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An experimental investigation of rill erosion processes in lateritic upland region: A pilot study

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Abstract

The present paper is based on field investigation and measurement of rill erosion processes at Rangamati Experimental Station (Medinipur, West Bengal in India). In rill experiments, three different natural rills were studies in field for understanding of the dynamics of soil erosion processes of a rill catchment area. Geometric and morphological characteristics of each rill catchment area were analyzed. Results showed the widening, deepening and extended of rills because of sidewall sloughing, knick-points and head-ward erosion during surface runoff process. Progressive increases of rill volume were observed in the upper, middle and lower catchment with the change of time. Rill area has increased by runoff processes of 4.2 % and 6.8 % for Rill-A and Rill-B respectively. These processes are depends on surface coverage, soil texture, slope gradients and runoff velocity.

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Introduction

Rill-gully erosion is major land degradation processes, causing both impacts on-site and off-site soil loss through sediment deposition in downstream environments. Rills were generated by water erosion and consist of several characteristics including a steep incised channel with an active headcut (Bruno et al. 2008; Stefano et al. 2013; Shit et al., 2014). The expansion of rills is due to the multifarious interface of soil properties with a high spatial and temporal variability (Nachtergaele et al., 2001), in which the morphology of a rill and the rill's headcut morphology may be determinant over and above stochastically motivated processes (Sidorchuk, 2005; Flores-Cervantes et al., 2006; Shit et al., 2013). This leads to great difficulties in quantifying soil erosion processes and makes soil erosion measurements hardly comparable (Knapen et al., 2007; Auerswald et al., 2009).

The mechanisms of inter-rill and rill erosion development by flowing water are completely different. The detachment in inter-rill erosion is caused and enhanced by drop-impact (Beuselinck et al., 2002) and, in addition to the soil's intrinsic characteristics (Kuhn and Bryan, 2004; Le Bissonnais et al., 2005; Brodie and Rosewell, 2007). Earlier study also stated that rill erosion is caused by the concentrated flow of water (Bryan, 2000; Govers et al., 2007; Knapen et al., 2007) and is considered to be the most important process of sediment production (Cerdan et al., 2002). The resulting rills may be persistent and develop into gullies, hindering further land use (Woodward, 1999; Vandekerckhove et al., 1998). Especially on fallow land and

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shrub land, rills can develop without disturbance by land management measures. In India, huge areas of fallow land and wasteland exist (Pandey et al., 2007). Thus rills can develop very fast and cause high soil losses and about 5334 m-tonnes of soil are being removed annually due to various reasons (Pandey et al., 2007).

Most experimental work about rill erosion has been carried out in the laboratory (Brunton and Bryan, 2000; Mancilla et al., 2005) and under the field conditions with different textures and natural or simulated rainfall (De Santisteban et al., 2005; Rejman and Brodowski, 2005). The main problem the laboratory experiments is that the results cannot be easily transferred to natural rills (Wirtz et al., 2010, 2012). In field condition rill erosion measurements are still lacking and there is a recognized need to perform field experiments to ascertain the role of rills in soil erosion. As the observation of erosion in the field is subordinated to the stochastic character of the erosion events and to a high dependency of the measurement technique standardized and reproducible field experiments are needed. Therefore, the present study focused on the mechanism of rill erosion process and quantifies the rill erosion at Rangamati experimental station, Medinipur (West Bengal, India).

Material and Methods

Study area

Experimental work has been conducted at Rangamati in Paschim Mednipur district (West Bengal, India), extended between 22°24' N latitude and 87°17' E longitude (Figure 1). The parent material of the study area consists of tertiary and secondary lateritic, sands, silts and clay. Mean annual rainfall is about 1450 mm, distributed in 110 rainy days while mean annual temperature is 28 °C and mean monthly temperatures range between 8°C in January and 43 °C in June (Shit et al., 2013). The area is dominated by low shrubs, *Eragrostis cynosuroides* grass and some wild species. The land cover at south-side of Rangamti is covered with abandoned fields and extensively grazed by cattle's. Cossi River side characterized by agricultural land use and is comprised mainly of crop-farming and vegetables (Shit et al., 2014). The landscape is characterized by hard rock up-lands, barren lateritic covered area and non-arable lands. The main erosive processes that affect the landscape are related to runoff waters and mass failures that causes gully erosion.

