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UNDERSTANDING THE MORPHOMETRY OF THE CATCHMENT FOR ITS MANAGEMENT (A CASE STUDY OF MINI CATCHMENT OF MURHEPU IN PHEK DISTRICT, NAGALAND)

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Abstract

Murhepu Catchment, a mini-catchment, is in Phek District of Nagaland. The catchment ecosystem is under constant threat of mass wasting and erosion. It is, therefore, imperative for planners and managers of environment to understand the morphometry of the catchment for its better management. Murhepu Catchment is a 4th order stream catchment (Table 1) having 123 streams with a total area of 17.5 km^2 and total stream length of 68.76 km respectively. The catchment has high Stream frequency of 7no/km^2 and drainage density of 3.9km/km^2 showing high dissection and closeness of one channel to another channel. Murhepu catchment is a semi-circular basin. Both Absolute & Relative reliefs are high. Murhepu exhibit steep gradient (Fig. 5 & Table 2) indicating active vertical erosion of river bed and the catchment is in juvenile stage. The gradient of slopes increases along with increasing altitude (Fig. 6). Murhepu is a purely deforested catchment and therefore, massive afforestation is required. Need measures to check devastating slope failure. Action plans is required for rejuvenation of drying spring wells and also to combat emerging positive thermal anomaly in Pfutsero town in order to restore highly degraded Murhepu catchment. Therefore, the author proposed environmental management plans for Murhepu Catchment (Table 5).

Introduction

Catchment also known as the drainage basin or the river basin, is the area drained by stream or a system of connecting streams such that all the surface runoff originating in this area leaves the area in a concentrated flow through a single outlet.

Measurement of the shape or geometry of any natural form is termed morphometry (Strahler, 1969). In geomorphology, morphometry is

the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms (Clarke, 1970). Catchment morphometry, therefore, may be considered as the measurement and analysis of the configuration of the Catchment basin.

The catchment ecosystems are under constant threat of mass wasting and erosion caused by natural processes, deforestation, unscientific agricultural practices and other developmental activities. Some catchment ecosystems are fairly robust and are less affected by a certain level of human disturbance. Others are extremely fragile and are quickly destroyed by human activities. Mountain catchment ecosystems of NE India are extremely fragile, as the degradation of forest cover leads to severe soil erosion and changes in river courses. Catchment ecosystems are frequently disrupted by human actions, leading to the mass wasting processes and extinction of species of plants and animals. Understanding the morphometry of the catchment for its planning and management become extremely important especially in the hilly mountainous regions.

"Murhepu Catchment" has been selected as a representative sample of degraded catchment for this study.

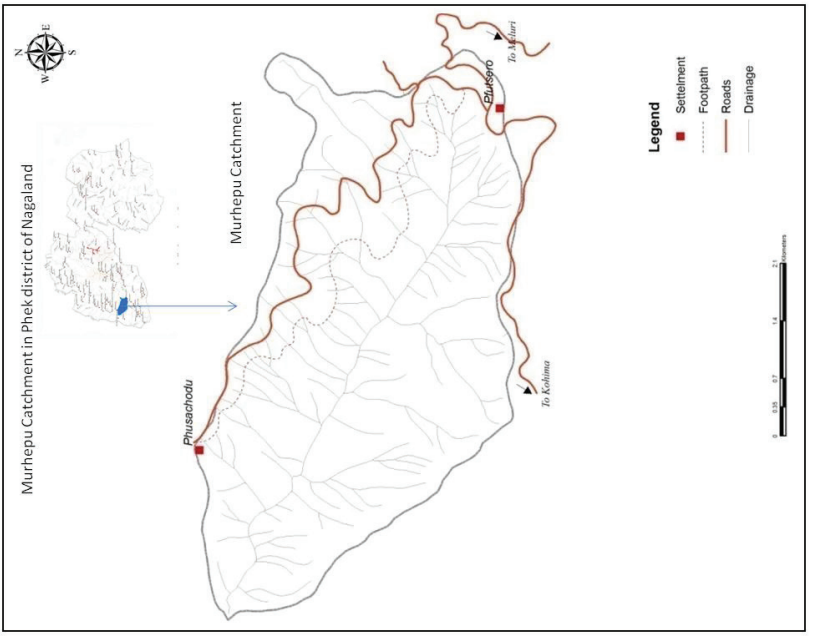


Fig.1: Location & Index Map of Murhepu Catchment

A brief description of the Murhepu Catchment

Murhepu Catchment is in Phek District of Nagaland, located between latitudes 25° 34' 10" N & 25° 36'' 25" N and longitudes 94° 14' 15" E & 94° 18' 20" E covering a total area of about 17.5 km^2. Pfutsero Town and Phusachodu Village are on East and West edges of the catchment respectively. The river Murhepu originates near west of Pfutsero town and flows towards North-East. It is a tributary of Sedzu River. The elevation ranges from 980 m to 2200 m above msl. Pfutsero town which is at the elevation of 2046 m above msl is located on the eastern edge of the catchment area. The highest elevation is 2200 m above msl on the northern edge. The area is mostly covered by open scrub. Paddy fields are along the stretch of the river banks. Except small patches of forests cover north of Pfutsero Town, Murhepu Catchment exhibits a typical example of purely deforested Catchment Ecosystem. The geomorphic characteristics of this Catchment have been presented.

