Characterization of sediment yield behaviour from a micro catchment area of a farm pond forstorm wise runoff events in North-Eastern Dry Zone of Karnataka

Comment [gs1]: Where is it?

Abstract:

Aims: To measure the runoff event wise sediment yieldfor a micro catchment area of the farm pond and characterise its behaviour

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Place and Duration of study: The study was conducted in a micro catchment (field sized area) of a dugout farm pond, having an area of 6 ha located in the new area of UAS campus Raichur, which comes under Zone II in Region-I of Karnataka state. Geographically it is located at 16° 12′ N latitude and 77° 20′ E longitude and at an elevation of 389 m above the mean sea level (MSL). The study was conducted for a period of one year during 2019.

Comment [gs3]: For an international paper, it is necessary to mention the country ASAP in the manuscript; e.g. in the title

Methodology: The existing farm pond ~~constructed~~ was used to ~~for~~ conduct~~ing~~ sediment yield studies in ~~for~~ a micro catchment area. The rainfall intensity for each storm has been measured using self-recording rain gauge. The runoff has been measured at the out let of the field sized micro catchment area of farm pond using hydraulic structures coupled with automatic runoff recorder. The runoff sampling has been done for sediment/ soil loss assessment. The event wise rainfall, rainfall intensity and runoff followed by sediment yield have been have been measured and analysed to see the relationship between rainfall intensity and runoff with prevailing soil and topographical characteristics of the study area.

Results: The event wise runoff samples of the micro catchment area during the runoff events were collected from the stilling well coupled with hydraulic structure constructed at the outlet of the micro catchment area. As rainfall intensity increases it causes the water loss and surface soil erosion and increases sediment yield at the surface.

Conclusion: In the present study the red gram crop was grown and it had affected the sediment yield especially during September and October months. Rainfall is most dynamic factor which affects the sediment yield.

Keywords: Sediment yield, gross domestic product, agriculture production, climate change

I. INTRODUCTION

Agriculture is the back bone of the Indian economy. Agriculture and allied sector contribute nearly 22 percent of gross domestic product (GDP) while about 65-70 percent of the population is dependent on agriculture output. India has 16 percent of world population and holds 2.41 per cent of the world's land and 4 per cent of the world water resource. The average annual rainfall of India is about 1194 mm considered over the geographical area of 328 M ha, amounts to 392 M ha-m of surface water. A part of this which ~~that~~ is around 150 M ha-m flows as surface and subsurface runoff and is not useful form the point of agriculture production.

Comment [gs4]: Rewrite! What does it mean?

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The climate change/variability and unabated land degradation are the twin problems that are impacting productivity, profitability and sustainability of rainfed production of rainfed production systems. Most of the semi-arid regions in India, (about 82.2 M ha of land) suffers from severe rainfall erosion, often more than in humid tropics because of the high erosive capacity of erratic rains received on merge or fragile vegetative protection. The rainy season in semi-arid topics is characterized by short duration and variable intensity rains, interspersed with unpredictable dry spells.

Understanding hydrological processes helps to identify water resource potentials, runoff source areas, and erosion danger zones. This in turn helps with the estimation of runoff and sediment yield, which is the basis for developing watershed management plans involving soil and water conservation measures (Pandey *et al.*, 2008). It helps to represent and simulate the actual hydrological processes so that areas most prone to severe damage and in need of greater soil and water conservation measures can be prioritized. This is the key step to better target finite resources for enhanced soil conservation measures.

Soil is one of the world's most important natural resource and it is essential for life, in the sense that they provide the medium for plant growth, habitat for many insects and other organisms. Soil formation is a very slow process, may be as little as 1 cm of thickness in 500 years, so we can't just replace them in our own lifetime and it is particularly sensitive to climatic conditions (Amutha*et al.,* 2009). Many of our soils are becoming damaged and are at risk. Water, along with soil, is the most essential natural resource for economic and social development.

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Soil erosion by running water has been recognized as the most severe hazard threatening the protection of soil as it reduces soil productivity by removing the most nutrient rich topsoil analysis of sediment yield relationship with event precipitation and discharge characteristics can help in the understanding of processes acting in the sediment transporting events. Thus, sediment yield rates may be expected to change in response to changes in rainfall (Old *et al.,* 2003; Nearing *et al*., 2005), including total precipitation as well as intensity. In the world map on the status of human-induced soil degradation, it is accounted that loss of topsoil and terrain deformation due to soil erosion are the consequences of deforestation, removal of natural vegetation and overgrazing in the mountainous regions (Shrestha *et al.,* 1997). The prevention of soil erosion, which means reducing the rate of soil to approximately that which would occur under natural conditions, relies on selecting appropriate strategies for soil conservation. The factors which influence the rate of erosion are rainfall, runoff, soil, slope, plant cover and the presence or absence of conservation measures. Erosion control requires a quantitative and qualitative evaluation of potential soil erosion considering these factors.

The sediment yield data at micro watershed level is required to be assessed to device appropriate control measures to be adopted at micro watershed level. The measurement of soil loss data helps to assess the rate of soil loss and planning suitable management practices namely, the selection of crops, cropping pattern, adoption of conservation practices could be planned to reduce soil loss at micro watershed level.