Figure 1. Location of the study areas (Rill –A, Rill –B, Rill –C)

Description of Rill sites

The study was carried out into rill channel data at three different sites in Rangamati badland at Midnapur town (West Bengal). The texture of soil was characterized based on the FAO (2006) guidelines. Rill-A (Figure 1 A) was situated on the steepest slope (average 5º) with a catchment area of 59.04 m2. The total rill length was 17 m with a maximum width of 1.21 m and 0.316 m depth (Table 1). Vegetation and rock fragments cover approximately 7% of the rill area. Three cross-sections were drawn, such as 0.0275 m^2 at 5 meters; 0.1047 m^2 at 11 meters and 0.1154 m^2 at 17 m of the tested gully length. The soil texture was classified as medium clay silt with a particle 2.70 gcm^{-3} and moderate bulk density of 1.61 g cm^{-3}.

Table 1. Rainfall data for experimental events

Date	Rainfall (mm)	Total duration (in hours)	Intensity of rainfall (mm/h)
08.09.2014	14.5	1.30	9.66
16.09.2014	17.0	1.0	17.00
21.09.2014	20.0	1.40	11.97
27.09.2014	24.5	2.20	10.51

Rill-B was characterized by an average slope of 4º and with a catchment area of about 160 m^2 (Figure 1B). The maximum width was recorded as 1.40 meter and the depth of 0.35 meter. Only 5% of the rill was covered by rock fragments and vegetation cover. The cross sections were measured in three areas as follows: 0.1317 m^2 at 25 m; 0.133 m^2 at 42 m and 0.0268 m^2 at 52 m (Table 1). The soil texture is classified as silt clay loam with a low bulk density of 1.3 gcm^{-3}. The particles density value reaches to 2.56 gcm^{-3}.

Rill -C developed in a loam soil with a high content of sand (24 % of the find soil) and coarse fragments (11% of the total soil). An average slope of the rill area was recorded as 7˚ and catchment area of about 136 m^2 (Figure 1C). The maximum width of the rill was estimated 1.21 meter and maximum depth of 0.31 meter. Vegetation and rock fragment cover about 15% of the entire rill area. The cross sections were measured at 11 meter, 24 meter and at 34 meter with the corresponding areas of 0.1850 m^2, 0.1026 m^2 and 0.1003 m^2 respectively. The bulk density was recorded as 1.41 gcm^{-3}, moderate and particles density was 2.58 gm^{-3}.

Monitoring rill morphology

The morphological characteristics of the rill areas were measured at 0.5 m interval. The information is recorded during the period between 06th and 29th September, 2014. The rainfall was recorded self recoding raingague in field (Table 1). Runoff was reassured using dry tracer techniques (Shit and Maiti, 2012). The transport sediment was measured within the rill at particular rill end by sediment concentration in the samples. Rills cross section was measured at each measuring point with thin metal sticks. The distance between ground level and rill bottom was measured in before and after rainfall for estimate the widening rate of rill erosion and also photographs captured during the experiment and channel widening was determined from capture photos at particular rainfall events.

Rill erosion measurement

The volume and surface area of the entire gully system was estimated through measurements of width, depth, and length of cross-sectional and length profiles using a 30 meter long tape. We identified three gully cross-sections based on the homogeneity of the gully profile. For each gully, cross section widths and depths were measured along the gully channels. In order to quantify gully volumes and gully cross-sectional morphology, 204 cross-sections were quantified with an equal number of gully segments. The maximum depth (D, in meters), top width (TW, in meters) and bottom width (BW, in meters) of the bankfull channels were estimated. The cross sections were surveyed by a rillmeter (Bruno et al., 2008). For each section, width (w) at the top of the cross section, maximum scour depth (H), cross section (A) and wetted perimeter (C) were measured (Figure 2 and 3). The surface area of entire gully system digitized and cross-checked with the surface area estimated with physical measurements of gully cross-section segments.

