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GULLY EROSION ASSESSMENT IN THE GOMAI RIVER BASIN

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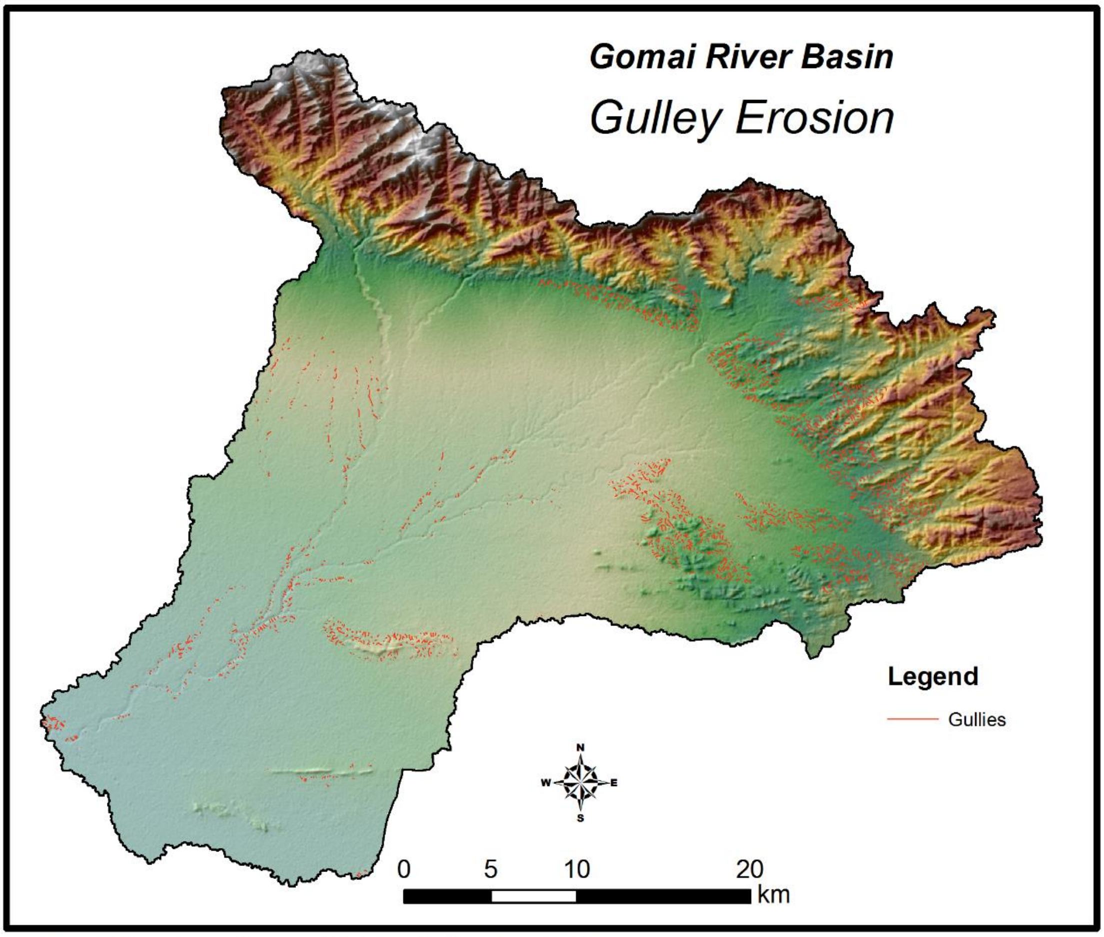
Abstract

Gullies are relatively permanent steep-sided watercourses that experience ephemeral flows during rainstorms. Present study focuses on the gulley erosion problem in the Gomai River basin. Gullies play prime role in soil erosion and most active in the Gomai River basin. The field survey of gullies in the Gomai River basin carried out during Jan 2017 to Dec 2019. Four prominent gullies in the study area observed and length, width and depth of the gullies have measured. The 1235 gullies also have been marked from satellite imageries and mapped. The gully frequency and gully density of the basin are 9 gullies per square kilometer area and 1.296 kms per square kilometer respectively within gullies erosion affected area. This higher gully frequency and density suggest that that Gomai River basin is severely suffering from gully erosion. Maximum gullies are observed on central, northern, southern, western and eastern part of the basin. This area is severely suffering from gully erosion.

Keywords Gullies, sediment discharge, runoff, Erosion, River basin.

Introduction

Gullies are relatively permanent steep-sided watercourses that experience ephemeral flows during rainstorms. Compared with stable river channels, which have a relatively smooth, concave upwards long profile, gullies are characterized by a head cut and various steps or knick-points along their course. These rapid changes in slope alternate with sections of the very gentle gradient, either straight or slightly convex in long profile. Gullies even have comparatively bigger depth and smaller width than stable channels, carry larger sediment loads and show terribly erratic behavior so relationships between sediment discharge and runoff are ofttimes poor (Heede 1975a). A widely recognized definition used to separate gullies from rills is that gullies have a cross-sectional area greater than 1 m^2 (Poesen 1993). Gullies are almost always associated with accelerated erosion and therefore with instability in the landscape.



