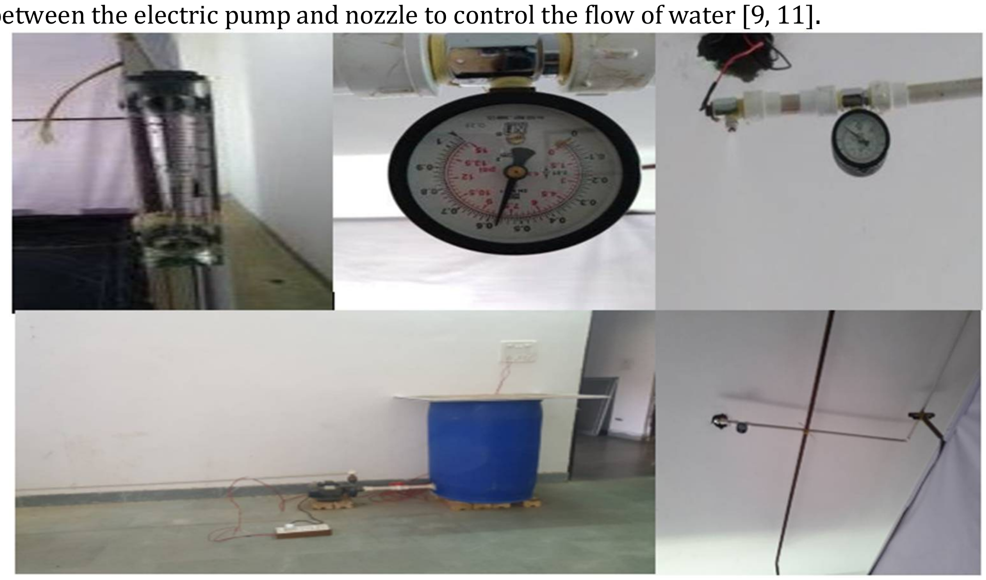


Fig. 2: Parts of Water Supply System in Soil Erosion Simulator (Maurya, 2022)

b) Artificial Land Surface

Artificial land surface is created by using a tabular surface, hydraulic jack, soil container, and runoff container bucket as shown in fig. 1 and fig.3. Artificial land area is 0.5-meter square. Soil container has two sections in it, the first section of the soil container is used to fill the compressed soil and the second section of container is used to collect the soil runoff after erosion. A hydraulic jack is adjusted below the soil container and under the table to move the surface from 0 to 40 degree angle to provide the real slope effect on the surface. In this system a protector is fixed along with the table to measure the slope of the surface. Runoff and sediment outlet given in the second section of the soil container, is connected with the bucket that is used to collect the soil runoff [10, 12].

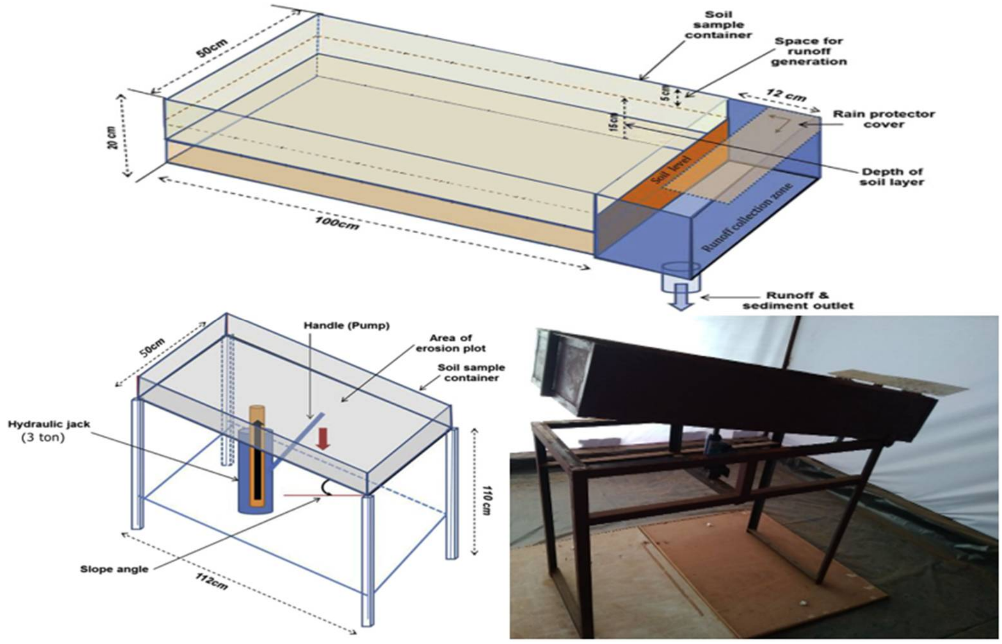


Fig. 3: Artificial land surface for soil erosion [10]

c) Temperature simulator

Temperature simulator is used to apply temperature on the artificial land surface before rainfall to study the effect of temperature variation and temperature duration. When temperature is applied on the surface it will give sunlight effect on the surface. This system has 3 bulbs of 200W, polystyrene sheet, Automatic temperature control system with 4 temperature sensors as shown in fig. 1 and fig. 4. The temperature sensor maintains the required temperature in the experiment. Polystyrene sheet is used around the experimental setup to control the dispersion of the temperature. The range of temperature controlled by the sensors is between 20 to 40 degrees. Silver foil is wrapped on the upper side of bulbs to reflect the temperature towards the artificial land surface [8, 10].