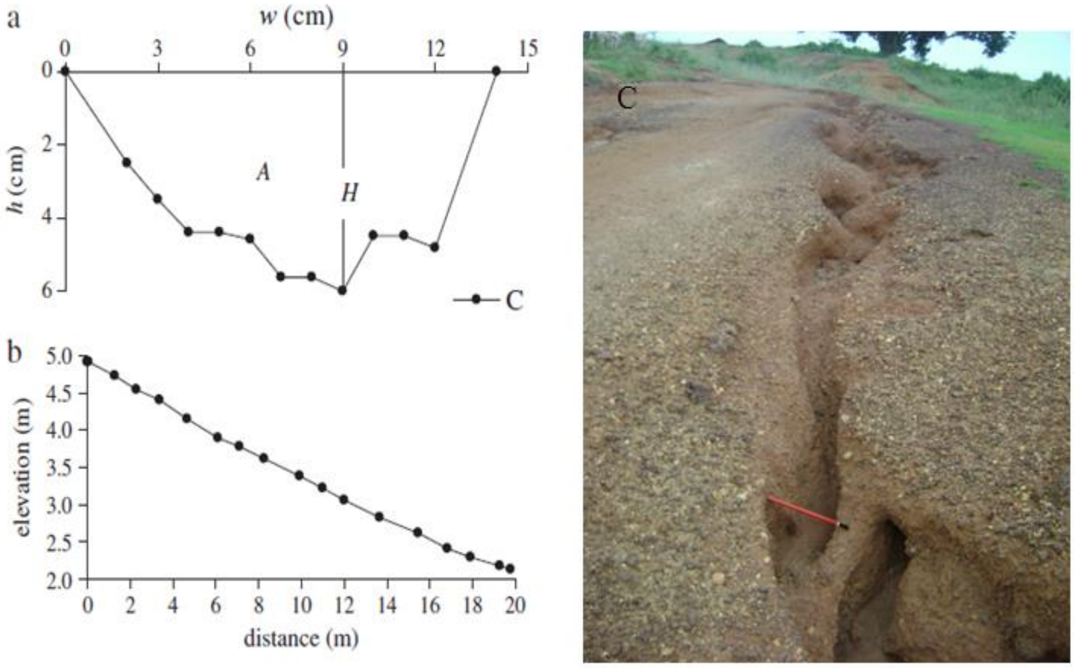

Figure 2. Example of the relief of (a) a rill cross section and (b) rill profile, (c) View of the Rill-C surveyed at Rangamati, Medinipur (after Stefano et al., 2013)

Figure 3. Rill erosion measurement

Once the rill size was determined from the cross-sectional measurements, the rates of erosion were calculated by determining the change in dimension (width, depth, and length) of the different gully segments. The eroded volume V (m^3) of each gully segment was calculated using the cross-sectional dimensions and distance between cross-sections (Eq. 1).

$$V = \sum_{i=1}^{n} L_i A_i \qquad \text{Eq. 1}$$

Where, L_i is the length of considered rill segments (m) and A_i is the representative cross-sectional area of the rill segments (m^2).

Results

Rill bed morphology

The longitudinal elevation profiles of the rill shows a succession of steps and pools (Figure 4). Two well defined pools were formed. The mean pool depth was 0.012 meter and the average value of pool length was 0.023 meter. The estimated pools were not symmetric and the downstream well was steeper (7º) than upstream well (13º). Between the depths of 0.026 meter, all pools were separated by steps. The slope gradient of the step surface was very close to the average slope rill width (0.011 to 0.037 meter) (Figure 5).