Sediment yield at a given place is a function of sediment production due to erosion of soil and its subsequent transport along the governing slope. Further, the erosion or sediment transport capacity of the agent may limit the sediment yield, depending upon the topography, soil characteristics, vegetative cover and rainfall-runoff rates and quantities, the controlling mechanism changes from season to season, storm to storm or even within a storm event. Thus sediment production and its transportation along with the runoff are location and time specific. Therefore, there is a need for investigation of the sediment yield under different agro climatic in order to quantify the actual soil loss quantities and their tolerance limits.

The sediment yield could be used for assessing the siltation and rate of sedimentation from the pond catchment. The presentstudy is undertaken to characterize storm wise sediment yield behaviour in the catchment area of farmpond at UAS

2.MATERIAL AND METHODS

2.1 Description of the experimental micro catchment area

2.1.1 Location

The study was conducted in a micro catchment (field sized area) of a dugout farm pond, having an area of 6 ha located in the new area of UAS campus Raichur, which comes under Zone II in Region-I of Karnataka state. Geographically it is located at 16° 12′ N latitude and 77° 20′ E longitude and at an elevation of 389 m above the mean sea level (MSL). The location map of the study area is shown in Fig 1a and 1b.

2.1.2 Climate

Agroclimatically, the micro watershed is a part of the Northern dry zone of Karnataka and also a part of the agro ecological region of the country. The climate is semi-arid and the average annual rainfall is 682.40 mm. The study area belongs to the North-Eastern Dry Zone (Zone-2 of region-1) under semi-arid region with subtropical climate and consists of parts of Raichur, Gulbarga and Bellary districts in Karnataka.

During the study period, the highest one-day rainfall of 113 mm was recorded in the month of September 25th, 2019 (Fig 2) and minimum 8.60 mm in the month of May and the total annual rainfall recorded was 651.50 mm during. The average maximum and minimum temperature of 43ºC and 19ºC were recorded in the month of May and December 2019 respectively. Day temperature shows a slight increase in October. From November, both day and night temperature gradually decreases till December. The mean

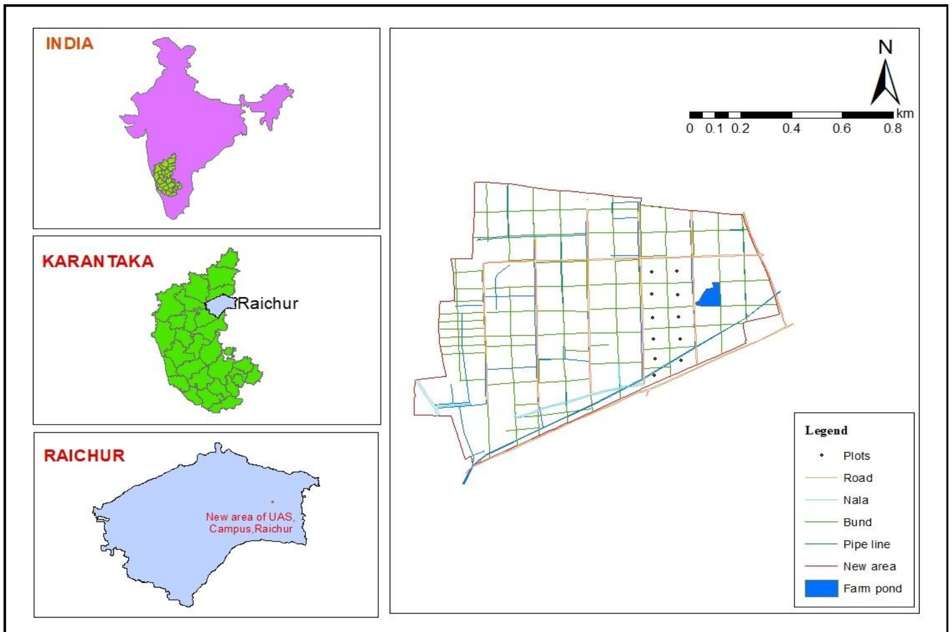

Fig 1a: Location map of study area in the UAS, campus Raichur

Fig 1b: Google earth satellite image showing the boundary of the study area and farm pond at UAS, Raihur campus