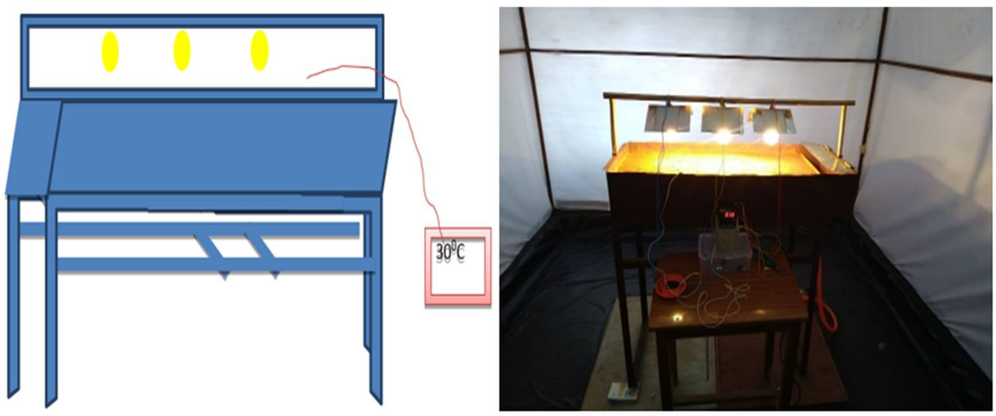


Fig. 4: Temperature Simulator [10]

RAINFALL CHARACTERISTICS

Rainfall has two characteristics i.e., rainfall uniformity and rainfall intensity.

a) Rainfall uniformity

To maintain the rainfall uniformity on the artificial land surface, a spray nozzle is adjusted over the centre of the surface and five petri dishes are used on the artificial land surface to check the uniformity of rainfall as shown in fig. 5. The diameter of these petri dishes is 10 cm. One petri dish is arranged at the centre and the other four are arranged at all the corners of the container.

Artificial rainfall is applied for a few minutes to estimate the rainfall uniformity. After rainfall the water collected in the petri dishes is measured separately for each petri dish. Rainfall uniformity is measured by using the Christiansen coefficient (Cu) equation given below [9, 13].

The coefficient of uniformity Cu = 1 - $\frac{\sum_{i=1}^{n} Ri \ - M}{n\, M}$

Where,

R_i : Water collected in each petri dish,

M : The mean of water collected in all five petri dishes,

n : The number of dishes.

The Cu value more than 80% is considered as similar rainfall uniformity.

Fig. 5: Petri Dish with Experiment Plot (Target Area) [10]

b) Rainfall Intensity

Rainfall intensity depends on the spray nozzle. Non Recording rain gauge instruments are used to measure the intensities of artificial rainfall. Artificial rainfall is applied again on the experimental setup but this time the rain gauge is placed instead of petri dishes. Water collected in the rain gauge is measured after the rainfall at five different places. Average rainfall intensity is measured by calculating the average of these five readings [9, 10].

Fig. 6: Non Recording Rain Gauge Instrument (Maurya, 2022)

Erosion Simulator Process

Soil container is created as an artificial land surface (Plot) for the experiment. Firstly, all grain sizes of soil with water are mixed in the container and compacted by a hammer. After compaction, leave the soil chamber to dry for 2 days. Prepared the upper soil layer like a normal hard earth surface.

A specific temperature is applied on the soil sample containers (experimental plot) using an automatic temperature simulator for various average temperatures (20, 25, 30, 35, and 40 degree celsius). These temperatures are applied for various durations (24, 48, 72, 96, 120, and 144 hr.) on the artificial land surface (Plot). Hydraulic jack is used to lift the soil sample container (experimental plot) to attain the desired slope angle (5, 10, 15, 20, 30, and 40 degrees) [10].

Artificial rain on soil sample container (experimental plot) is carried out for 30-minutes using a rainfall simulator. During rainfall soil sample surface runoff is collected in the closed bucket that is attached to the upper second part of the container. After 24 hours' sediment soil is transferred to the glass beaker from the bucket for accurate measurement of soil surface runoff. The above experiment is repeated separately for all samples of sandy clay loam and clay loam soil, which were collected from the Gurushikhar region. Various experiments are carried out by changing one of the parameters, and fixing all the other parameters. The experiments with i) varying average temperature and constant duration, slope, and soil type ii) varying duration applied for the same temperature and constant average temperature, slope, and soil type. These experiments are repeated for both types of soil, sandy clay loam and clay loam for surface runoff (erosion) on the experiment plot. Various experiments for various soil types are accomplished separately with various temperatures (20, 25, 30, 35, and 40 degree celsius) at that time, temperature durations and desired slope angle are constant. Experiment for temperature durations, i.e., the duration on which constant temperature is applied on the surface (24, 48, 72, 96, 120, and 144 hr.) with constant temperature and slope angle. In all the above two types of experiments pressure (5 psi), flow rate (1.9 l/min), rain intensity (94 mm/h), & rain duration (30 min) are constants [11].