Objectives

The objective is to obtain geomorphic information on catchment morphometry of Murhepu and to understand its geomorphometric characteristics for better planning and management of the catchment.

Materials and Methods

Catchment is used as a geomorphic unit because of its topographic, hydraulic and hydrological unity, which laid the keystone of Horton's morphometric system (1945). Catchment is an open system in terms of inputs of precipitation and solar radiation and, therefore, accepted as a fundamental geomorphic unit for the morphometric study of catchment (drainage basin) characteristics. Catchment ecosystem is being frequently selected as an ideal areal unit for the analysis of forms and processes of a region delineated by the basin perimeter. Catchment being widely used as a natural unit and, therefore, Mürhepü Catchment is been selected as a representative Sample catchment for the study.

Data collected are analysed using Quantitative techniques to obtain the nature of different morphometric characteristics. Morphometry data were derived from Topographic Sheet 83k/6 & 83 k/10 by using map measurer and planimeter and also from different sources. Data have been diagrammatically illustrated by using appropriate cartographic techniques.

Morphometric Characteristics of Murhepu Catchment

Linear aspects

linear aspects relates to the channel patterns of the drainage network where in the topological characteristics of the stream segments in terms of open links of the network system (stream) are analyzed (Singh, 1988).

Stream ordering: It refers to the determination of the hierarchical position of a stream within a catchment or drainage basin. Strahler's scheme, popularly known as 'Stream segment method' is employed here for stream ordering. Murhepu is a 4^{th} order stream consisted of 94 first, 23 second, 5 third, 1 fourth order streams (Table. 1).

Stream length: It is the total stream length of the different order of streams within a catchment. Murhepu has a total stream length of 68.76 km. 46 km (66.98%) is constituted by first order streams. The percentage of the second, third & fourth order streams stands at 19.2 %, 7.27 %, and 6.54 % respectively. The mean stream length of the different order streams of Murhepu catchment is 0.49 km, 0.575 km, 1 km, and 4.5 km respectively (Table. 1).

Bifurcation ratio: The ratio of the number of segments of a given order to the number of the segments of the higher order is termed as bifurcation ratio. The bifurcation ratio of the different order streams of Murhepu catchment ranges between 2 and 5.2.

Areal aspects

Areal aspect is related to the spatial distribution of a number of significant attributes such as drainage density, stream frequency, drainage texture, etc**.**

Basin area: The size of the mean basin area of the first, second, third and fourth order drainage basin of the Murhepu catchment stands at 0.12 km^2, 0.43 km^2, 2.167 km^2, and 17.5 km^2 respectively (Table 1)

Basin perimeter: Basin perimeter is obtained by measuring the outside edge of different order of streams. Mean basin perimeter of the first, second, third, and fourth order basins for Murhepu catchment stands at 1.62 km, 3.04 km, 5.4 km, and 19 km respectively (Table.1)

Basin length: Maximum length between drainage basin mouth and reach has been considered as basin length. The mean basin length of the first, second, third and fourth order streams of Murhepu catchment is 0.711 km, 1.19 km, 2.25 km and 7 km respectively.

Drainage density: It is the length of streams per unit area of the drainage basin. The mean drainage density of the first, second, third and fourth order drainage basins found in the catchment stands at 4.07 km/km², 1.33 km/km², 0.46 km/km², 0.257 km/km² respectively (Table. 1)

Stream frequency: Stream Frequency or Drainage frequency is the measure of number of streams per unit area. The mean stream frequency of the first, second, third and fourth order streams of Murhepu catchment stands at 8.3 no/km², 2.32 no/km², 0.46 no/km², & 0.057 no/km respectively (Table 1).

Basin circularity ratio: Basin circularity ratio actually refers to the shape of the drainage basin and when it is equal to unity, it indicates a perfect circular basin. The basin circularity ratio for Murhepu Catchment was obtained by using Miller's formula. The basin circularity ratio of first, second, third and fourth order of basins in Murhepu catchment stands at 0.57, 0.58, 0.93, and 0.60 (Table. 1). The circularity ratio of Murhepu catchment as a whole is Cr=0.60, indicates semi-circular basin

Drainage texture: Drainage texture connotes the relative spacing of the drainage lines or closeness or proximity of one channel to another. In other words, it is the distance of one channel to another channel. In Murhepu catchment, the distance between first, second, third and fourth order streams within their basin area is 0.489 km, 0.57 km, 1 km and 4.5 km apart respectively.