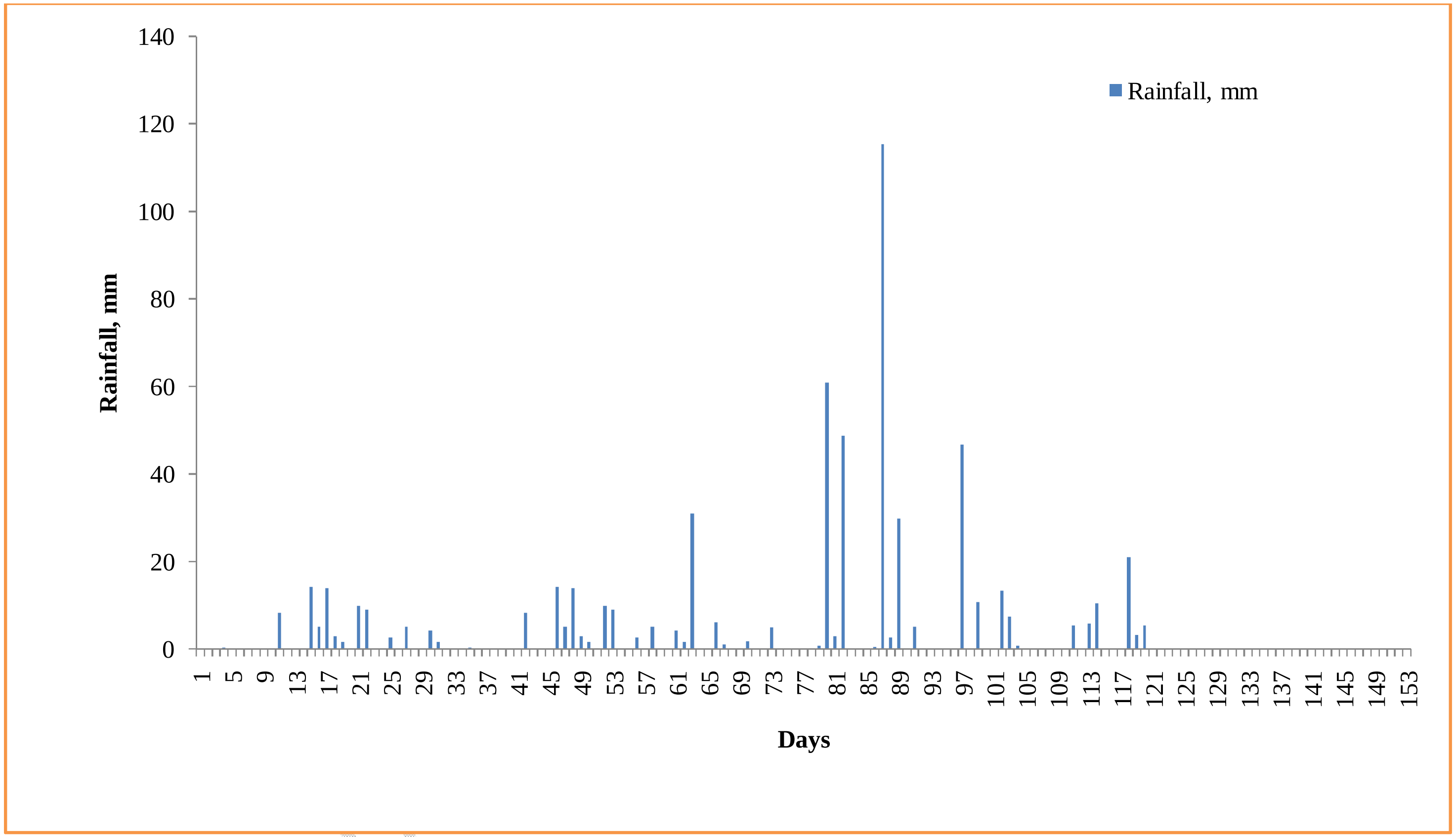

Fig 2: Daily rainfall (mm) recorded from July to November during the period of 2019-20

maximum relative humidity (RH) was noticed during August and September months (83

2.2 Cropping pattern in the study area

The cropping pattern in the study area confined to a few field crops. During kharif season the red gram (*Cajanuscajan*) crop was sown in the month of July 17th, 2019 and followed by Jowar crop was grown in the entire 6 ha area. During the runoff events, the red gram crop was sixty days old.

3.3. Topographic features of the study area

The details of the contour map of the catchment area along with 3D map are shown in Fig 3 and 4 respectively. The highest and lowest elevation was 100.7 m and 99.75 m and the average elevation of the study area is 99.5 m and with elevation difference of 0.95 m from head to toe of the watershed. The average slope of the area is 0.25 per cent.