Fig. 7: Erosion Simulator Process [10]

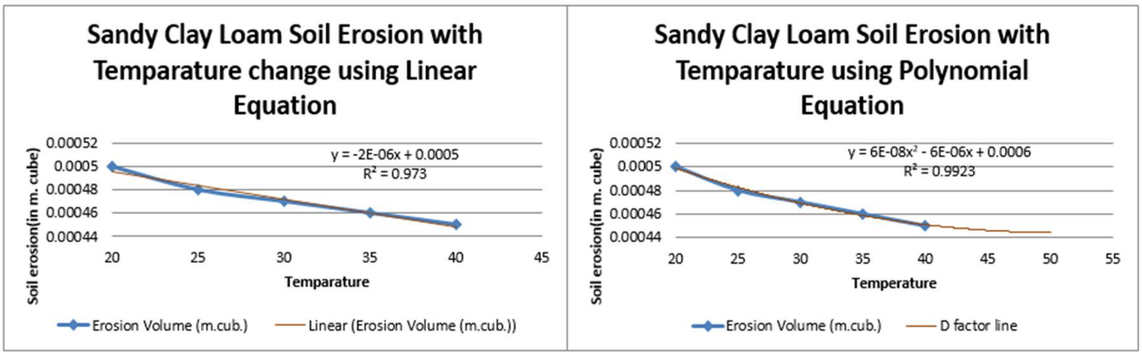
Varying Temperature Experiment:

i) Sandy Clay Loam

Table 1 shows varying temperature applied on sandy clay loam soil in soil erosion simulator where soil sample volume, open surface area, temperature duration, and slope angle are fixed. Volume of soil erosion is measured and noted down in the table.

Table 1: Sandy Clay Loam Soil Erosion Simulation with Varying Temperature (Other Parameters are Constant)

Sr No.	Soil Texture	Soil sample volume (m.cub.)	Open Surface (m.sq.)	Avg. Temperature	Temperature Duration	Slope Angle	Erosion Volume (m.cub.)
1	SCL	0.075	0.5	20	24 hr	5	0.0005
2	SCL	0.075	0.5	25	24 hr	5	0.00048
3	SCL	0.075	0.5	30	24 hr	5	0.00047
4	SCL	0.075	0.5	35	24 hr	5	0.00046
5	SCL	0.075	0.5	40	24 hr	5	0.00045



(a) **(b)**

Fig. 8: Sandy Clay Loam Soil Erosion with Varying Temperature using a) Linear Equation b) Polynomial Equation

The graph between temperature applied on the soil and soil erosion (in m^3) is shown in fig. 8. It shows that soil erosion decreases as we increase the temperature on the soil. Soil erosion is inversely proportional to temperature applied before rainfall for a fixed duration. Squared R is 0.973 in fig. 8(a) shows that the curve fits well in this equation.

Soil erosion of sandy clay loam $= -2 \times 10^{-6}T + 0.0005$ (1)

Where, T is temperature

If the curve is fitted using polynomial equation as given in fig. 8(b) then the equation becomes

Soil erosion of sandy clay loam $= 6.0 \times 10^{-8}T^2 - 6 \times 10^{-6}T + 0.0006$ (2)

Where, T is temperature

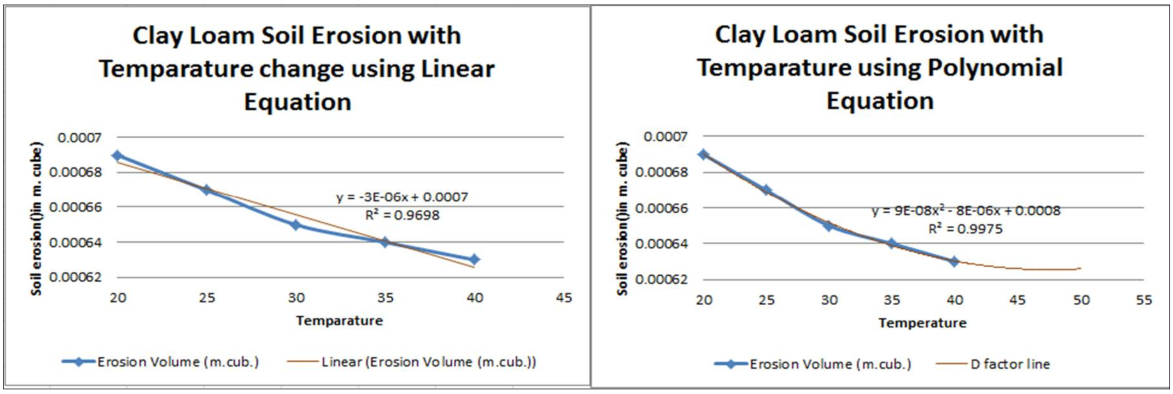
Eq. 2 is more suitable for this curve as squared R is 0.993 (R^2=0.9923 approx. 1) for the polynomial equation is closer to 1 than squared R of the linear equation (R^2=0.973) as given in eq.1.

.ii) Clay Loam

Table 2 shows varying temperature applied on clay loam soil in soil erosion simulator where soil sample volume, open surface area, temperature duration, and slope angle are fixed. Volume of soil erosion is measured and noted down in the table.

Table 2: Clay Loam Soil Erosion Simulation with Varying Temperature (Other Parameters are Constant)

Sr No.	Soil Texture	Soil sample volume (m.cub.)	Open Surface (m.sq.)	Avg. Temperature	Temperature Duration	Slope Angle	Erosion Volume (m.cub.)
1	CL	0.075	0.5	20	24 hr	5	0.00069
2	CL	0.075	0.5	25	24 hr	5	0.00067
3	CL	0.075	0.5	30	24 hr	5	0.00065
4	CL	0.075	0.5	35	24 hr	5	0.00064
5	CL	0.075	0.5	40	24 hr	5	0.00063



(a) (b)

Fig. 9: Clay Loam Soil Erosion with Varying Temperature using a) Linear Equation b) Polynomial Equation

The graph between temperature applied on the soil and soil erosion (in m^3) is shown in fig. 9. It shows that soil erosion decreases as we increase the temperature on the soil. Soil erosion is inversely proportional to temperature applied before rainfall for a fixed duration. Squared R is 0.9698 in fig. 9(a) shows that the curve doesn't fit well in this linear equation. Linear equation for clay loam is following

$$\text{Soil erosion of clay loam} = -3 \times 10^{-6}\text{T} + 0.0007 \qquad (3)$$

Where, T is temperature

If the curve is fitted using polynomial equation as given in fig. 9(b) then the equation becomes

$$\text{Soil erosion of clay loam} = 9.0 \times 10^{-8}\text{T}^2 - 8 \times 10^{-6}\text{T} + 0.0008 \qquad (4)$$

Where, T is temperature

Eq. 4 is more suitable for this curve as squared R is 0.9975 (R^2=0.9975 approx. 1) for polynomial equation is closer to 1 than squared R of the linear equation (R^2=0.9698) as given in eq. 3.