Figure 4. Rill geometry change during the period between 06th September, 2014 (left) and 29th September, 2014 (right)

Figure 5. Rill erosion during 06.09.2014 (left side) and 29.09.2014 (right side) at Rangamati experimental station (A & B = Rill-B; C & D= Rill-C)

Quantify rill geometry

Rill- A

Geometrical characteristics of the rill-A was assessed in different time periods (Table 2). In preliminary period (Day 1) the average depth was 18.42 cm, whereas the depth was increased up to 19.09 cm five days later. There was significant increase of minimum depth of rill (except in Day 5) in the entire study period (*P<0.01*). Consequently, continuing decrease of maximum depth of rill was observed from Day 2 onwards (*P<0.04*). Results also showed gradual increase of average depth of rill in the study period. The average top width of Rill-A showed steady increased with the time (*P<0.0001*); however, the average bottom width of the Rill-A not varied considerably with the change of time (*P<0.03*). Moreover, ongoing changes of the perimeter of the rill side were observed (*P<0.004*), although no such significant information was derived in gradient in the study site.

Rill-B

Minimum depth of the rill-B was increasing trend from date 1 to 3 and thereafter was a decreasing trend from date 4 to date 5 (Table 3). However, no such significant variation of maximum depth of rill-B was observed during the study period (*P>0.40*). Significant variation of average depth of rill –B was observed (*P<0.008*). Minimum value of top width of rill-B showed increasing trend and it significantly varied in the study area (*P<0.002*). Consequently, average value of top width showed increasing trend (*P<0.04*). Very less variation of average value of bottom width was observed in the study site (Table 3). The average perimeter of rill-B showed regular increasing trend with the change of time (*P<0.001*). However, significant variation of gradient was also observed in rill development (*P<0.03*).

Table 2. Descriptive Statistics of rill geometry: Rill-A

Date	Descriptive Statistics	Depth (cm)	Top width (cm)	Bottom width (cm)	Perimeters (cm)	Gradient (Slope)
Date-1	Minimum	4.40	35.00	16.00	41.00	1.00
	Maximum	40.50	118.00	85.00	131.00	19.00
	Median	19.30	75.00	26.00	94.50	4.00
	Average	18.42	73.79	32.97	87.15	6.06
	SD	9.18	25.88	16.70	28.05	4.93
	CV (%)	49.84	34.60	50.64	32.19	81.36
	Skewness	0.29	0.06	1.31	-0.32	1.61
	Kurtosis	-0.44	-1.18	1.46	-1.14	2.84
Date-2	Minimum	4.60	35.20	16.10	31.00	2.00
	Maximum	41.60	120.10	85.10	120.20	20.00
	Median	19.55	70.15	26.25	94.60	5.00
	Average	18.56	74.92	33.19	87.37	6.24
	SD	9.26	26.17	16.66	27.95	4.24
	CV (%)	49.87	35.40	50.19	31.99	67.93
	Skewness	0.33	0.15	1.30	-0.31	1.22
	Kurtosis	-0.33	-1.23	1.46	-1.15	1.73
Date-3	Minimum	5.00	35.20	16.20	31.30	2.00
	Maximum	40.80	118.30	85.20	141.30	21.00
	Median	19.75	80.30	26.25	94.65	5.00
	Average	18.70	75.34	33.06	87.69	6.56
	SD	9.16	25.28	16.95	28.08	4.43
	CV (%)	48.97	33.11	51.27	32.13	67.58
	Skewness	0.29	0.05	1.24	-0.29	1.21
	Kurtosis	-0.45	-1.15	1.32	-1.19	1.73
Date-4	Minimum	5.20	35.30	18.30	40.40	3.00
	Maximum	31.50	120.50	85.40	121.50	22.00
	Median	19.90	75.40	26.35	94.85	5.50
	Average	19.05	76.35	33.73	88.08	7.09
	SD	9.04	25.96	16.67	27.91	4.49
	CV (%)	47.46	34.45	49.44	32.05	63.41
	Skewness	0.25	0.05	1.25	-0.37	1.31
	Kurtosis	-0.36	-1.20	1.37	-1.18	2.01
Date -5	Minimum	5.00	35.30	17.40	31.40	3.00
	Maximum	31.60	120.60	85.40	131.60	23.00
	Median	19.95	75.55	26.40	95.00	6.00
	Average	19.09	77.42	33.80	89.82	7.53
	SD	9.02	25.95	16.68	27.88	4.65
	CV (%)	47.26	34.41	49.35	31.75	61.80
	Skewness	0.25	0.05	1.25	-0.29	1.33
	Kurtosis	-0.34	-1.20	1.35	-1.17	2.10