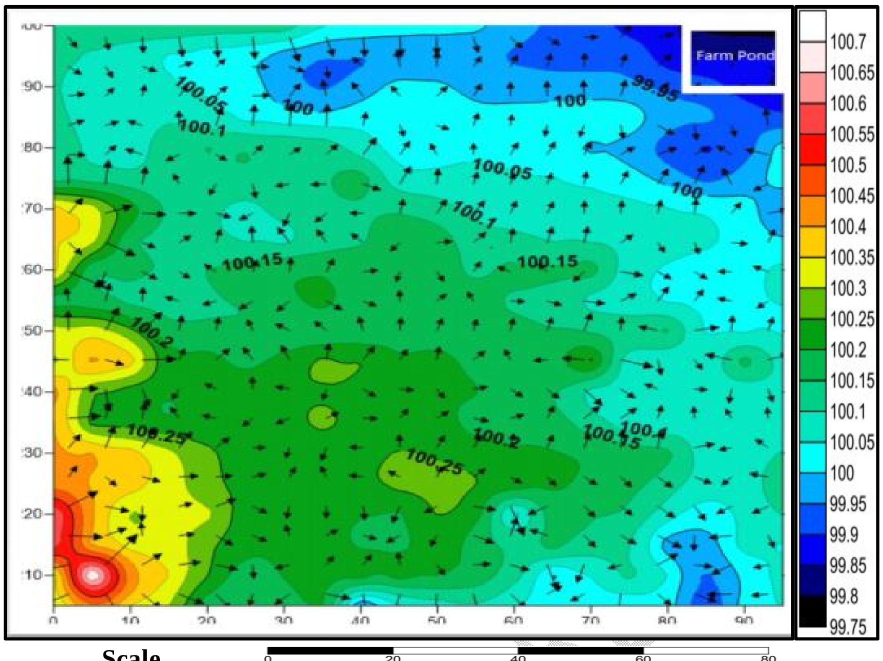

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Fig 3: Map showing the contours, flow direction and topographic features of the study area

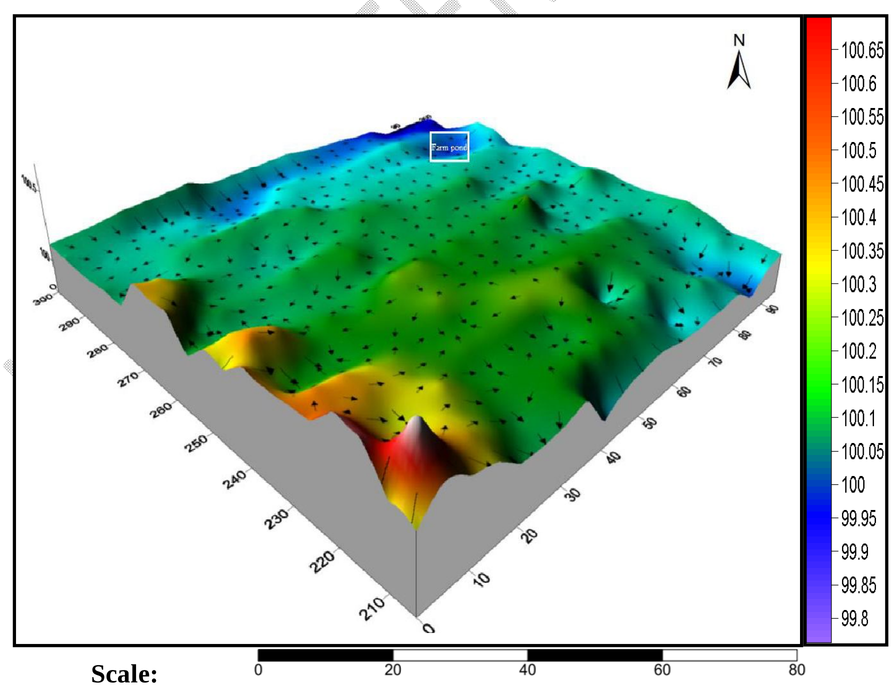

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Fig 4: Map showing the 3D map depicting the topographic feature of the catchment area

From the figure 3 and 4 it is clearly understood that, the study area topographically covered with low and high spots where part of the runoff is accumulating and further flow towards farm pond which is being located at the lowest elevation of the study area. Therefore, identify the farm pond is at the outlet point of the micro catchment where all the sediment laden runoff was drained and collected for sediment yield assessment.

2.4 Determination of soil characteristics of the study area

The soil samples were analysed in respect of the following properties.

It is the thickness of soil, present above the bed rock or the impermeable layer. The average depth was recorded as < 50 cm for the study area. The soil characteristic of the study area is shown in Table 1.

Texture refers to the size distribution of the primary particles namely sand, silt, and clay which constitute most of the soil media. The distribution of particles sizes was determined by following standard sieve analysis method, followed by International pipette method (Igaz, *et al*. 2020). The results of the textural analysis of soil samples at different depths are given in Table 2.

Soil structure refers to the arrangement of the primary particles to form stable aggregate within the soil mass. Soil structure has a definite influence on water-air movement, resistance to water flow, penetration of roots and crops production. During the course of the investigation, structural properties of the soil were determined by profile study. Infiltration is the downward entry of water into the soil through the soil surface. The rate at which water enters the soil under prevailing surface conditions, including the presence of depression storage. The nearly constant rate that develops after a certain elapsed time from the start of the application of water is called the basic infiltration rate and the total quantity of water that enters the soil in a given time is called cumulative infiltration. Soil infiltration rate was measured at the micro watershed using double-ring infiltrometer (Sidirasand Roth, 1987).The infiltration values were observed at increasing intervals of 5,10,15,30 and 60 minutes, for a total period of 8 hours. Infiltration characteristics of the study area is shown in Fig 5. The average infiltration rate of the soil is 9 cm/hr.

Comment [gs6]: What does it mean? How did you observe? Any previous establishment?