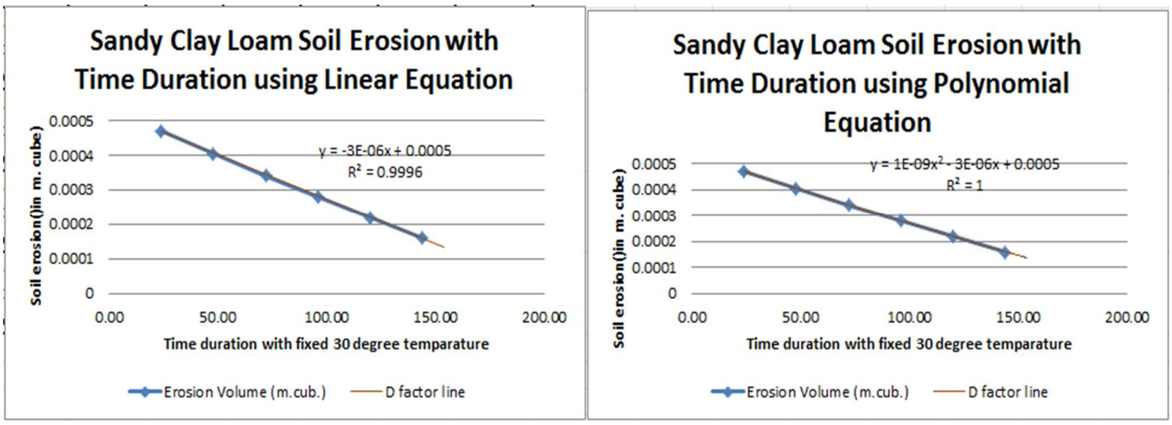
Varying Duration Experiment:

i) Sandy Clay Loam

Varying time duration with fixed temperature applied on sandy clay loam soil in soil erosion simulator where soil sample volume, open surface area, temperature, and slope angle are fixed. Volume of soil erosion is measured and noted down in table 3.

Table 3: Sandy Clay Loam Soil Erosion Simulation with Varying Duration for Same Temperature (Other Parameters are Constant)

Sr. No.	Soil Texture	Soil sample volume (m.cub.)	Open Surface (m.sq.)	Avg. Temperature	Temperature Duration	Slope Angle	Erosion Volume (m.cub.)
1	SCL	0.075	0.5	30	24 hr	5	0.00047
2	SCL	0.075	0.5	30	48 hr	5	0.000405
3	SCL	0.075	0.5	30	72 hr	5	0.00034
4	SCL	0.075	0.5	30	96 hr	5	0.00028
5	SCL	0.075	0.5	30	120 hr	5	0.00022
6	SCL	0.075	0.5	30	144 hr	5	0.00016



(a) (b)

Fig. 10: Sandy Clay Loam Soil Erosion with Time Duration of Temperature using a) Linear Equation b) Polynomial Equation

The graph between the duration on which a fixed temperature is applied on the soil and soil erosion (in m^3) is shown in fig.10. It shows that soil erosion decreases as we increase the duration of the temperature on the soil. Soil erosion is inversely proportional to the duration. According to linear curve fitting, squared R is 0.9996 in fig. 10(a) shows that curve fits well in this equation.

Soil erosion of sandy clay loam $= -3 \times 10^{-6}\mathrm{D} + 0.0005$ (5)

Where, D is temperature duration

If the curve is fitted using polynomial equation as given in fig. 10(b) then the equation becomes

Soil erosion of sandy clay loam $= 1.0 \times 10^{-9}\mathrm{D}^2 - 3 \times 10^{-6}\mathrm{D} + 0.0005$ (6)

Where, D is temperature duration

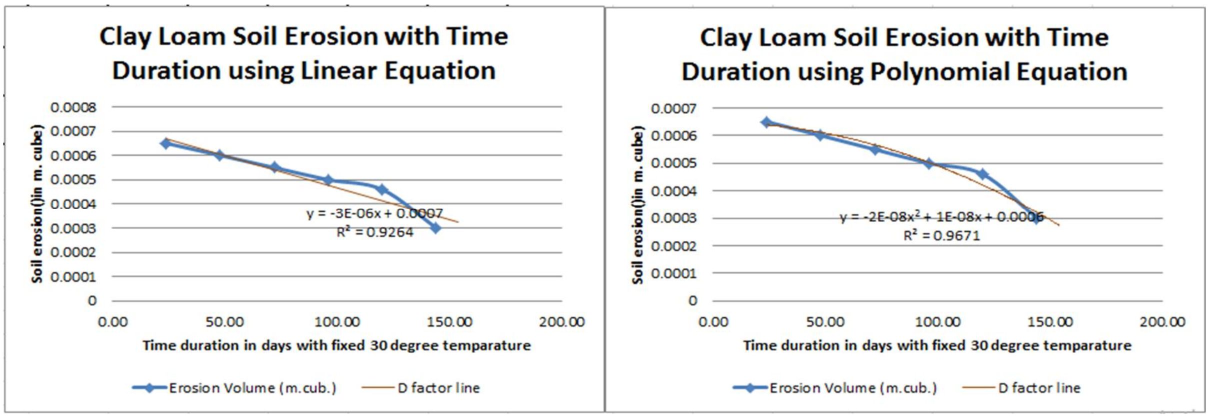
Eq. 6 is more suitable for this curve as squared R is 1 in this case in comparison to the linear equation discussed in eq. 5. Polynomial equation 6 is more suitable for this curve as squared R is 1, it shows that it completely fits the curve, that is not the case in the linear equation, where squared R is less than 1(R^2=.9996) as given in eq. 5.