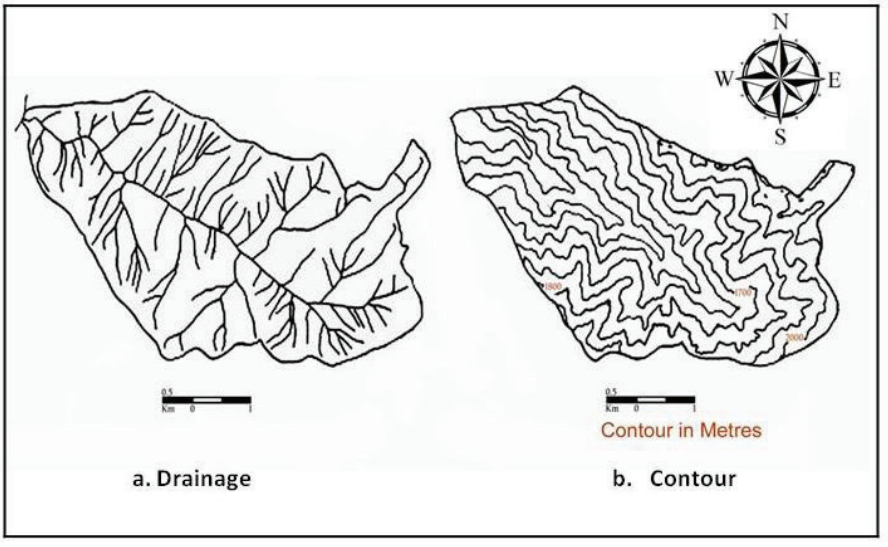


Fig. 2: Drainage and Contour Maps of Murhepu Catchment

Table 1: Summary of linear & areal aspects of Morphometry of the Murhepu Catchment

Morphometric parameters	*Symbol used*	*Stream Order (μ)*			
		1st	*2nd*	*3rd*	*4th*
Total no. of streams	(N)	94	23	5	1
Total stream length (Km)	(L)	46.06	13.2	5	4.5
Mean stream Length (km)	(mL)	0.49	0.57	1	4.5
Stream Length Ratio	(Lr)	—	1.17	1.73	4.5
Total Basin Area (Km^2)	Ab	11.31	9.90	10.83	17.5
Mean Basin area(Km^2)	mAb	0.12	0.43	2.16	17.5
Bifurcation Ratio	Br	4.08	4.6	5	—
Drainage Density (km/ Km^2)	Dd	4.07	1.33	0.46	0.25
Basin Length(Km)	BL	0.71	1.19	2.25	7
Basin Perimeter(Km)	Bp	1.62	3.04	5.4	19
Stream Frequency(no/ Km^2)	Sf	8.30	2.32	0.46	0.05
Basin Circularity ratio	Cr	0.57	0.58	0.93	0.60
Drainage Texture (km/ no)	Dt	0.489	0.57	1.0	4.50

Relief aspects

The relief aspects of the catchment relates to the study of three dimensional features. The relief aspects in this study include the description of absolute relief, relative relief, average slope, ruggedness number, dissection index and profiles of river and terrain.

Absolute Relief (AR): Absolute relief is the maximum height of a unit from the mean sea level. Murhepu catchment has been divided in to 24 grids. Absolute relief ranges from less than 1300 m to more 2200 m. Absolute Relief increases from North-West to East. The frequency curves (Fig.4a) which depict the frequency of different absolute relief zones of the catchment.

Relative Relief (RR): Relative Relief also termed as 'amplitude of available relief 'or 'local relief 'is the difference in height between the highest and the lowest points (height) in a unit area (grid square). Relative Relief of Murhepu catchment ranges between less than 200 m and more than 500 m (Fig.4b). The highest relative relief groups

are found in the middle and north-west of the catchment. The lowest relative relief groups are confined in the side on the boundary edge of the catchment due to summital flatness.

Average slope (AS): Slopes is an angular inclination of terrain between hill-tops and valley bottoms. The technique of Wentworth (1930) is been used here. The values of slope angles are classified into categories and isopleth map (Fig.3a) is prepared for the study of spatial variation within the catchment. Mean average slope stands at 23.95°. The frequency distribution of average slope (Fig. 3) reveals that the maximum occurrence of slope group falls in (20°to 30°) and minimum in (30° and above) slope group.