Rill-C

In Rill-C, gradual increase of minimum depth of rill was observed, except in day 3; however, gradual expansion of maximum depth was also observed (except in date 2). Significant variation of average depth of rill was found in the study area (*$P<0.05$*). The average top width of the study area was varied from 70.74 to 76.32 cm and significant increasing trend of top width was also documented (*$P<0.03$*). The maximum bottom width of the study area was varied from 50.10 to 78.60 cm. Significant variation of bottom width of the study area was evidenced with the change of time (*P<0.05*). There was a gradual increase of average perimeter (varied from 82.53 – 88.03 cm) was documented (Table 4); whereas, any significant variations were not found in the study area (*P>0.11*).

Table 3. Descriptive Statistics of rill geometry: Rill-B

Date	Descriptive Statistics	Depth (cm)	Top width (cm)	Bottom width (cm)	Perimeters (cm)	Gradient (Slope)
Date - 1	Minimum	2.00	22.00	7.00	39.00	1.00
	Maximum	35.10	140.00	134.00	146.00	14.00
	Median	16.70	65.00	31.50	81.00	4.00
	Average	16.62	61.85	27.28	73.13	5.13
	SD	8.80	18.84	25.69	18.87	3.21
	CV (%)	52.97	28.61	68.90	23.55	62.68
	Skewness	-0.10	0.51	1.89	0.32	1.06
	Kurtosis	-1.00	2.13	4.42	0.94	0.27
Date - 2	Minimum	2.20	22.40	5.30	40.00	2.00
	Maximum	31.40	120.40	134.40	148.00	17.00
	Median	16.50	60.50	31.00	73.50	4.00
	Average	16.96	62.75	31.74	76.90	5.41
	SD	9.01	21.39	25.97	22.49	3.31
	CV (%)	56.09	34.09	67.05	30.44	61.17
	Skewness	0.07	1.62	1.83	0.71	1.14
	Kurtosis	-0.72	4.38	4.00	3.36	0.63
Date - 3	Minimum	5.70	22.40	5.30	41.00	2.00
	Maximum	35.60	120.50	104.30	148.00	17.00
	Median	16.70	66.00	27.00	82.50	4.00
	Average	16.99	64.44	35.06	79.43	6.05
	SD	8.80	20.09	14.20	22.88	5.45
	CV (%)	52.97	32.70	45.72	28.81	90.08
	Skewness	-0.10	-0.56	1.21	-0.34	3.13
	Kurtosis	-1.00	-0.51	1.61	-0.41	14.11
Date - 4	Minimum	3.60	22.50	5.60	45.00	2.00
	Maximum	30.60	120.80	134.70	149.90	18.00
	Median	18.00	69.00	27.00	84.00	4.00
	Average	17.85	65.32	36.39	81.97	6.05
	SD	9.81	20.13	14.12	21.74	5.45
	CV (%)	54.96	31.29	44.98	26.52	90.08
	Skewness	-0.13	-0.52	1.17	-0.21	3.13
	Kurtosis	-1.21	-0.49	1.58	-0.55	14.11
Date - 5	Minimum	2.10	22.60	5.80	40.50	3.00
	Maximum	35.70	120.90	134.80	149.30	19.00
	Median	18.00	66.00	23.50	87.50	4.00
	Average	17.93	66.41	37.42	86.58	6.05
	SD	9.72	20.41	14.17	25.78	5.45
	CV (%)	54.19	32.18	51.66	32.39	90.08
	Skewness	-0.13	-0.15	1.37	-0.47	3.13
	Kurtosis	-1.19	-0.89	1.28	-0.70	14.11

Rill development processes

Rill -A

The depth and width of the Rill-A valley bottom was estimated during the period between 08th and 27th September 2014. In the upslope, the total volume of the study area was varied between 17.83 and 20.44 m (mean±S.D. 19.25±1.04). In the middle slope and lower slope, the estimated average volume was 87.33m and 73.41m respectively (Table 5). The total length of the rill-A at upper slope was recorded as 5m, whereas, the recorded value in the middle and lower slope was 6 m. Significant changes of rill volume in the middle slope (*P<0.0011*) and down slope (*P<0.007*) were observed.