ii) Clay Loam

Varying time duration with fixed temperature applied on clay loam soil in soil erosion simulator where soil sample volume, open surface area, temperature, and slope angle are fixed. Volume of soil erosion is measured and noted down in table 4.

Table 4: Clay Loam Soil Erosion Simulation with Varying Duration for Same Temperature (Other Parameters are Constant)

Sr. No.	Soil Texture	Soil sample volume (m.cub.)	Open Surface (m.sq.)	Avg. Temperature	Temperature Duration (hr.)	Slope Angle	Erosion Volume (m.cub.)
1	CL	0.075	0.5	30	24	5	0.00065
2	CL	0.075	0.5	30	48	5	0.0006
3	CL	0.075	0.5	30	72	5	0.00055
4	CL	0.075	0.5	30	96	5	0.0005
5	CL	0.075	0.5	30	120	5	0.00046
6	CL	0.075	0.5	30	144	5	0.0003



(a) (b)

Fig. 11: Clay Loam Soil Erosion with Time Duration of Temperature using a) Linear Equation b) Polynomial Equation

The graph between the temperature duration on which a fixed temperature is applied on the soil and soil erosion (in m^3) is shown in fig. 11. It shows that soil erosion decreases as we increase the duration of the temperature on the soil. Soil erosion is inversely proportional to the temperature duration. According to linear curve fitting, squared R is 0.9264 in fig. 11(a) shows that curve fits well in this equation with some exceptions.

$$\text{Soil erosion of clay loam} = -3 \times 10^{-6}\text{D} + 0.0007 \qquad (7)$$

Where, D is temperature duration

If the curve is fitted using polynomial equation as given in Fig. 11(b) then the equation becomes

$$\text{Soil erosion of clay loam} = -2.0 \times 10^{-8}\text{D}^2 - 1 \times 10^{-8}\text{D} + 0.0006 \qquad (8)$$

Where, D is temperature duration

Eq. 8 is more suitable for this curve as squared R is 0.9671 in this case in comparison to the linear equation discussed in eq. 7. Polynomial equation 8 is more suitable for this curve as squared R is 0.9671, it shows that it fits the curve well, in comparison to the linear equation(R^2=0.9264) as given in eq. 7.

RESULT AND DISCUSSION

Results of Temperature and Temperature Duration parameters are below.

(i) Temperature Factor:

As RUSLE doesn't depend on temperature, this will be the same for the samples having the same R, slope, slope length, K, P, and C. So, the value for such a sample will give the same results according to RUSLE. But the results in the experiments show that it is different and depends on temperature too.

(a) Sandy Clay Loam

As per experiment done in the implementation section for varying avg. temperature experiment, it is required to find the T factor for sandy clay loam soil erosion. Experiment done on sandy clay loam soil erosion due to varying average temperature (T) with constant volume = 0.75 m^3, open surface area = 0.5 m^2, temperature duration = 24 hrs, Slope = 5 degree using temperature soil erosion simulator show that erosion is dependent on varying temperature (see table 1). Erosion is converted to kg m^3 hr^{-1}.

According to RUSLE for slope =5 deg., R=0.001072386, LS=0.78, K=0.226, P=1, & C=0.1

RUSLE Erosion = $1.86874396 \times 10^{-9}$ kg m^3 hr^{-1}

Table 5: Temperature Factor Evaluation for the Experiment of Same Samples of Sandy Clay Loam Soil

Sr. No.	Avg. Temperature	Experiment Erosion W*V*hr^{-1}(kg m^3 hr^{-1})	RUSLE Erosion (kg m^3 hr^{-1})	Difference (Exp-RUSLE)
1	20	4.25E-10	1.86874E-09	-1.44374E-09
2	25	3.9168E-10	1.86874E-09	-1.47706E-09
3	30	3.7553E-10	1.86874E-09	-1.49321E-09
4	35	3.5972E-10	1.86874E-09	-1.50902E-09
5	40	3.4425E-10	1.86874E-09	-1.52449E-09

As temperature is not part of RUSLE, it will give the same soil erosion, but the difference of experiment and RUSLE equation is due to impact of temperature. So, the difference is due to the T factor. This experiment shows that the hypothesis assumed is true that erosion is dependent on temperature.
Plot the graph between temperature and difference of soil erosion from experiment and RUSLE (as shown in fig. 12).