(Source: Gullies digitize from GeoEye Satellite Data (0.30 m))

Erosion forms caused by flowing water are usually classified as inter-rill erosion which is a combination of splash erosion and sheet flow erosion or wash, rill erosion and gully erosion. The distinction between rills and gullies is a practical one, the first consists of numerous small channels that can be obliterated by normal tillage operations, while the second cannot be obliterated nor crossed with farm equipment. Furthermore, the formation of rills is associated with micro-relief generated by tillage or land-forming operations, whereas gullies are permanent erosion features formed along natural concentration flow lines such as depressions and thalwegs. There are problems with these definitions: first, there is a lot of evidence that gullies can form along artificial flow lines such as field boundaries and, second, they are not always permanent features in the landscape but may be removed by the farmer, although maybe not every growing season. Foster (1986) therefore discussed the term 'ephemeral gully' to indicate channels that are formed in agricultural fields in natural concentration lines but that are removed in tillage operations. These are distinguished from rills by the fact that they may reoccur each year in the same location. Furthermore, Poesen (1993) proposes a cross-section of 1 ft^2 (or 929 cm^2) to distinguish between rills and ephemeral gullies. Analysing data collected in different parts of the world, Poesen et al. (2003) show that soil loss rates by gully erosion represent from 10% up to 94% of total sediment yield caused by water erosion. Poesen et al. (1996, 2003) show that ephemeral gullies are not a rare feature caused only by exceptionally severe rainstorms: the relative importance of ephemeral gullies as contributors to the total sediment budget is highest for the more frequent rainfall events. Despite this importance, the explicit modelling of gullies lags far behind compared to the progress made with catchment-based erosion modelling. In a recent review of gully erosion and environmental change, Poesen et al. (2003) conclude that there is a great need for monitoring, experimental and modelling studies of gully erosion in the Gomai River basin as a basis for predicting the effects of environmental change (climatic and land-use changes) on gully erosion rates.

Location, Extent and Area

The Gomai River basin is a Seventh order river basin of the Tapi river system, rises in the Satpura Mountain. The total length of Gomai River basin is 75.352 km from its source at Satpura Mountain to confluence with its parent stream near Prakasha. It is a major right bank tributary of Tapi River. The river drains an area about 1366.600 sq.km. The Gomai River basin is approximately semicircular in shape having its broad base towards north. It extends in south-north direction for about 45.728 km and east-west for about 49.149 km. The Gomai River basin extends between 21° 26’ 29’’ N to 21° 51’ 56’’ N latitude and 74° 21’ 21’’ E to 74° 54’ 48’’ E longitude. Administratively it lies in the Shirpur tahsil of Dhule district and Shahada and Dhadgaon tahsil of Nandurbar district of Maharashtra State. While it also lies Pansemal tahsil of Barwani district of Madhya Pradesh.

Database

Gullies play prime role in soil erosion and most active in the Gomai River basin. The field survey of gullies in the Gomai River basin carried out during Jan 2017 to Dec 2019. Four prominent gullies in the study area observed and length, width and depth of the gullies have measured. The gullies also have been marked from satellite imageries and mapped as shown in the Fig. 1 and table (1).

Fig. 1 Gulley erosion in the Gomai River Basin

Table 1 Gully Erosion map data

No	Parameter	Dimension
1	Total no of Gullies	1235
2	Total Gullies length	172.834 km
3	Max length	0.745 km (745 m)
4	Min length	0.029 km (29 m)
5	Mean length	0.139 km (139 m)
6	Gully erosion occupied area	133.335 km^2

Result and discussion

Four gullies in the Gomai River basin have been selected for actual measurement and the estimation of erosion. The first observed gully is located on southern side of the basin. The dimensions of these gullies and gully volume also have been estimated as shown in table. no 6.2 to 6.5. The length of first gully is 114.5 m. The maximum and minimum depth of this gully are 1.371 m and 0.381 m respectively. The average width of this gully is 1.524 m in the range of max 0.101 m. Considering the length average depth and average width the gully volume is 81.45 m^3. Considering the volume of gully is equal to volume of material excavated from that gully. The soil removed by the respective gullies are estimated and given in the same table. The total soil mass removed by these four gullies is equal 999.02 Metric tons approximately 1000 m. tone during the formation of that gullies. The maximum and minimum slope of these four gullies 11.63 degree and 6.47degree.

Total 1235 gullies have been marked from satellite imageries in the Gomai River basin. Their total length is 172.834 kms. The maximum and minimum length of these gullies ranges between 0.745 km (745 m) and 0.029 km (29 m) respectively. The mean length of gullies is 0.139 km (139 m). The overall gully frequency and density of the Gomai River basin also have been estimated. The gully frequency and gully density of the basin are 9 gullies per square kilometer area and 1.296 kms per square kilometer respectively within gullies erosion affected area. This higher gully frequency and density suggest that that Gomai River basin is severely suffering from gully erosion. Maximum gullies are observed on central, northern, southern, western and eastern part of the basin. This area is severely suffering from gully erosion.