Ruggedness Number (Rn): Ruggedness Number is the product of RR and drainage density: The value of Rn derived for each grid of one

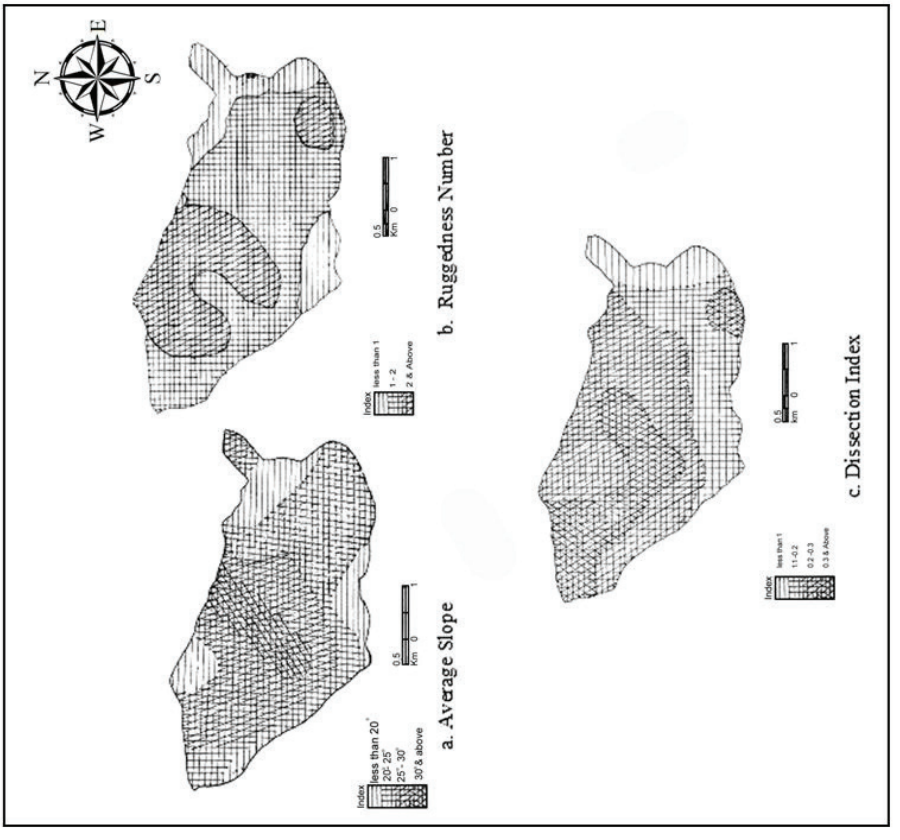


Fig. 3: Maps of Average Slope, Dissection Index and Ruggedness Number of Murhepu Catchment

km^2 is classified into different categories and isopleths map (Fig.3b) is prepared for the study of spatial variation. The frequency distribution of ruggedness number reveals that the ruggedness number of Murhepu catchment ranges between less than 1 and more than 2**.** The maximum area (i.e., 37.5%) falls in 1-2 ruggedness number group and minimum area (i.e.29.2%) falls in 2-3 ruggedness number group.

Dissection index (DI): Expressing as the ratio of the maximum RR to the maximum AR, is an important morphometric indicator of the nature and magnitude of dissection of terrain. The values of DI derived for each grid of one km^2 are classified into different categories and isopleths map (Fig.3c) is prepared for the study of spatial variation. The DI of Murhepu catchment ranges between less than 0.08 and 0.35. The maximum area (i.e., 41.7%) falls in 0.2-0.3 dissection index group and minimum area (i.e., 12.5%) falls in less than 0.1 dissection index group. About 12.5% of the catchment is under old stage of cycle of erosion and 66.7% is in early mature stage (0.1-0.3 D.I). About 20.8 % is still in youthful stage (more than 0.3D.I) of cycle of erosion.

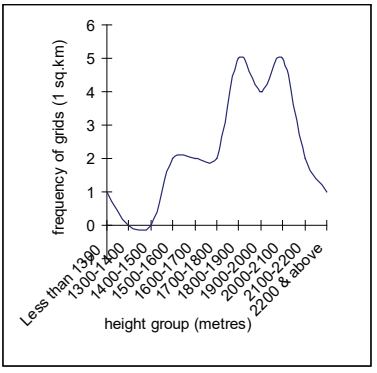
Hysometric analysis

Hypsometry involves the measurement and analysis of relationships between altitude and basin area to understand the degree of dissection and stage of cycle of erosion. Here, percentage hypsometric curve, suggested by Strahler 1952, is used to establish stage of cycle of erosion. The hypsometric curve (Fig. 4f) and hypsometric integral (H.I) obtained for the Murhepu catchment shows (HI=63.01%) indicating about 36.99 percent area of the Murhepu catchment has been eroded by various degradational processes and the catchment is passing through young to early mature stage of geomorphic development.

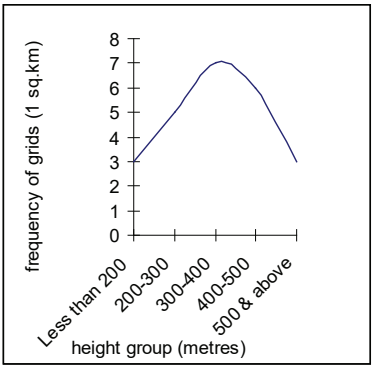
Profile Analysis

Profiles provide a visual perception of the actual nature of terrain and are of great assistance to the geomorphologists. In this study, longitudinal river profile and superimposed & projected profiles of terrain are dealt with in the analysis. Superimposed and Projected profiles were drawn out of many serial profiles combine and it may be preferred to be called MODEL PROFILE (Lohe, 2014).