Table 4. Descriptive Statistics of rill geometry: Rill-C

Date	Descriptive Statistics	Depth (cm)	Top width (cm)	Bottom width (cm)	Perimeters (cm)	Gradient (Slope)
Date - 1	Minimum	3.00	36.00	9.00	45.00	3.00
	Maximum	31.00	108.00	59.00	131.00	14.00
	Median	20.10	72.00	22.00	83.00	7.00
	Average	18.37	70.74	25.03	82.53	7.31
	SD	7.35	20.79	10.79	19.33	5.46
	CV (%)	37.98	28.99	43.11	22.87	74.73
	Skewness	-0.36	0.06	0.66	0.04	4.64
	Kurtosis	-0.46	-0.83	-0.34	-0.18	30.39
Date - 2	Minimum	3.00	39.30	11.20	45.20	1.00
	Maximum	35.20	121.10	78.20	131.30	17.00
	Median	20.00	72.00	22.50	83.00	6.00
	Average	19.41	71.06	25.34	83.93	6.65
	SD	7.26	20.85	10.81	21.29	3.18
	CV (%)	38.32	29.35	42.65	25.67	47.84
	Skewness	-0.38	-0.01	0.63	-0.44	0.67
	Kurtosis	-0.60	-0.71	-0.40	1.23	-0.13
Date - 3	Minimum	2.80	39.40	12.70	63.20	3.00
	Maximum	31.50	121.50	78.30	141.60	17.00
	Median	20.10	72.00	22.00	83.00	7.00
	Average	19.66	71.74	26.03	84.53	7.31
	SD	7.35	20.79	10.79	19.33	5.46
	CV (%)	37.98	28.99	43.11	22.87	74.73
	Skewness	-0.36	0.06	0.66	0.04	4.64
	Kurtosis	-0.46	-0.83	-0.34	-0.18	30.39
Date - 4	Minimum	3.10	39.50	11.40	45.40	3.00
	Maximum	31.80	121.70	78.60	129.50	19.00
	Median	18.00	61.50	21.00	78.00	5.00
	Average	21.28	74.99	25.50	87.68	5.99
	SD	6.18	24.53	27.18	26.00	2.95
	CV (%)	35.76	41.59	55.61	34.81	49.28
	Skewness	-0.12	0.20	1.55	-0.40	0.69
	Kurtosis	-0.30	-0.56	2.20	-0.45	-0.26
Date - 5	Minimum	3.10	36.60	11.80	45.60	4.00
	Maximum	31.70	122.00	50.10	130.10	19.00
	Median	19.60	64.50	24.00	81.50	5.00
	Average	24.08	76.32	27.93	88.03	5.99
	SD	6.39	25.09	14.56	26.14	2.95
	CV (%)	35.33	40.26	52.15	33.94	49.28
	Skewness	-0.18	0.12	1.52	-0.51	0.69
	Kurtosis	-0.46	-0.52	2.26	-0.27	-0.26

Table 5. Geometric characteristics of the surveyed rills

Rills	N	Total length, L (m)	Total volume, V (m)				
Rill – A			**Day-1**	**Day-2**	**Day-3**	**Day-4**	**Day-5**
Upslope	10	5	17.825	18.308	19.372	20.307	20.435
Middle slope	12	6	85.671	86.891	87.273	88.123	88.707
Lower slope	12	6	72.142	72.431	73.439	74.347	74.693
Rill – B							
Upslope	50	25	268.445	271.3698	284.6438	297.2735	325.579
Middle slope	34	17	106.641	107.5913	109.4451	135.7981	183.394
Lower slope	18	9	35.8430	37.3594	38.803	43.04863	43.627
Rill – C							
Upslope	22	11	118.844	120.140	131.197	132.4593	132.361
Middle slope	26	13	137.399	140.3138	137.241	141.666	145.926
Lower slope	20	10	57.4650	61.9208	63.4534	63.75795	60.5008