Table 1: Site characteristics of the study area by profile study

Sl. No.	Soil properties	Details
1	Topography	Undulating
2	Gradient (%)	1-3
3	Drainage	Medium well
4	Erosion	Moderate
5	Runoff	Medium
6	Texture	Sandy loam

Table 2: Soil textural classification of study area

Sl. No.	Soil depth (cm)						
	Soil separates	0-11	11-23	23-48	48-73	78-102	>102
1	Clay (%)	14.8	10.0	13.2	15.0	18.2	15.4
2	Silt (%)	3.60	11.40	26.80	25.0	41.8	21.8
3	Sand (%)	81.60	78.6	60.0	60.0	40.0	62.8
Soil textural class		Sandy loam	Sandy loam	Silty loam	Silty loam	Silty loam	Loam

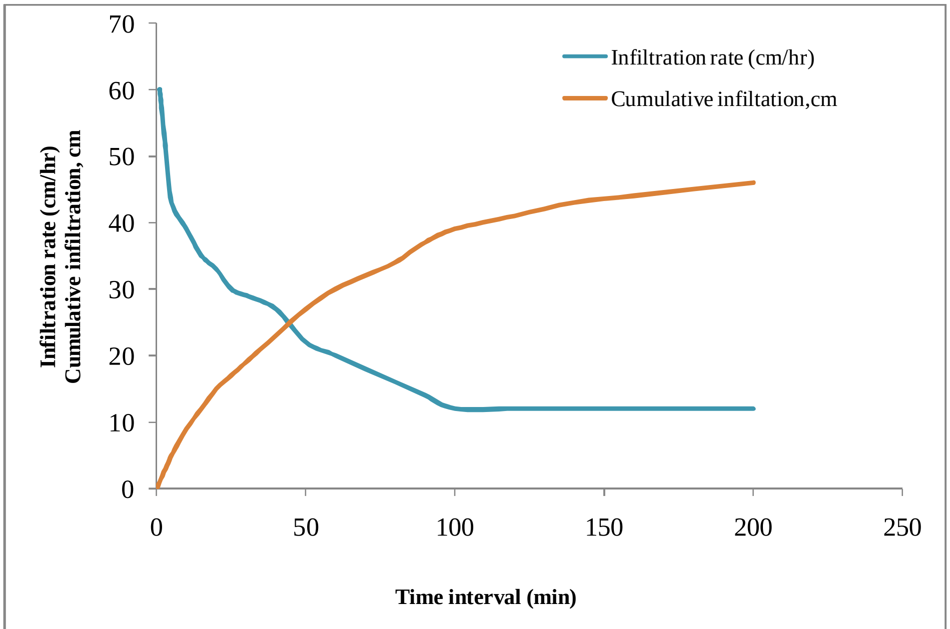

Fig 5: Infiltration characteristics of the study area

The dry bulk density of the soil at 0-30 cm and 30-60 cm depths at three locations namely upper, middle and lower reaches of the micro catchment area were determined using the core cutter method (Plate 1). The average bulk density of the soil was found to be 1.52, 1.56 and 1.60 g/cc at above mentioned locations.

2.5 Farm pond constructed at the outlet of the micro catchment

Farm pond is a dug out structure with definite shape and size having proper inlet and out let structure for collecting the surface runoff flowing from the farm area. It is one of the most important rain water harvesting structures constructed at the lowest portion of the farm area. The stored water can be used for supplemental irrigation. The design details and capacity of the farm pond is shown in Table 3 and Fig 6.

Farm pond was constructed under "All India Coordinate Research Project on Dryland Agriculture" (AICRPDA) in dry land agriculture scheme in the year 2015 at UAS Campus, Raichur. This farm pond is ideally located at the outlet of the micro catchment area where all the runoff water drains in to farm pond.

2.6 Instrumentation setup and data collection for sediment yield

2.6.1 Measurement of runoff for quantifying sediment yield

The experimental setup consisted of a Thalimede data encoder type digital water level recoreder for recording continuous and uninterrupted measurements of changes in the water level over long period of time have been installed at the inlet section of the farm pond which is the outlet point of the micro catchment area (Plate 1a and 1b). The whole experimental setup was created under the "All India Coordinate Research Project on Dry land Agriculture" (AICRPDA) project, UAS, Campus, Raichur.

Table 3: Design details of farm pond at AICRPDA centre UAS, Campus, Raichur, Karnataka

Sl. No.	Particulars	Details
1	Shape	Square
2	Bottom dimensions	10×10 m
3	Top dimensions	18×18 m

4	Depth	2.70 m
5	Side slope	1.5:1
6	Storage capacity	547.77 m^3
7	Lining	RCC concrete
8	Total cost including lining	Rs. 3,20,000
9	Catchment area	6.0 ha
10	Command area	1.0 ha
11	Soil type	Sandy loam