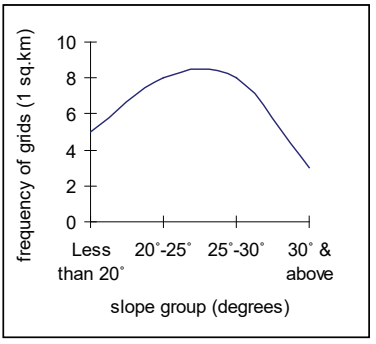
Longitudinal River profile: Longitudinal River profile gives a vivid picture of longitudinal course of the river (Fig. 5). The river course in the upper segment of Murhepu exhibit steep gradient (Table 2) indicating active vertical erosion of river bed; a characteristic feature of juvenile



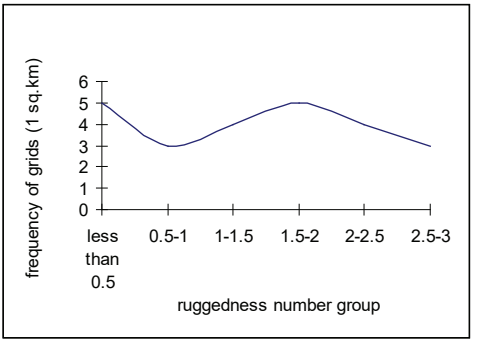
a Frequency curve of Absolute Relief



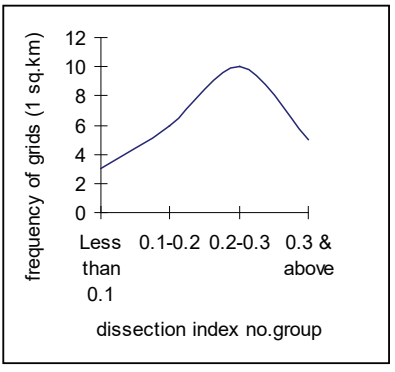
b. Frequency curve of Relative Relief



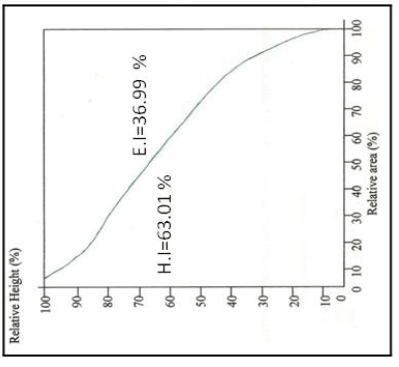
c. Frequency curve of Average Slope



d. Frequency curve of Ruggedness number



e. Frequency curve of Dissection index number



f. Percentage Hypsometric Curve

- Hypsometric integral=H.I, Erosion integral=E.I

Fig. 4: Frequency curve of a. Absolute Relief b. Relative Relief c. Average Slope d. Ruggedness number e. Dissection index number f. Percentage Hypsometric Curve of Murhepu Catchment

stage of cycle of erosion. As we move downward along the river course, the gradient gradually decreases (Table 2). Consequently, flow velocity of river also decreases although the volume of flow increases with the increase in number of streams joining the main stream. Higher volume of water with lower flow velocity (consequent upon low gradient) at the lower segment of the river course produces lateral erosion. Lateral erosion and overtopping of terrace paddy fields near the river bank is a notorious feature in the lower segment of the river course during rainy season. High negative coefficient of correlation (Table 3) also shows that lower stream order exhibits higher slope gradients and higher stream order exhibits lower slope gradients.

Table 2: Mean Channel slope (degree) of the Selected Catchment channels

River	$\overline{S1}$	$\overline{S2}$	$\overline{S3}$	$\overline{S4}$
Murhepu	18°	12.9°	11°	5.3°

$\overline{S1}$….. $\overline{S4}$ denote mean Channel slope of 1st, 2nd, 3rd and 4th order basins.

Table 3: Coefficient of Correlation between stream order and channel slope

Stream/river	*Coefficient of correlation (r) between stream order and channel slope*
Murhepu	r = -0.98449 High negative coefficient of correlation