N= number of surveyed cross sections

Rill –B

In Rill-B, the average volume of upslope rill was documented as 289.46 m and volume of upslope varied between 268.44 and 325.58 m. In the middle slope, volume is varied from 106.64 to 183.39 m (mean±S.D. 128.57±29.48). In the lower slope, the volume is varied from 38.84 to 43.63 m. The length of the rill of the upslope, middle slope and lower slope was recorded as 25m, 17m and 9m respectively (Table 5). Significant changes of rill volume were observed with the change of time in the up slope ($P<0.007$) and lower slope ($P<0.002$).

Rill -C

In rill-C, the average volume of upslope was 127 m with standard deviation of ±6.16. In the middle slope, the volume is varied from 137.40 to 145.93m (mean±S.D. 140.51±3.20). In the lower slope, volume of the rill was varied form 57.45 – 60.51m. The rill length of the middle slope was slightly higher in comparison to up slope and lower slope. However, the results showed an increasing trend of rill volume in the up slope, middle slope and down slope with the change of time (Table 5).

Estimating rill erosion rates

Table 5 represents the erosion rate for the Rill-A, Rill -B, and Rill -C. The increase in the erosion rate of the Rill-C, between 06.09.2014 and 29.09.2014 can be explained by recent widening and deepening of the rill at lower section (Figure 6). The areal extension of the rill was estimated during the period between 06.09.2014 and 29.09.2014 (Figure 6). The erosion rate has increased from 06.09.2014 to 29.09.2014 (11.4 %) in Rill-C area. During study period rill area has increased by 4.2 % and 6.8 % in Rill-A and Rill-B (Figure 6). The rill size from the cross-sectional measurements and mean rill erosion rate has been estimated since the incision period (from 06.09.2014 to 29.09.2014), representing 21.8 cm per year in the contribution small rill watershed. Present analysis also illustrated that the rill erosion rate was accelerated significantly since rainfall period in all the study area of rill development.

Discussion and Conclusion

Rill erosion is the result of the combination of different processes including headcut erosion, sidewall sloughing, tunnelling, micro-piping, slaking piping and sapping (Knapen et al., 2007; Wirtz et al. 2012). Our study showed runoff rates were the prime cause of rill development in the study site because of toppling, knickpoints and subsidence processes effect on rill sidewalls. During the observed runoff events, sidewall sloughing and headcut erosion processes caused 23% and 29% respectively of total rills erosion. However, the successive field studies revealed that channels widening and extended through sidewall sloughing and headward erosion. The valley lengthening is considerable due to high intensity of energy available from intensive rain that acted on steep slope. The rates of increase in length of rills are not same everywhere, which varies according to upslope contributing area, gradient, length, texture, etc. Valley widening is mainly performed by basal erosion along valley sides and the subsequent slab failure. Continuous removal of materials from the base of valley sides is to be maintained for active valley widening. Survey shows that the extent of widening increases manifold after the junction with a tributary or entering a gentler course. The concentrated energy along the channels was responsible for valley deepening.