Gully formation in the Gomai River basin

At only once it had been thought that gullies developed as enlarged rills, however studies of the gullies unconcealed that their initiation could be an additional advanced method. within the 1st stage, tiny depressions or knicks type on a slope as a result of the localized weakening of the vegetation cowl by grazing or fire. Water concentrates in these depressions associated enlarges them till many depressions coalesce and an inchoate channel is created. Erosion is concentrated at the heads of the depressions, where near-vertical scarps develop over which supercritical flow occurs. Some soil particles are detached from the scarp itself but most erosion is associated with scouring at the base of the scarp, which results in deepening of the channel and the undermining of the headwall, leading to collapse and retreat of the scarp upslope. Sediment is also produced further down the gully by Gomai River main channel bank erosion. This occurs partially by the scouring action of running water and the sediment it contains and partially by slumping of the banks. Between flows, sediment is created out there for erosion by weathering and bank collapse. This sequence of valley formation delineated by Leopold et al. (1964).

Not all gullies develop purely by surface erosion, however, according to Berry and Ruxton (1960), gullies in Gomai River basin that formed following clearance of natural forest cover, found that most waters were removed from the hillsides by subsurface flow pipes and when heavy rain provided sufficient flow to flush out the soil in these, the ground surface subsided, exposing the pipe network as gullies.

According to Downes (1946), in the Gomai River basin overgrazing and removal of vegetation cover cause crusting of the surface soil, resulting in the greater runoff. This passes into the soil through small depressions, cracks and macropores but, on reaching the top of the soil B horizon, moves along it as subsurface flow. Localized dispersion of the clays in areas of underground wet accumulation is followed by piping. Heavy monsoon rains or orographic rain cause the water in the pipes to break out on to the surface. Eventually, the roofs of the pipes collapse, and gullying happens.

Table 2 Observed Gully No.1

Sample No	**Parameter** (South Side)	**Value**
1	**Total Gullies length**	**114.5 m**
	Max Depth	1.371 m
	Min Depth	0.381 m
	Avg. Depth	**0.876 m**
	Max width	1.524 m
	Min width	0.101 m
	Avg. width	**0.812 m**
	Max elevation	70.139 m MSL
	Min elevation	57.004 m MSL
	Slope	6.47 Degree
	Gully Volume	**81.45 m^3 (196.3 Metric Tons)**

Table 3 Observed Gully No.2

Sample No	**Parameter** (East side)	**Value**
2	**Total Gullies length**	**151.5 m**
	Max Depth	1.300 m
	Min Depth	0.389 m
	Avg. Depth	**0.844 m**
	Max width	1.545 m
	Min width	0.100 m
	Avg. width	**0.822 m**
	Max elevation	313.859 m MSL
	Min elevation	285. 065 m MSL
	Slope	10.47 Degree
	Gully Volume	**105.11 m^3 (253.32 Metric Tons)**

Table 4 Observed Gully No.3

Sample No	**Parameter** (North Side)	**Value**
3	**Total Gullies length**	**101.98 m**
	Max Depth	1.520 m
	Min Depth	0.410 m
	Avg. Depth	**0.998 m**
	Max width	2.892 m
	Min width	0.943 m
	Avg. width	**1.917 m**
	Max elevation	243.559 m MSL
	Min elevation	222.076 m MSL
	Slope	11.63 Degree
	Gully volume	**195.1 m^3 (470.2 Metric Tons)**

Table 5 Observed Gully No.4

Sample No	**Parameter** (West side)	**Value**
4	**Total Gullies length**	**83.20 m**
	Max Depth	0.762 m
	Min Depth	0.152 m
	Avg. Depth	**0.457 m**
	Max width	0.980 m
	Min width	0.750 m
	Avg. width	**0.865 m**
	Max elevation	189.276 m MSL
	Min elevation	178.009 m MSL
	Slope	7.53 Degree
	Gully volume	**32.89 m^3 (79.2 Metric Tons)**

Problem of Gulley erosion should be solved in the Gomai River basin using various methods as following;

- Growth of vegetation: The simplest and natural way to prevent gulley erosion is through planting vegetation. Plants establish root systems, which stabilizes geomaterial and prevents gulley erosion.
- Mulch: Applying a layer of mulch to the topsoil allows the geomaterial to slowly soak up water, as it protects against rain drop impact.
- Retaining Walls: Retaining walls can be built around the area of gulley erosion to prevent water runoff. Runoff water leads to further erosion, and if used with other methods, retaining walls can be a very effective way to prevent gulley erosion.

Conclusion

Although gullies can remove vast quantities of soil, gully densities are not usually greater than 1.296 km per km^2 and the surface area covered by gullies is rarely more than 9.75 per cent of the total area. This results in a considerable contrast between the erosion rate for an individual gully and its contribution to the overall soil loss of an area. Rates of headwall extension can be very rapid for relatively short periods of time. Erosion from a gully developed on arable land at the eastern side of the Gomai River basin.

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