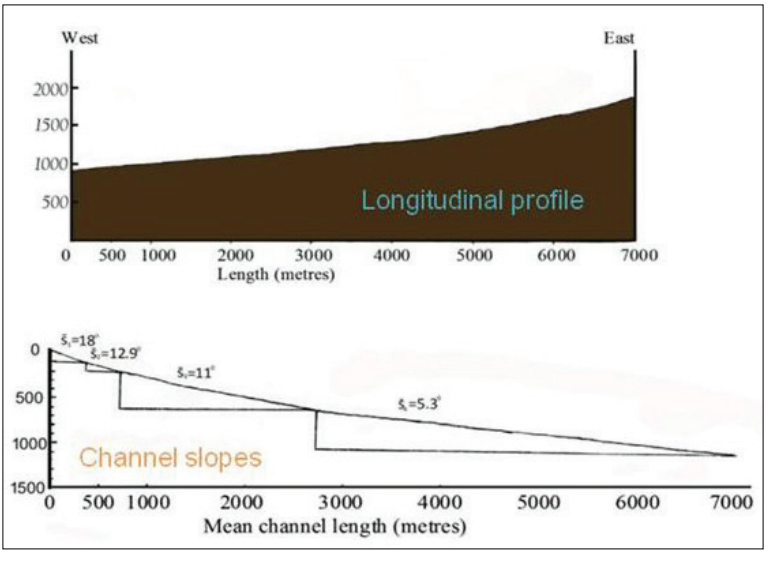


Fig. 5: Longitudinal profile and Channel slope (gradient) of Murhepu Catchment. $\overline{S}_1$, $\overline{S}_2$, $\overline{S}_3$, and $\overline{S}_4$ denote mean channel slope angles of 1st, 2nd 3rd and 4th order of river basins.

- ***Terrain profile***: Terrain profile of Murhepu catchment is drawn viewed from the north-west near its mouth. The gradient of slopes between the north and south limbs of the Murhepu catchment increases along with increasing altitude (Fig. 6). Though the difference of slope gradient between north and south diminishes, higher slope gradient continue to exist with slight higher slope angles in the lower segment of the river course and its mouth. This suggests that the river may shift its course towards the north. Shifting of course towards its north limb will trigger slope failure (land slide) and may cause havoc to agricultural lands of Phusachodu and its neighbouring villages which were located on the summital tops of the north limb of the catchment.

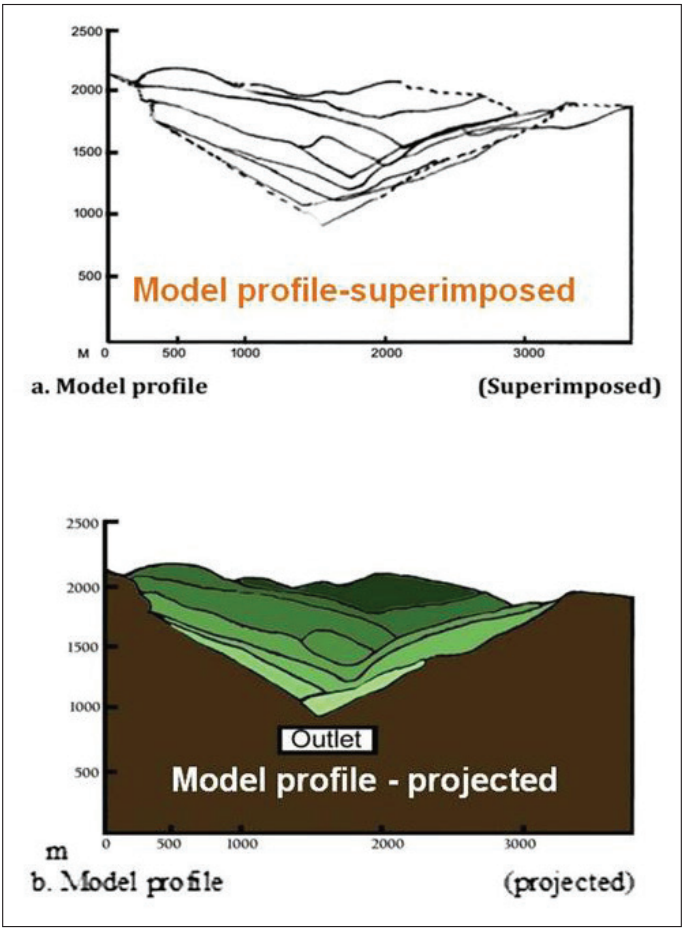


Fig. 6: Model profiles of Murhepu Catchment (a. Superimposed, b. Projected)

Geographic information and attributes of environmental management

Table 4: Detail of geographic information and attributes of environmental management in Murhepu catchment.

3.	Murhepu: Between Latitudes 25° 34' 10" N & 25° 36'' 25" N and Longitudes 94° 14' 15" E & 94° 18' 20" E in the Phek District, Nagaland.	From 980 m to 2200 m above msl	Pfutsero Phusachodu (17, 167)	17.5	Murhepu is a purely deforested catchment. Massive afforestation is required Tree plantation to arrest soil erosion and landslide in areas cleared of vegetation due to potato cultivation and orchard. Need measures to check devastating slope failure below Phusachodu, located on the eastern. Measures require for rejuvenation of drying spring well, Need plans to combat emerging positive thermal anomaly in Pfutsero town. Urgently action plans for restoration of highly degraded Murhepu catchment.