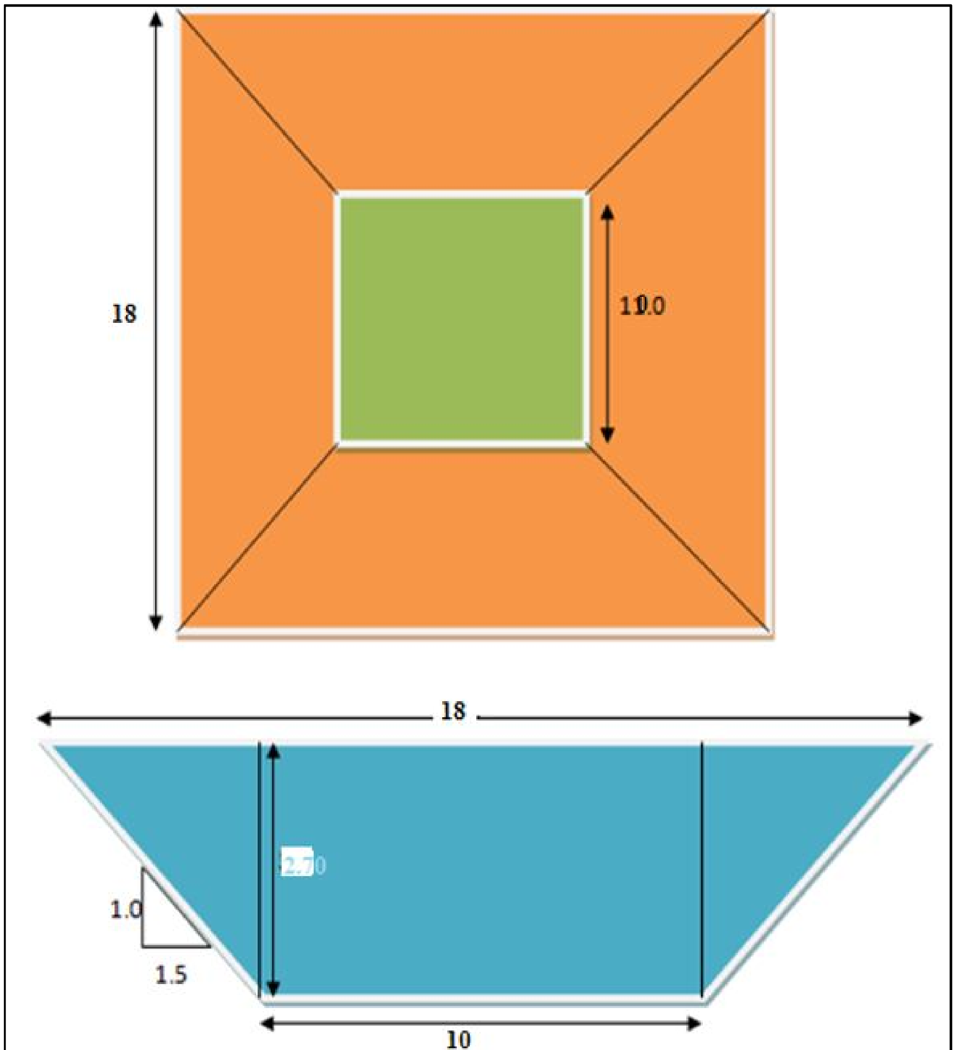

Fig 6. Plan and sectional view of Farm Pond showing design dimensions

Plate 1a: Image showing setup of Thalimede data encoder, data logger and self recording rain gauge at the inlet section of form pond

Plate 1b: Close view of thalimede data encoder and data logger used in the study area

2.6.2 Measurement of sediment yield

Assuch measurement of sediment yield is considered, the sediment sampling instruments have not been used during the study. Runoff samples for all the six events were collected from the stilling well at morning 8:00 clock whenever there is a event during night hours. Before collecting the sample, the runoff water was stirred using a rod to have representative sample of well mixed runoff sample. Whenever, runoff events occurred during day time, the real time runoff samples were collected at the weir channel using plastic bottles of one and two litter's capacity physically. This was possible since the experimental field is located in the campus very near to the departments. The collected runoff samples were brought to the hydrology laboratory (Plate 2a and 2b) and required amount of Alum (KAI $9SO_4)_2.12H_2O$) was added (a colourless compound which is a hydrated double sulphate of aluminium and potassium) and left 2-3 days for settling of sediment. After settlement of sediment at the bottom of the bottle the clean water from the bottle was separated. Afterwords the sediment concentration was poured into the 15 ml beaker and those beakers were kept for drying. Once the moisture is lost the weight of the sediment was measured using sensitive accurate digital weighing balance and expressed in g/lit. The quantity of sediment load that was transported along with the runoff volume for each event was calculated and expressed in terms of t/ha using the following formula.

$$\text{Sediment yield}\left(\frac{t}{ha}\right)=\frac{Q\times \text{weight of sediment concentration}}{A\times 1000\times BD} \quad \text{... (3.5)}$$

Where,

Q = Discharge, m^3

A = Area of watershed, ha

BD = Bulk density, g/cc

The quantity of sediment thus estimated from runoff volume of an event is assumed to be equivalent to the quantity that got transported out of the plot area and that

Plate 2a: A view of runoff samples kept for sediment yield measurement in hydrology laboratory

Plate 2b: Image showing the collection of runoff samples from the stilling well for sediment yield calculation

the same is received at the outlet. Hence, the sediment load collected is expressed in terms of tonnes per area and same is converted to tonnes per hectare (t/ha).

3. RESULTS AND DISCUSSION

3.1 Measured sediment yield

The event wise runoff samples of the micro catchment area during the runoff events were collected from the stilling well coupled with hydraulic structure constructed at the outlet of the micro catchment area. Table 4 and Fig 7. shows the event wise sediment yield analysis data (t/ha) for each runoff event.