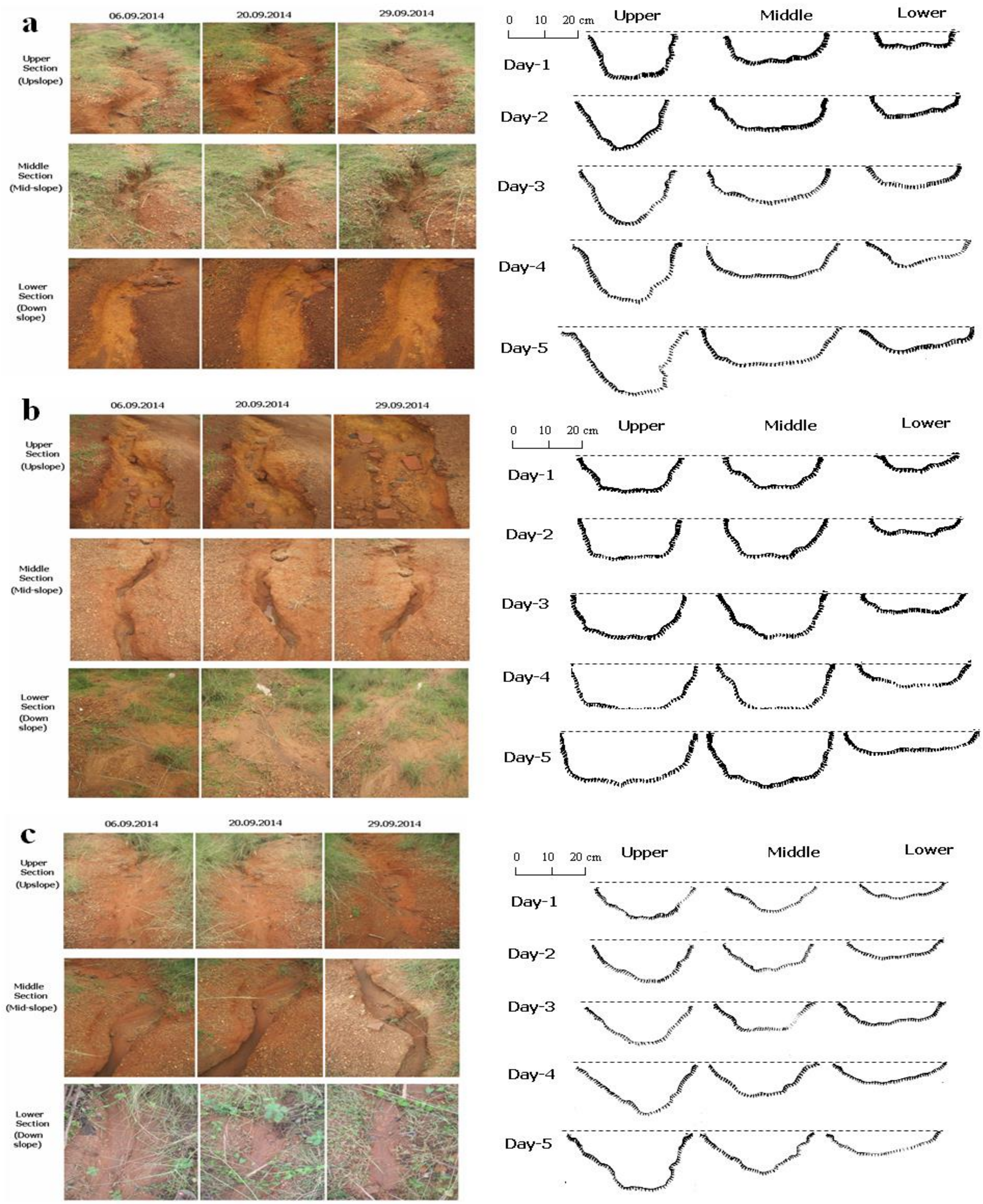

Figure 6. Rill erosion during 06.09.2014 and 29.09.2014 with field photo corresponding cross-sections, (a) Rill-A (b) Rill-B, and (c) Rill-C

The records of the measurements showed that some of the favourable points experienced down-cutting to an amount of 6.0 to 7.0 cm respectively during rainfall event period of 2014. The down-cutting was assisted by the knick development at the source region where surface runoff collected from sheet flow fell from a certain height. This down-cutting and associated back wasting helped in the removal of both lateral and basal support of the materials at the source, and thus an over-hanging slope developed. This slope, thus, retreated by the dislodgement of the overhanging materials which led to valley lengthening. Intense overland flow erosion in the form of rills can wreck barren land and generate environmental tribulations. The present study examined the lateral expansion of channel banks and deepening of channel under the condition of shallow overland flow. However, further experiment is needed at large scale to assess the rill development for its management practices in the study site.

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