Environmental Management in the Murhepu Catchment

Murhepu Catchment is one of the degraded ecosystems. The area is mostly covered by open scrub. Few wet paddy fields are along the stretch of the river bank. Except small patches of forest cover north of Pfutsero town, Murhepu exhibits a typical example of purely deforested catchment ecosystem (Plate 1). About 36.99 percent of the Murhepu Catchment ecosystem has been eroded by various degradational processes and the catchment is passing through youthful stage of geomorphic development (Fig. 4f) reflecting active vertical cutting of rivers bed. High channel slope in the catchment indicates steep gradient and vulnerability to slope failure like landslide. Table 5 is showing 93.59 % of the area suffering from various types as degradation in this catchment. Potato is highly cultivated even on steep slopes resulting to soil erosion and loss of soil fertility and as a consequence, low productivity of agriculture in recent years because potato cultivation offers least protection to soil erosion (Plate 2). Construction of Agri-link roads on fragile slopes has done great damage to the stability and environment of the catchment ecosystem (Plate 3). Unless cut soils get consolidated with roots, devastating slope failure such as landslide

can occur during rainy season. Pfutsero town, located on the eastern border of the catchment, was once known for its robust spring well and water, is getting dry and insufficient in most parts of the year. This is a serious problem but may continue to exacerbate with the urbanization and concomitant increase in population and unabated environment degradation. Moreover, it is presumed that Pfutsero town located at high altitude of 2134 m and considered to be coldest inhabited place in Nagaland, is experiencing positive thermal anomaly in recent years (temperature more than mean temperature of the latitude/altitude) probably due to deforestation. In this regard, it is urgently needed that scientific environmental management with adequate geomorphic knowledge is adopted for the restoration of highly degraded Murhepu catchment ecosystem.

The high relief and rugged terrain of the northeast may be allotted for natural vegetation and forest land use. Steep hills found in the middle and North West of the catchment should be allowed to remain with least interference because these areas are very sensitive to any change. Slope with higher gradients in the north east (north of Pfutsero), in the middle segment of the catchment on both side of the limbs of the river Murhepu and on the north west (below Phusachodu village) may be used for tree plantation wherever the trees have been cut for various reasons. This can arrest soil erosion and landslide because some of these areas have been cleared of vegetation due to potato cultivation and orchard (e.g., just north of Pfutsero town). It may be mentioned that Potato cultivation on steep and vulnerable land have resulted soil erosion and loss of soil fertility and as a consequence, low productivity of agriculture in recent years because Potato cultivation offers least protection to soil erosion.

The gradient of slopes between the north and south limbs of the Murhepu catchment increases along with increase in altitude. Though the difference of slope gradient between north and south diminishes, higher slope gradient continue to exist with slight higher degree of slope gradient in the lower segment of the river course and its mouth indicating that the river may shift its course towards the north and may trigger slope failure (land slide) causing havoc to agricultural lands of Phusachodu locating on the summital tops of the north limb of the catchment. This will have cascading effects on the neighbouring villages too. Anthropogenic activities of clearance of land for agricultural purposes and road construction on these slopes may aggravate the problem of soil erosion which will ultimately accelerate

erosion and process of shifting of the river course towards north limb. It is unfortunate, at least from environmental/ecological point of view, that the inhabitants of this catchment use Mahatma Gandhi National Rural Employment Guaranty Scheme (MGNEGS) for the construction of Agri-link roads on fragile slopes (Plate 3). This work has done great damage to the stability and environment of the catchment ecosystem. Unless cut soils get consolidated with roots, devastating slope failure such as landslide can occur during rainy season. Massive tree plantation, therefore, need to be carried out in this areas.

In general, the catchment may be used, developed and managed based on the line of proposed planning strategy for environmental management of Murhepu Catchment for sustainable development as shown in Fig. 5. For quality environment, massive afforestation has been proposed (Table 5). To check soil erosion and land sliding, plantation of trees has been proposed in and around potato cultivation and orchard areas. There is urgent need to check the slope failures below Phusachodu. Development of spring sanctuaries is also required in this catchment. In all the degraded lands, there is an urgency to reclaim the environment and ecology of this area through massive afforestation and plantation. The detailed plans for land, water and forest resources management for environmental conservation have been presented in Table 5.

Table 5: Proposed environmental management plans for Murhepu Catchment.

MANAGEMENT PLAN FOR MURHEPU CATCHMENT					
Sl. No.	*Name & geographic location*	*Range of altitude (m)*	*Village/ sub-town/ town and Population*	*Area (km^2)*	*Aspects of planning for environmental management*
	Management plan for Degraded land				
1.	In the high slopes in and around Pfutsero				Limit or Check land degradation due to potato cultivation. Crop rotation instead of field rotation.
2.	along the road between pfutsero and Phusachodu				Plans for agro forestry and plantation.
3.	In the middle section				Checking unrestricted grazing of mithuns