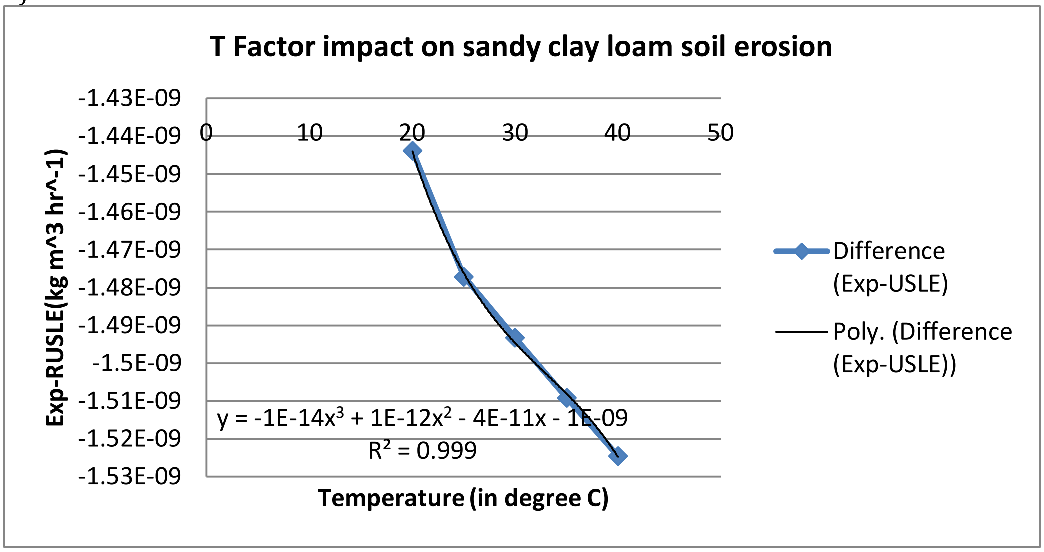


Fig. 12: T Factor Impact on Sandy Clay Loam Soil Erosion

Resulting equation for the T factor of the curve-by-curve fitting method for sandy clay loam soil is given as follows.

$$\text{T factor for SCL} = -10^{-14}\text{temp}^3 + 10^{-12}\text{temp}^2 - 4 \times 10^{-11}\text{temp} - 10^{-9}$$

R^2 =0.999 for this curve shows that it perfectly fits on the curve so this equation is perfect for sandy clay loam.

(b) Clay loam

As per experiment done in the implementation section for varying temperature experiment, it is required to find the T factor for clay loam soil erosion. Experiment done on clay loam soil erosion due to varying average temperature (T) with constant volume = 0.75 m^3, open surface area = 0.5 m^2, temperature duration = 24 hrs, slope = 5 degree using temperature soil erosion simulator show that erosion is dependent on changing temperature (see table 2). Erosion is converted to kg m^3 hr^{-1}.
According to RUSLE for slope =5 deg., R=0.001072386, LS=0.78, K=0.2911, P=1 and C=0.1
RUSLE Erosion $= 2.04431 \times 10^{-9}$ kg $m^3 hr^{-1}$

Table 6: Temperature Factor Evaluation for the Experiment of Same Samples of Clay Loam Soil

Sr. No.	Avg. Temperature	Experiment Erosion W*V*hr⁻¹(kg m³ hr⁻¹)	RUSLE Erosion (kg m³ hr⁻¹)	Difference (Exp-RUSLE)
1	20	7.6176E-10	2.04431E-09	-1.28255E-09
2	25	7.1824E-10	2.04431E-09	-1.32607E-09
3	30	6.76E-10	2.04431E-09	-1.36831E-09
4	35	6.5536E-10	2.04431E-09	-1.38895E-09
5	40	6.3504E-10	2.04431E-09	-1.40927E-09

As temperature is not part of RUSLE, it will give the same clay loam soil erosion, but the difference of the experiment and RUSLE equation is due to the impact of temperature. So, it can be said that the difference is due to the T factor. This experiment shows that the hypothesis assumed is true that erosion is dependent on temperature.
Plot the graph between temperature and difference of clay loam soil erosion from experiment and RUSLE (as shown in fig. 13).

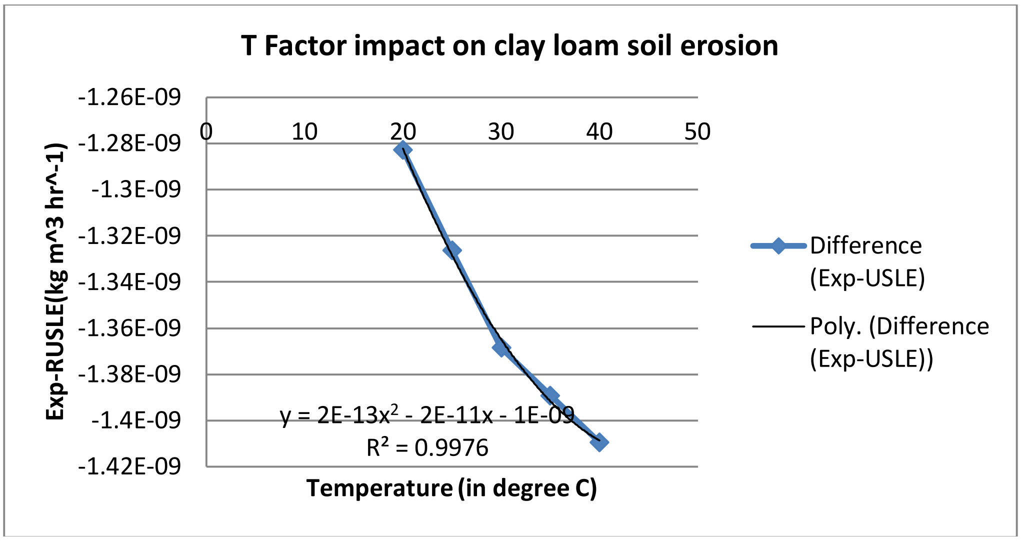


Fig. 13: T Factor Impact on Clay Loam Soil Erosion

Resulting equation for the T factor of the curve-by-curve fitting method for clay loam soil is given as follows.

$$\text{T factor for CL} = 2 \times 10^{-13}\text{temp}^2 - 2 \times 10^{-11}\text{temp} - 10^{-9}$$

R^2 =0.9976 for this curve shows that it perfectly fits on the curve so this equation is perfect for clay loam.