The results revealed that there are about six runoff events occurred during the experimental period from 01-01-2019 to 31-12-2019. The minimum sediment yield of 0.04 t/ha was transported on 18-09-2019 against the runoff volume of 431.25 m^3(7.18 mm) and maximum sediment yield of 0.41 t/ha was noticed on 25-09-2019 against the runoff volume of 2985.48 m^3 (49.75 mm). The variation in sediment yield in each runoff event is not only depending on the volume of runoff produced but rainfall intensity was played an important role. By comparing events occurred on 18-07-2019 and 18-09-2019 though the runoff volume produced on 18-09-2019 was high (431.25 m^3) compared to the event on 18-07-2019 (142.66 m^3) the sediment yield obtained on 18-07-2019 was higher (0.09 t/ha) than the event on 18-09-2019 (0.04 t/ha). This clearly shows the dependence of sediment yield on intensity of rainfall. During the subsequent runoff events on 19-09-2019, 25-09-2019, 4-10-2019 and 25-10-2019, the measured sediment yield was 0.19, 0.41, 0.12 and 0.06 t/ha respectively which resulted from the runoff values of 944.24, 2985.48, 1086.65 and 665.62 m^3 respectively.

The relationship between sediment yield (t/ha) and runoff (mm) is depicted in the Fig8. The storm wise sediment yield and runoff showed a statistically significant linear relationship with R^2 value of 0.877. It clearly showed that there is a close relationship between sediment yield and runoff.

As rainfall intensity increases it causes the water loss and surface soil erosion and increases sediment yield at the surface. Rainfall is most dynamic factor which affects the sediment yield. The sediment yield and runoff those two are mainly determined by the intensity of rainfall because of rainfall erosivity factor for soil erosion. More the runoff more will be the soil erosion. The runoff usually carries less sediment at the end of

October because of having low intensity of rainfall. The total soil loss was 0.93 t/haagainst the total runoff of 6255.90 m^3. The variation in the sediment yield could be

Table 4: Event wise measured sediment yield during 2019-20

Sl. No.	Date of rainfall	Rainfall (mm)	Average rainfall intensity (mm/hr)	Runoff volume (Q) m^3	Sediment concentration (g/lit)	Sediment yield (t/ha)
1	18-07-2019	35	19.93	142.66	0.09	0.08
2	18-09-2019	48	21.63	431.25	0.9	0.04
3	19-09-2019	42	20.00	944.24	1.96	0.19
4	25-09-2019	113	18.73	2985.48	2.40	0.41
5	4-10-2019	46	19.70	1086.65	0.168	0.12
6	25-10-2019	22	19.00	665.62	0.06	0.06
Total				**6255.90**		**0.90 tonnes**