MANAGEMENT PLAN FOR MURHEPU CATCHMENT					
Sl. No.	*Name & geographic location*	*Range of altitude (m)*	*Village/ sub-town/ town and Population*	*Area (km^2)*	*Aspects of planning for environmental management*
	Along agri-link road below phusachodu				Massive tree plantation to arrest soil erosion and landslide
	Water resources management and water harvesting				
1	Pfutsero town				Need to strengthen the method of tapping spring wells, rooftop water harvesting for drinking. Need to construct Water harvesting structures to supplement water for domestic use.
2.	Near the settlement and fields				Dugout pond/farm pond (Zabu or Dzudu) need to be constructed for vegetable crops.
3.	In any area				Previous lake and ponds should be revived
	Forest management/ conservation plans				
1.	In and around Pfutsero especially in the high hill slopes				Checking destruction of forest by limiting potato and cabbage cultivation.
2.	Middle and higher reaches				Massive afforestation covering about 10.9 sq.km (or 53.59 %) is required to meet national ecological principle and also to combat positive thermal anomaly in pfutsero town in recent years.
3.	In Pfutsero town				Restrict/limit opening of new sawmill. Green belt should be raised around the town.

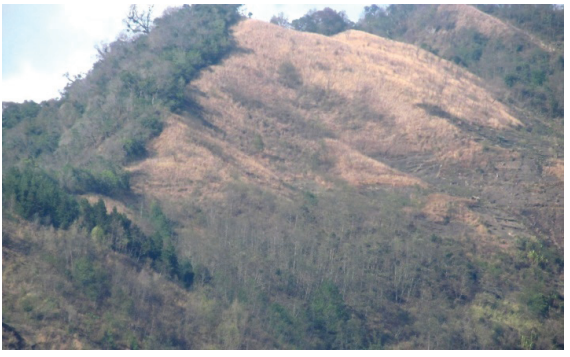


Plate 1: Encroachment of forests through Jhum cultivation (on the north western limb of Murhepu catchment).

Plate 2: Potato cultivation in Pfutsero located on the eastern ridge of Murhepu catchment. Potato cultivation offers least protection to the soil and lead to soil erosion and loss of fertility.

Plate 3: Construction of Agri-Link Road in Murhepu Catchment. Road Construction on the steep hill slopes accelerates soil erosion and landslide below Phusachodu.

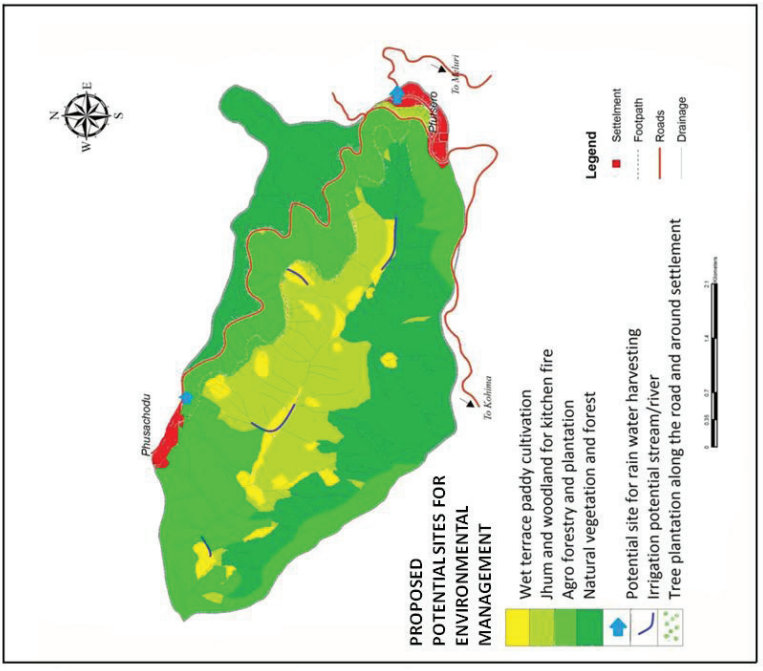


Fig. 7: Map for proposed planning strategy for environmental management in the Murhepu Catchment.

Table 6: Land resources degradation (in sq.km) in the Murhepu Catchment.

Name of the Catchment	*Total Area (sq.km)*	*Degraded Area (sq.km)*				*% Degraded to Total Area*	*Forest Cover in*	
		Terrace area (sq. km)	*Settlement Area (sq. km)*	*Jhum/ fallow Area (sq. km)*	*Total*		*sq.km*	*%*
Murhepu	17.5	1.07	0.53	14.78	16.38	93.59	1.12	6.41

Conclusions

Morphometry involves quantitative study of the area, altitude, volume, slope, profiles of the land and drainage basin characteristics of the area concerned. Morphometric analysis provides detail geographic information and attributes of the Catchment for it management and enables to understand morphometric personality of the catchment. Through morphometric analysis, it is understood that Murhepu Catchment is a 4th order stream catchment with a total basin area of 17.5 km^2 having a semi-circular shape criss-crossed by a number of streams with steep slope gradient and active in erosion indicating juvenile stage

of cycle of erosion. The catchment is a purely deforested one and need proper measures to restore back its ecological health to normal. And, therefore, after understanding its morphometry, suitable measures have been proposed (Table 6 & fig.7) for sustainable management of the catchment.

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