(ii) Duration Factor:

As RUSLE doesn't depend on temperature duration, this will be the same for the samples having the same R, slope, slope length, K, P, and C. So, the value for such a sample will give the same results according to RUSLE. But the results in the experiments shows that it is different and also depends on temperature duration on which particular temperature applied on the surface.

i) Sandy Clay Loam

As per experiment done in the implementation section for varying duration applied for fixed temperature experiment, it is required to find the D factor for sandy clay loam soil erosion. Experiment done on sandy clay loam soil erosion due to varying temperature duration (D) with constant volume = 0.75 m^3, open surface area = 0.5 m^2, temperature = 30^{0}C, Slope = 5 degree using temperature soil erosion simulator show that erosion is dependent on changing temperature duration (see table 3). Erosion is converted to kg m^3 hr^{-1}.

According to RUSLE for slope =5 deg., R=0.001072386, LS=0.78, K=0.2226, P=1 and C=0.1

$\text{RUSLE Erosion} = 1.86874396 \times 10^{-9}\ \text{kg m}^3\text{hr}^{-1}$

Table 7: Varying Duration Factor Evaluation for the Experiment of Same Samples of Sandy Clay Loam Soil

Sr. No.	Temp. Duration	Experiment Erosion W*V*hr^{-1}(kg m^3 hr^{-1})	RUSLE Erosion (kg m^3 hr^{-1})	Difference (Exp-RUSLE)
1	24 hr	3.7553E-10	1.86874E-09	-1.49321E-09
2	48 hr	3.2912E-10	1.86874E-09	-1.53962E-09
3	72 hr	1.9652E-10	1.86874E-09	-1.67222E-09
4	96 hr	1.3328E-10	1.86874E-09	-1.73546E-09
5	120 hr	8.228E-11	1.86874E-09	-1.78646E-09
6	144 hr	4.352E-11	1.86874E-09	-1.82522E-09

As temperature duration applied on soil is not part of RUSLE so, it will give the same soil erosion according to RUSLE, but the difference of experimental erosion and erosion according to the RUSLE equation is due to the impact of temperature duration applied on it. So, the difference is due to the D factor. This experiment shows that the hypothesis assumed is true that erosion is dependent on the duration of temperature applied on soil.

Plot the graph between temperature duration and difference of soil erosion from experiment and RUSLE (as shown in fig. 14).

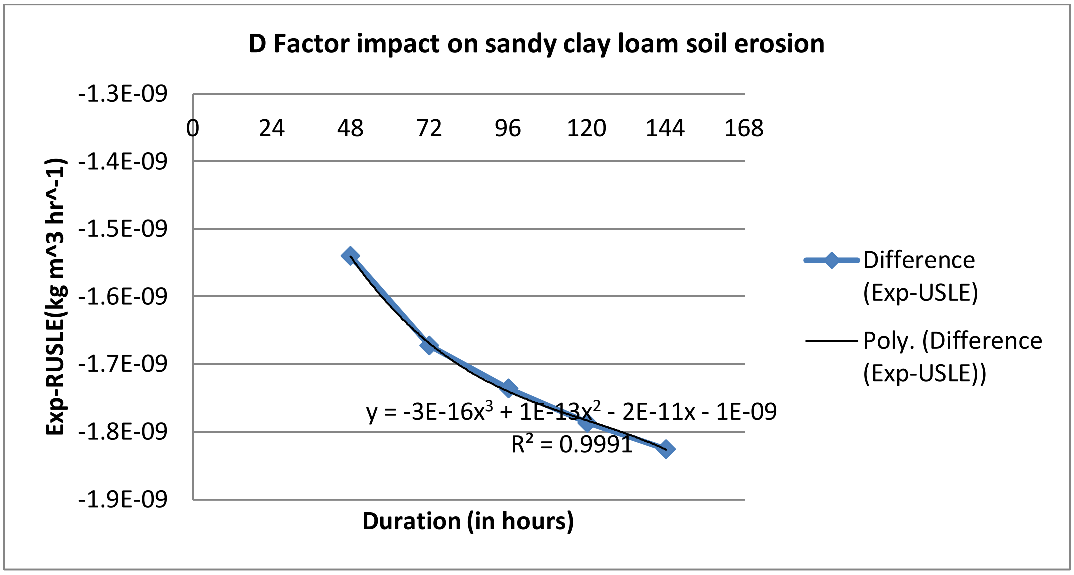


Fig. 14: D Factor Impact on Sandy Clay Loam Soil Erosion (After excluding the first data it fits to the curve)

Resulting equation for the D factor of the curve-by-curve fitting method for sandy clay loam soil is given as follows.

$$\text{D factor for SCL} = -3\times10^{-16}\text{dura}^3 + 10^{-13}\text{dura}^2 - 2\times10^{-11}\text{dura} - 10^{-9}$$

R^2 =0.9991 for this curve shows that it perfectly fits on the curve so this equation is perfect for sandy clay loam.

ii) Clay Loam

As experiments done in the implementation section for varying duration applied for fixed temperature experiment, it is required to find the D factor for clay loam soil erosion. Experiment done on clay loam soil erosion due to varying average temperature Duration (D) with constant volume = 0.75 m^3, open surface area = 0.5 m^2, temperature = 30^{0}C, Slope =5 degree using temperature soil erosion simulator show that erosion is dependent on changing temperature duration (see table 4). Erosion is converted to kg m^3 hr^{-1}.