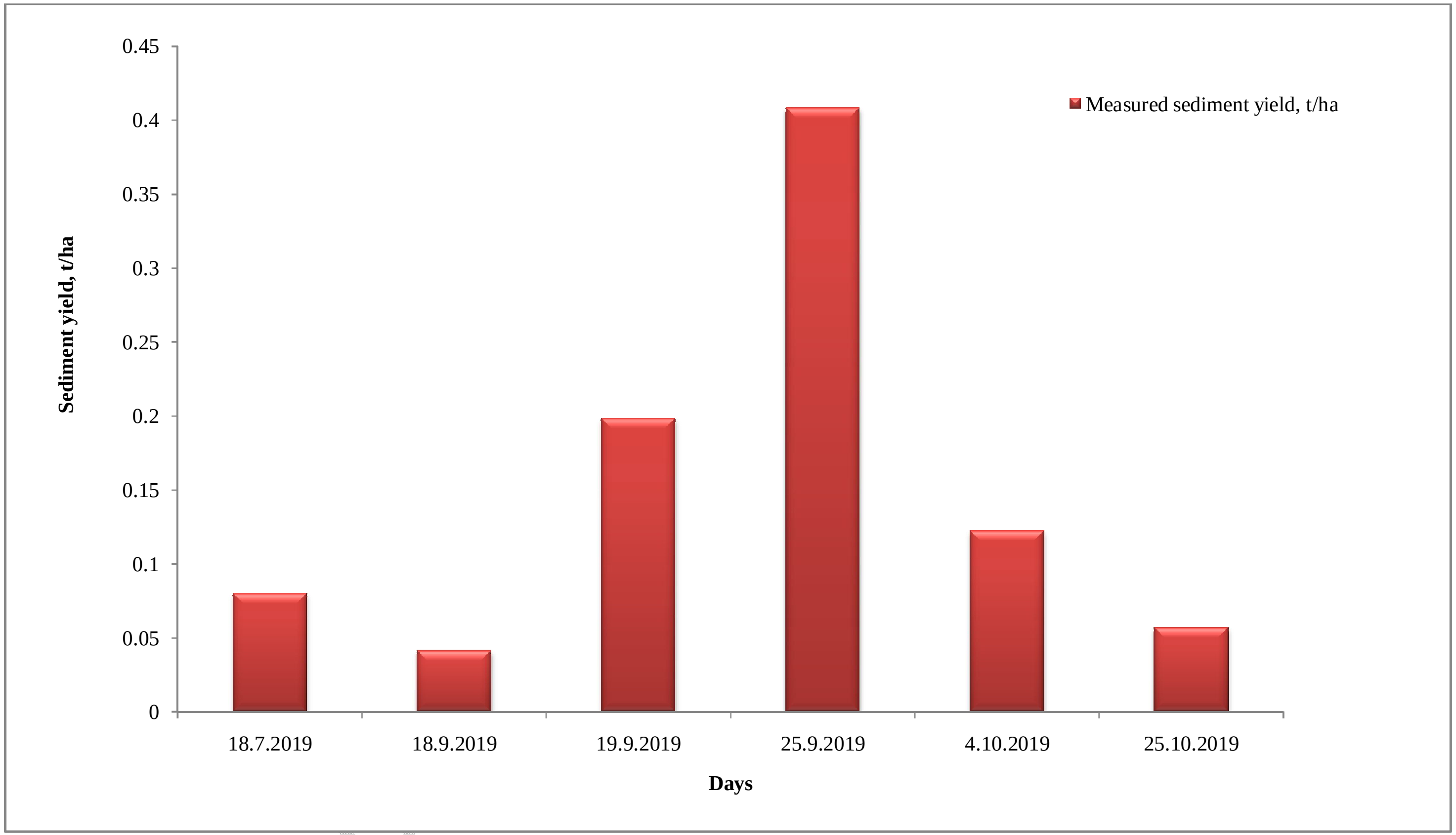

Fig 7: Measured sediment yield during 2019-20

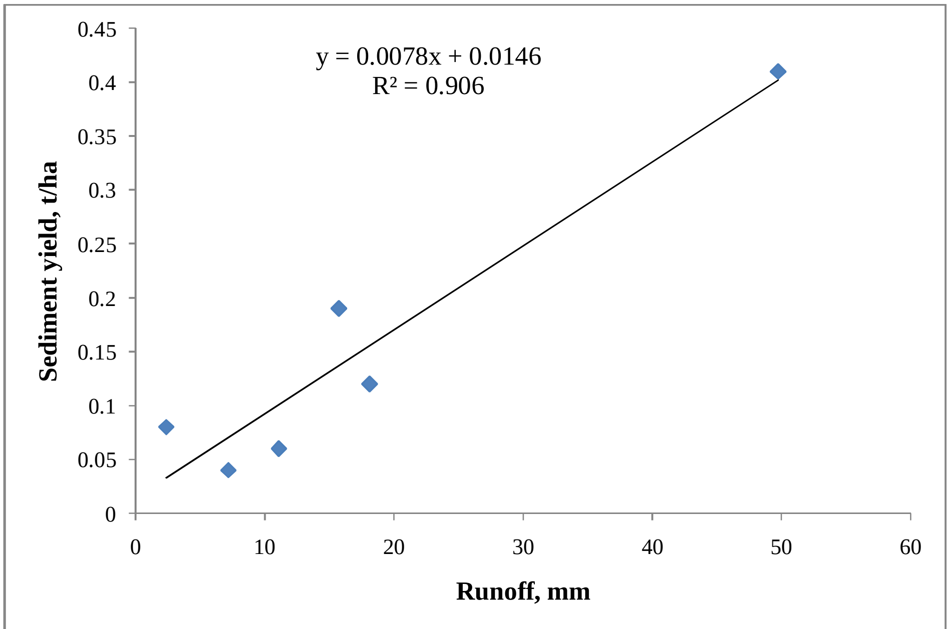

Fig 8: Scatter plot of measured sediment yield and runoff during 2019

Strongly affected by variation in runoff volume which in turn due to rainfall intensity. The crop cover management practices in the study area also affected the sediment yield as it varied from month to month and year to year.

Similar results were found by Premanand2018, it revealed that there are about 15 runoff events occurred during calibration period (2012-2014) and 7 runoff events during validation period (2015-2016). During calibration period sediment yield varied from 0.023 to 0.554 t/ha with a corresponding runoff volume of 28185.79 m^3 and 199492.50 m^3 respectively, conducted at Patapur micro-watershed. However, during validation period the day wise sediment yield varied from 0.054 to 0.878 t/ha against runoff volume of 37767.55 m^3 and 41350.65 m^3,respectively and Pathak *et al*., 2016 who found that mean annual rainfall, runoff for Alfisols were 890 mm, 199.70 mm and 0.21m^3 s^{-1} ha^{-1} and 4.76 t/ha, respectively at the ICRISAT centre, Patancheru, AP, India. Where as in the present study sediment yield varied from 0.096 to 0.056 t/ha with a corresponding runoff volume of 142.66 to 665.62 m^3.

Comment [gs7]: t ha^{-1}?

Conclusion

In the present study the red gram crop was grown and it had affected the sediment yield especially during September and October months.Rainfall is most dynamic factor which affects the sediment yield. The sediment yield and runoff those two are mainly determined by the intensity of rainfall because of rainfall erosivity factor for soil erosion.

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