According to RUSLE for slope =5 deg., R=0.001072386, LS=0.78, K=0.2911, P=1 and C=0.1

RUSLE $Erosion = 2.04431\times10^{-9}\ \text{kg}\ \text{m}^3\text{hr}^{-1}$

Table 8: Varying Duration Factor Evaluation for the Experiment of Same Samples of Clay Loam Soil

Sr. No.	Temp, Duration	Experiment Erosion W*V*hr^{-1}(kg m^3 hr^{-1})	RUSLE Erosion (kg m^3 hr^{-1})	Difference (Exp-RUSLE)
1	24	6.76E-10	2.04431E-09	-1.36831E-09
2	48	5.76E-10	2.04431E-09	-1.46831E-09
3	72	4.84E-10	2.04431E-09	-1.56031E-09
4	96	4E-10	2.04431E-09	-1.64431E-09
5	120	3.3856E-10	2.04431E-09	-1.70575E-09
6	144	1.44E-10	2.04431E-09	-1.90031E-09

As temperature duration applied on soil is not part of RUSLE so, it will give the same soil erosion for clay loam according to RUSLE, but the difference of experimental erosion and erosion according to the RUSLE equation is due to the impact of temperature duration applied on it. So, the difference is due to the D factor. This experiment shows that the hypothesis assumed is true that erosion is dependent on the duration of temperature applied on soil.

Plot the graph between temperature duration and difference of soil erosion from experiment and RUSLE (as shown in fig. 15).

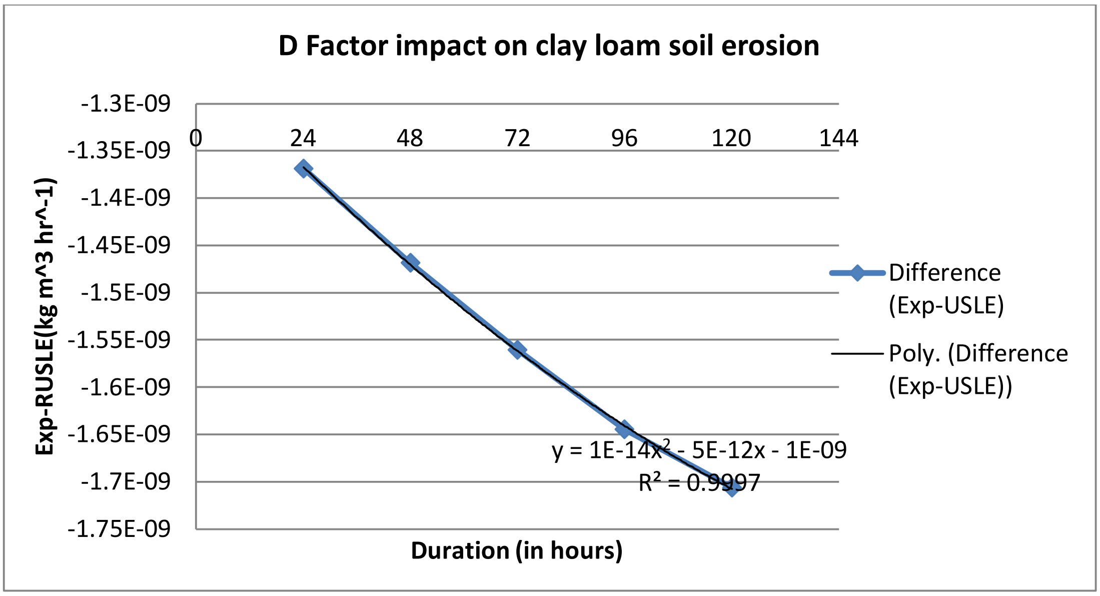


Fig. 15: D Factor Impact on Clay Loam Soil Erosion (After excluding the last data it fits to the curve)

Resulting equation for the D factor of the curve-by-curve fitting method for clay loam soil is given as follows.

$$\text{D factor for CL} = 1 \times 10^{-14}\text{dura}^2 - 5 \times 10^{-12}\text{dura} - 10^{-9}$$

R^2 =0.9997 for this curve shows that it perfectly fits on the curve so this equation is perfect for clay loam.

CONCLUSION

The key conclusion points of this study are, temperature variation and temperature duration factors in different climates that impacts on the erosion along with the existing RUSLE factors.

As RUSLE doesn't depend on temperature (T factor) and temperature duration (D Factor), so for the samples having the same R, slope, slope length, K, P, and C, erosion is the same. But the experiments done using erosion simulators shows that their erosion is different and depends on temperature variation and temperature duration too.

Resulting equations of T and D factors are as following:

$\text{T factor Sandy clay loam} = -10^{-14}\text{temp}^3 + 10^{-12}\text{temp}^2 - 4 \times 10^{-11}\text{temp} - 10^{-9}$

$\text{T factor Clay loam soil} = 2 \times 10^{-13}\text{temp}^2 - 2 \times 10^{-11}\text{temp} - 10^{-9}$

$\text{D factor Sand clay loam} = -3 \times 10^{-16}\text{dura}^3 + 10^{-13}\text{dura}^2 - 2 \times 10^{-11}\text{dura} - 10^{-9}$

$\text{D factor Clay loam} = 1 \times 10^{-14}\text{dura}^2 - 5 \times 10^{-12}\text{dura} - 10^{-9}$

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